Comparison of Seakeeping performance of the two super yachts of 53 and 46 m in length

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Genoa, February 2015

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Contents

Abstract

General Seakeeping qualities of the projected 53-meter and 46-meter motor yachts have been determined by means of theoretical calculations. With the help of a Two-dimensional source distribution program and a linear strip theory method various ship motions and acceleration as well as different extreme effects like deck wetness and bottom slamming were derived for the vessel running in irregular short-crested seaways. Thereby the full ranges of relative course angels and ship speed up to 16 knots have been taken into consideration.

In this study two operational areas (Mediterranean and Aegean Sea) and three sea ways conditions (sea State 3, 4 and 5) were investigated which feature significant wave height in the range of 0.88 m and 3.25 m.

The outcome of the theoretical study was checked against various performance criteria. The compliance of the projected motor yacht with limiting criteria is illustrated in the form of polar diagrams. Besides this, the seakeeping characteristics of the vessel (ship motion and extreme seakeeping effects) are represented in the form of Cartesian diagrams for all combination of seaway condition, relative course angle and ship speed.

In sea State 3 conditions the projected vessels can run without restriction in both areas of operation. In contrast, some performance criteria are exceeded in sea State 4 while the operations of the yachts are restricted in sea State 5 by at least one performance criteria.

Keywords: Ship Motion in Waves, Numerical Calculation, Extreme Effects, Motor yacht, Operational Criteria

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Chapter 1
Introduction

Introduction

The project is to investigate numerically the seakeeping performance of two motor yacht 53 and 46 meter long. On the behalf of cantieri S.p A. La Spezia Italy, the seakeeping performance assessment carried out by means of theoretical calculation of projected 53 and 46 m motor yachts. Significant amplitude of Roll and Pitch Motion, lateral and vertical acceleration has been computed for the two motor yachts at one load condition when travelling in various irregular short-crested seaways. Seakeeping Calculation conducted for the full range of ship speeds and relative courses.

The overall dynamic performance of the ships depends upon the seakeeping performance of the yacht or vessels in a particular sea States or areas where the vessel has to operate. Seakeeping assessment is becoming the crucial part in the engineering and design process from the large offshore plat form to the racing yacht. Now days there are several numerical methods used to assess the seakeeping performance of vessels in regular and irregular waves. The combination of experimental study with numerical method making this problem more sophisticated to handle. In this thesis, the seakeeping analysis has been carried out on two superyachts of different length by using commercial software's HydroStar.

Although there are not specified criteria to investigate the seakeeping performance of the motor yachts but Gillard Stated in his research that seakeeping analysis is based on the short-term Stateistical approach and ship motions, limiting criteria, according to the sea States [5]. In presented thesis the seakeeping analysis is based on the ISO and (Odabas¸ı et al., 1991) seakeeping limits, hydrodynamics and inertial characteristics of the yacht hull, sea States where yacht will operates and short term wave power density spectrum function [7]
The ship response characteristics in terms of roll and pitch motion, vertical and lateral acceleration at a specific position in different velocities and headings have been analysed in different sea States of Mediterranean and Aegean seas. The comfort and performance of the yachts have been analysed regarding the limiting criteria provided by the organizations and rules.

1.1 Aim and Objectives

Objective of the present work is to investigate the Seakeeping behaviour of a projected 53 and 46 meter motor yachts in regular and irregular waves at 6 different sea States of Mediterranean and Aegean Sea by means of:

- Estimation of sea States and environmental condition encountered by the ship
- Prediction of Ship Response Characteristics
    - Significant amplitude of Roll motion
    - Significant amplitude of Pitch motion
    - Significant amplitude of Vertical acceleration at owner's cabin
    - Significant amplitude of Vertical acceleration at bridge
    - Significant amplitude of Vertical acceleration at saloon
    - Significant amplitude of Lateral acceleration at bridge
- The limiting criteria specified for the ship

The BUREAU VERITAS software Hydrostar will be used to compute the transfer functions. Seakeeping performance of 53 meter motor yacht in both Mediterranean and Aegean seas, at different sea States; will be compared by the results obtained by HSVA Hamburg and (ISO 2631-3, 1985) limiting criteria. By validating the concurrency of the computation method of HydroStar and HSVA Hamburg the Seakeeping performance of the 46 meter motor yacht will be calculated and to be checked whether it is under the defibed limiting criteria or not. Finally the seakeeping performance of 46 meter yachts will be calculated in Mediterranean and Aegean seas at different sea States regarding its operability and comfort of the crew, owner and guest.

1.2 Input and Response Variables

Table 1-1 Input and Response Variable

Input variables	Response Variables
Input Geometry Sea State Speed Headings	Yacht Response

1.3 Seakeeping Analysis Methodology

The characteristics of Seakeeping analysis of moving ship in regular and irregular waves can be explained by the behaviour of ship in waves.

Ship seakeeping performance hugely depends upon the

- Sea States and environmental condition
- Ship speed, headings and loading conditions

Analysis of Seakeeping can be solved in three steps,

- Estimation of sea States and environmental condition encountered by the ship
- Prediction of ship Response Characteristics
- The limiting criteria specified for the ship

1.4 Seakeeping Performance Assessment Procedure

The assessment of seakeeping performance depends upon the dynamic response of oscillating ship in irregular waves, according to the sea States during its operating life. Fig. 1-1 represent the overall procedure of seakeeping performance assessment.

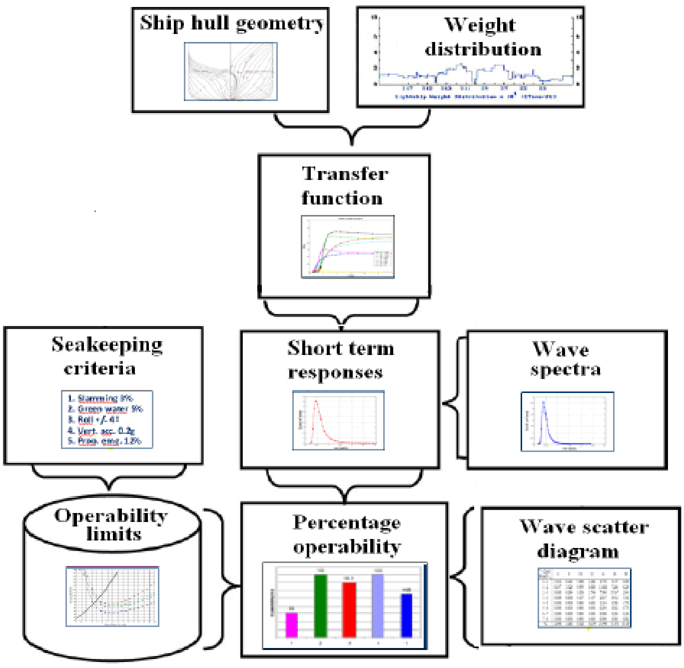


Figure 1-1: Overview of the seakeeping performance assessment procedure [1]

1. The procedure starts with the prediction of the ship's hydrodynamic response for a range of speed and heading angle values.
2. Computation of the transfer functions of the absolute ship motions and of derived values, such as accelerations and relative motions. The transfer functions can be computed with 2D strip theory based computational codes [5], while taking into consideration of the ship geometric and inertial characteristics.
3. Short term dynamic response of ship, based on the specific wave spectra and transfer functions or the amplitude of the ship motions in irregular waves predicted according to the sea State and the specific wave spectra.
4. Finally, based on the seakeeping safety conditions and the long-term wave scattering diagram the seakeeping Cartesian and polar diagram obtained.

1.5 Summary

The following is the hierarchy of the project.

Chapter 1: Introduction, Aim and Objectives and methodology explained in this chapter.

Chapter 2: Seakeeping theory and application.

Chapter 3: Numerical methods to evaluate the seakeeping performance.

Chapter 4: Seakeeping performance assessment on two different yachts with Hydrostar software has explained,

Chapter 5 Results and discussion has been done in this chapter.

Chapter 2
Seakeeping Theory

Seakeeping Theory

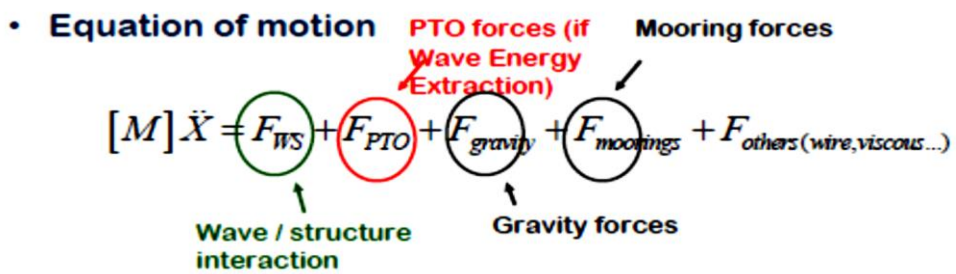
Seakeeping of the yacht normally explain by two ways comfort and performance. The motion of the ship and waves has strong impact on the crew/passenger life on board and the hydrodynamics load. The above influence becomes significant and clear when sailing a yacht in a significant sea State or condition.

The seakeeping analysis commonly considered as the calculation of velocity, displacement, and acceleration of the boat, which it experiences during its operation in a particular sea State conditions. To comprehend the response of the ship there is a common approach, to calculate the response amplitude operator RAO that is a transfer function in a frequency domain of the specific boat or vessel in function of the following parameters, wave amplitude, phase, period etc. Instead of complex, costly and time-consuming experimental test, ship response calculated under famous steady solution strip theory, potential flow theory plus free surface linearization approach.

There is an increase in the computational power of the personal computer combined with the increase of CFD simulation validation, there are different approaches are introducing to solve seakeeping problems. (Gaillarde et al.[6], Bartesaghi et al. [7]). In yacht engineering unsteady time domain approach simulations are starting to be used and Bunnik in his research paper explain the comprehensive difference between the seakeeping prediction tools[8] and they concluded that there is no clear added value of CFD in forward-speed ship-motion computations, as long as there are no strong nonlinearity or viscous effects.

2.1 Seakeeping Theory and Problem

The basic idea of seakeeping problem can be extract from the equation of motion of the moving vessel, which represent the different contribution of forces. The following is the basic equation of the floating structure,[9]



(2.1)

In momentum equilibrium, we can write the inertia force and hydroStateic force is equal to the hydrodynamics plus external forces

$$F_{Inertia} + F_{HydroStateic} = F_{Hydrodynamic} + F_{external} \quad (2.2)$$

The hydroStateic force in the above equation is related to the buoyancy force on the vessel and geometry while the external force is related to the mooring, current, wind, PTO etc. Hydrodynamics force can be decomposing into four different forces.

$$F_{hydrodynamic} = F_{incident} + F_{diffraction} + F_{radiation} + F_{drag} \quad (2.3)$$

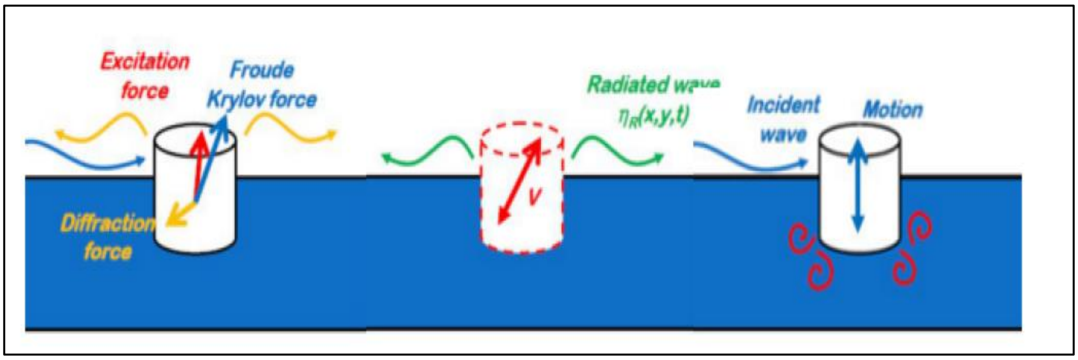


Figure 2-1 Hydrodynamics decomposition of force [9]

The question that comes into mind, do we really have to consider all the forces (hydroStateic force, Excitation force, Radiation force, drag force) in all problems. So thanks to the kelugan carpentry number to answer this question.

If Kc < 2 (large bodies compare to the waves) the flow has been attached to the body, large perturbation of the incident flow, diffraction and radiation forces are most important while the effect of drag forces important only at the resonance condition.

Hydrodynamic forces normally described by the nonlinear second order non-homogeneous Equations, the usual approach for the resolution is to assume a set of hypothesis, it enablesus to model a wave-structure interaction as linear time invariant system, and perform the solution in a frequency domain which is basically the principle of linear time invariant system for seakeeping theory [9].To understand and calculate the Harmonic response of the floating structure the following system of six equation is used.

$$(-\omega 2\ [M + A(\omega)] + i\omega\ [B(\omega)] + [K])X = FI(\omega) + FD(\omega) \tag{2.4}$$

To physically understand the above equation the following references were interested [9], [14], and [11].

In regular airy waves sea State the following problem solve under the linear potential theory with assumption of non-.viscosity and small steepness. While in the irregular waves sea State the spectral method must be employed with Fourier transformation theory.

2.2 Ship response characteristics

Motion response amplitude and phase for six degree of freedom in the frequency domain is the first step to find the seakeeping performance. RAOs Response amplitude operator calculated for each mode of motion like translational and angular at specific point on yacht or vessel in terms of acceleration and displacement. RAO define the Response amplitude due to unit wave excitation. Heave, roll and pitch are particular important because these are three different motions with the hydroStateic restoring force and possess the natural response period and potential for resonance behaviour. Vertical and lateral acceleration are of main concern for comfort in the passenger vessel.

2.3 Definition of the seaway

Stateistical model is used to describe the natural seaways in which the ship operates. The function of spectral density is the primary source for signifying the seaways and oscillation response of vessel to the seaway.

The characteristics of waves in a specific area should be known regarding wave energy distribution, with respect to the direction and frequency, as well as the severity of seas.

The irregular seas can be described by the JONSWAP-spectrum with the parameters significant wave height, Peak period and the enhancement factor γ. The JONSWAP-spectrum is intended to represent sea areas, where geographical boundaries limit the fetch of the wind like in the Baltic sea, north sea, Aegean and Mediterranean sea.

2.4 Prediction of Responses in a Specified Seaway

Short-range response obtained by the superposition of the yacht or vessels RAOs with wave spectral family define by mean steady-State response for seas of varying sternness in addition to the standard deviancy about the mean due to variations in spectral shape in each group of wave height.

2.5 Seakeeping criteria

There is a not specific criterion to evaluate seakeeping performance it varies from one ship to another ship depending upon the mission of the ship, the important parameter for yacht and passenger vessel is the comfort ride, it can express in terms of low percentage of passenger seasickness in rough sea. Lateral and vertical acceleration are the responsible for seasickness.

2.6 Motion Seasickness Index

Motion seasickness is referred to the discomfort which is associated with the condition of motion of any type of transport. G.Redondo and S.Bartesaghi [7] described that the seakeeping analysis should be able to explain the ability of the yacht to operate efficiently and safely even in a high sea State. The parameters which effects from the seakeeping analysis are added According to ISO 2361 it is well Stated that the major cause of seasickness with minor and no effects from roll and pitch is due to the vertical component of the motion. So, to avoid seasickness, it is required to design a vessel with small motion in the range of 0.1-0.315 Hz frequency. Moreover, the slight variation in terms of time exposure leads to a significant change or difference in the estimated habitability.

O'Hanlon and McCauley in 1974 presented the first analytical model to predict how much percentage of people vomit after two hour exposure.[20].The following formula for motion seasickness index is using after several modification of different authors

$$MSI = 100\left[0.5 + erf\left(\frac{Log(\zeta/g) + 0.819 - 2.32(Log(f_e))}{0.4}\right)\right] \tag{2.5}$$

Where.

ζ is average vertical acceleration over one motion cycle, *erf* is error function

fe is encounter frequency.

Equivalent to the MSI, the Motion Sickness Dose Value (MSDV) estimates the percentage of people who may vomit (VI) after a specific time-period of exposure:

$$V\,I \;=\; K_m MSDV \tag{2.6}$$

$$MSDV = \left[\int_0^T a_w(t)^2 dt\right]^{1/2} \tag{2.7}$$

Where Km is an empirical coefficient that has value vary between 0.15 to 0.45. To derive these equations only heave motion has been considered to calculate the vertical acceleration but in actuality the magnitude of the absolute motion and acceleration of the ship vary with position around vessel due to influence of rotational motions.so it is required to consider the all component from pitch and roll motion to investigate the stern and bow part of the yacht.

Boote et al. [21] investigated the seakeeping of Rodriquez ferries in which he explain that principally the motion seasickness index is less relevant in stern seas , but it increase with head sea significantly.

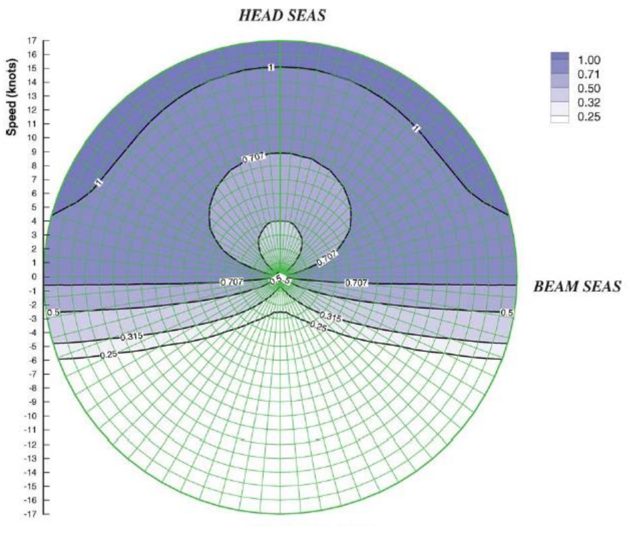


Figure 2-2 Typical polar diagram for Motion Sickness Index [12]

Bartesaghi [7] Stated in his work, unsteady CFD simulation can be performed for MSI calculation. However, the computations require high computation time at the design stage. He also studied a full scale model at initial design speed with five degree of freedom by using Star CCM plus Solver and confirmed that the position of crew/passenger at bow part of the yacht is the most uncomfortable place.

Chapter 3
Numerical Methods Overview

Numerical Methods Overview

The experimental test are very important to see the seakeeping behaviour of the vessel, but now a days there are several numerical methods are also used to predict the seakeeping characteristics of a ship.

3.1 Frequency Domain Methods

The equation of motion for six degree of freedom can be explained or expressed in frequency domain. The main advantage of the equation to express in frequency domain is the direct use of RAO transfer function and the use of wave spectrum model as sources of loads. While in the spectrum analysis sea State and response can be reconstructed in time domain method as sum of multiple sinusoids of different frequencies and phases e.g random elevation of waves in 2D at certain point in time can be expressed as

$$\eta(t) = \sum A_i cos(\omega_i t + \theta_i) \tag{3.1}$$

$$A^2 = 2S(\omega_i) \cdot d\omega_i \tag{1}$$

Where

η is wave elevation

ω is the wave frequency

θ is the phase angle and A is the amplitude.

The linear motions in random sea-State can be reconstructed as a motion in irregular waves.by using (3.1) & (3.2) equation

Once we decide or get the wave spectrum from the equation, (2.4) than it is easy to get the relative response of a yacht simply multiply with the Response Amplitude Operators.

3.2 Strip Theory

The principle of strip theory can be define as the hydrodynamic properties of a certain vessel like added mass and damping and stiffness can be projected by dividing whole vessel into series of small two-dimensional transverse strips, for these strips hydrodynamic properties may be computed. The global values of hydrodynamic properties than calculated by integration of the two dimensional strips over the length of yacht or vessel [22]

Salvesen et al. (1970) explain the strip theory, Linear strip theory assumes that the motion of the vessel is linear and harmonic and in this case the response of the vessels in both pitch and heave , for a given speed and frequency has been proportional to the amplitude of waves.[22]

Lloyd in 1989 States the assumption of linear strip theory.

- Inviscid fluid
- Slender Ship
- Hull is rigid and no flexure of structure occurs.
- Speed is moderate so there is no appreciable planning lift
- The ship hull sections are well sided.
- The water depth compared to wavelength much greater.
- Hull presence has no effect on waves (Froud-Krilove Hypothesis)

Convert 3D problem into several 2D problems independent of other are the basic of strip theory. Traditional seakeeping tools for early seagoing vessels are mostly based on the strip theory. Seakeeping programmes are good for reasonable prediction for ship motion with length over beam ratio over five. Bertrarm et al. [11] gave the open source programme for the preliminary evaluation of the seakeeping analysis of the vessel.

Seakeeper is also the seakeeping analysis software which is based on the strip theory and allows to estimate the MSI directly.[22]

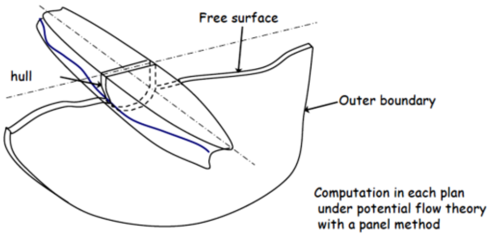


Figure 3-1 Strip Theory Source [Lionel Lecture]

3.3 Boundary Elements Method

The B.E.M uses the same hypothesis of potential flow theory.

Hypothesis:

- incompressible fluid
- non rotational flow :
- $\Delta\phi = 0$
- use of a panel method
- linearized and non-linearized free surface boundary conditions

Under these hypotheses, the NAVIER stroke equation can be decomposed into seven problems. Six of them are radiation condition of the body moving in a still water and one is the diffraction problem by the wave when the body is in fixed position.

Hydrostar is software for seakeeping analysis generated by BUREAU VERITAS use the above Stated theory and solves the hydrodynamic problem by means of Green function, which describe the whole domain only by the meshing of the submerged hull, this advantage save the computational time considerably.

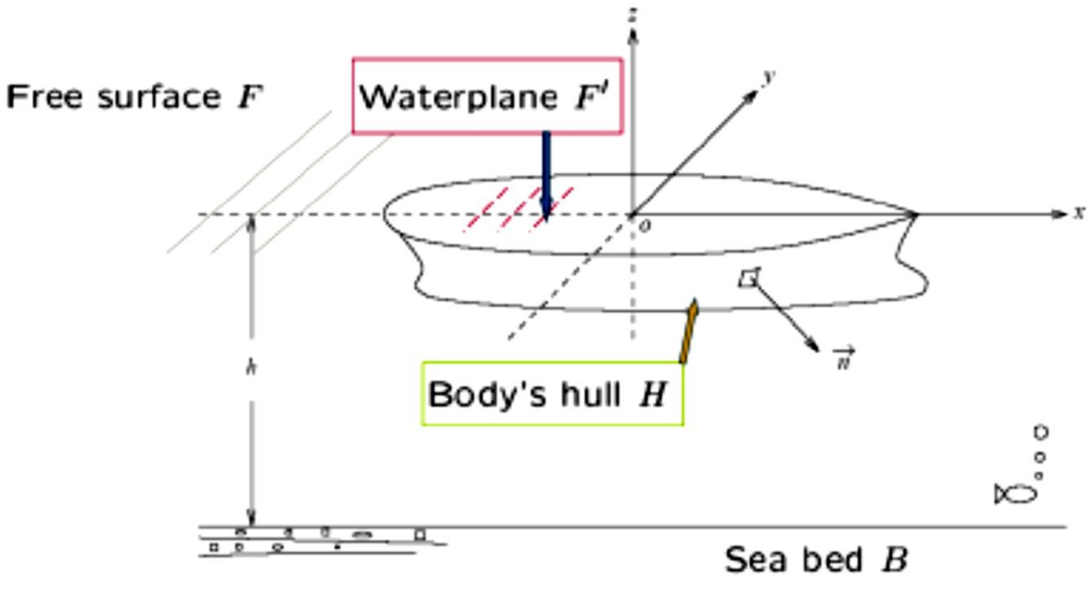


Figure 3-2 Hydrostar reference frame [19]

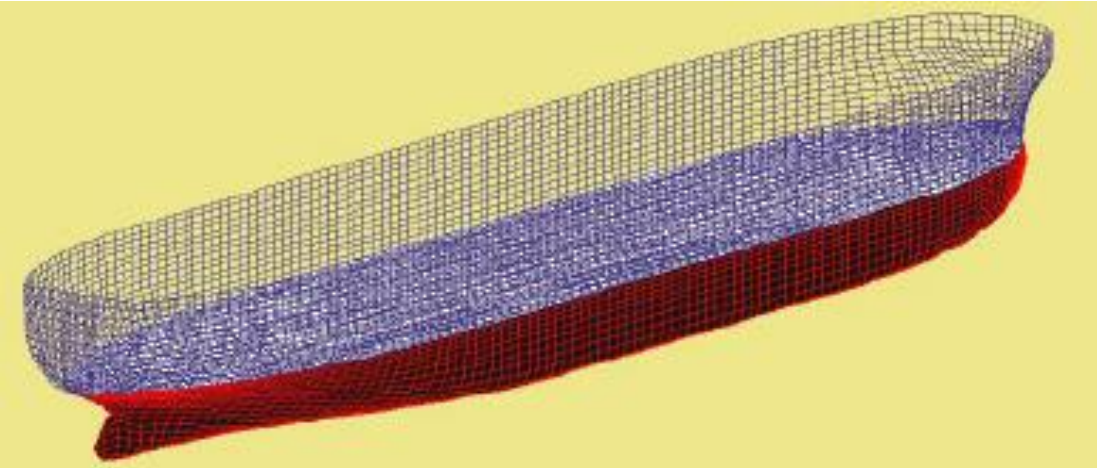


Figure 3-3 Hull meshing in Hydrostar [19]

Advantages of B.E.M

Obtaining of integrals on the boundaries of the fluid domain

(Hull, free surface, lateral walls and bottom)

Low number of unknowns (~ 103)

Full linear system

Linear point of view:

Meshing of:

- Immersed part of the hull
- Free surface at rest

Nonlinear point of view:

Free surface tracking and deformation of the free surface mesh

Results given by this method

- Wave field around the hull
- Total drag acting on the hull

3.4 Time Domain Methods: R.A.N.S. Equations

To perform more complex CFD simulation the software are used that are able to compute the RANS equation with several model of turbulence according to the requirement of the designers. The advantage is that the non-linearity due to the ship motion and breaking waves are computed in un-steady conditions. By means of Stateistical averaged methods, important hypothesis is made on the approximation of viscous effect in the boundary layer that help to compute the turbulent equations.

Kohlmos and Bertram[18] Stated in design and construction of super and mega yachts 2013 conference that the computing time or power is the main limiting factor of this software. RANSE simulation needed if study concerns about

- High speed
- Large wave or motion because of wave breaking phenomenon at the bow and water on the deck.
- Full 3d analysis require by the complex hull geometry.

In CFD simulation to analyse the seakeeping analysis of yacht, the analysis can start from a simplified model test only for some most important degree of freedom like heave and pitch and sea State can be represent by regular monochromatic wave or regular waves.

Chapter 4
Seakeeping Performance Assessment

Seakeeping Performance Assessment of Superyachts

4.1 Theoretical Background

The following study is related to the linear seakeeping analysis in an irregular wave for motor yachts. In the presented thesis Heave, Pitch, Roll, vertical and lateral acceleration at different headings and velocity have been checked and compared the results obtained to the result given by the HSVA Company, and after validating these result the seakeeping analysis has been performed on 46 meter motor yacht.

It may be possible that the prediction of other motion like surge, yaw and sway are less important or reliable than the other motion responses. It may be due to that the moments and restoring forces calculation are not correctly treated in frequency domain.

By using the strip theory the transfer functions were obtained for yacht motion. Transfer function was used to get the significant amplitude of the motion and acceleration at different courses (0 degree represents stern and 180 degree correspond head seas) and ship speeds in irregular waves (0 to 16 knots).

Irregular sea is described by the Jonswap spectrum with following parameters

- Enhancement Factor γ
- Significant Wave Height $\zeta_{w,sig}$
- Peak Period T_p

Jonswap-spectrum represents the sea areas of North Sea, Baltic Sea, Aegean and Mediterranean Sea.

Density Spectral Function for the dynamic response variation of ship has the following expressions which have been used in the present thesis.

Density Spectral Function for Heave Motion:

$$S_z(\omega,\mu) = H_z^2(\omega,\mu) \cdot \Phi_{\zeta_v\zeta_v}(\omega) = RAO_z(\omega,\mu) \cdot \Phi_{\zeta_v\zeta_v}(\omega) \tag{4.1}$$

Density Spectral Function for Pitch Motion:

$$S_\theta(\omega,\mu) = H_\theta^2(\omega,\mu)\cdot\Phi_{\zeta_v\zeta_v}(\omega) = RAO_\theta(\omega,\mu)\cdot\Phi_{\zeta_v\zeta_v}(\omega) \qquad (4.2)$$

Density Spectral Function for Roll Motion:

$$S_\varphi(\omega,\mu) = H_\varphi^2(\omega,\mu)\cdot\Phi_{\zeta_v\zeta_v}(\omega) = RAO_\varphi(\omega,\mu)\cdot\Phi_{\zeta_v\zeta_v}(\omega) \qquad (4.3)$$

Moments of Spectral Density Function

$$m_{oz}(\mu) = \int_0^{\omega max} S_z(\omega,\mu)d\omega;\quad m_{o\theta}(\mu) = \int_0^{\omega max} S_\theta(\omega,\mu)d\omega;\quad m_{o\varphi}(\mu) = \int_0^{\omega max} S_\varphi(\omega,\mu)d\omega \qquad (4.4)$$

$$m_{4z}(\mu) = \int_0^{\omega max} \omega^4 S_z(\omega,\mu)d\omega;\quad m_{4\theta}(\mu) = \int_0^{\omega max} \omega^4 S_\theta(\omega,\mu)d\omega;\quad m_{4\varphi}(\mu) = \int_0^{\omega max} \omega^4 S_\varphi(\omega,\mu)d\omega \qquad (4.5)$$

Theoretical Calculation of significant amplitude of Vertical Motion

$$RMS_z(\mu) = \sqrt{m_{0z}(\mu)} \qquad (4.6)$$

$$RMSac_z(\mu) = \sqrt{m_{4z}(\mu)} \qquad (4.7)$$

$$RMS_{zmax} = F + Fs - z_{pv\theta} \qquad (4.8)$$

Significant amplitude = 2*RMS(vertical) (4.9)

Calculation of significant amplitude of Pitch Motion

$$RMS_\theta(\mu) = \sqrt{m_{0\theta}(\mu)} \qquad (4.10)$$

$$RMSac_\theta(\mu) = \sqrt{m_{4\theta}(\mu)} \qquad (4.11)$$

$$RMSac_{\theta pv}(\mu) = \frac{L}{2}\cdot RMSac_\theta(\mu) \qquad (4.12)$$

$$\text{RMS}_{\theta\max} = 3^0 = 0.052\text{rad} \Rightarrow Z_{pv\theta} = \frac{L}{2} \cdot \text{RMS}_{\theta\max}\ ; \quad (4.13)$$

Significant amplitude = 2*RMS(pitch) (4.14)

Calculation of significant amplitude of Roll Motion

$$\text{RMS}_{\varphi}(\mu) = \sqrt{m_{0\varphi}(\mu)} \quad (4.15)$$

$$\text{RMSac}_{\varphi}(\mu) = \sqrt{m_{4\varphi}(\mu)} \quad (4.16)$$

$$\text{RMSac}_{\varphi sb}(\mu) = \frac{B}{2} \cdot \text{RMSac}_{\varphi}(\mu) \quad (4.17)$$

$$\text{RMS}_{\varphi\max} = 6^0 = 0.105\ \text{rad} \quad (4.18)$$

Significant amplitude = 2*RMS(roll) (4.19)

4.2 B.E.M: Method: Hydro Star

Boundary elements method is use for the seakeeping analysis and it allows having results rapidly. By using hydro star software, we can study the influence of different or several important parameter of motor yacht in many different conditions, especially the influence on the heave, pitch and roll motion, which are the main factors of the floating vessels.

Hydrostar is hydrodynamic software that is used to calculate the first and second order wave load and induced motion of one or several ships or any kind of floating structure in a deep and finite water depth. The following analysis can be done by Hydrostar.

- RAO generation or hydrodynamic analysis of the floating bodies.
- Multi-bodies interaction analysis.
- Hydrodynamic analysis of transhipper during its towage.

4.3 Workflow of Hydrostar Software Bureau VERITAS

The figure 4-1 and 4-2 represent the step by step process to calculate the RAO using Hydrostar while using free ship and rhinoceroses for modeling respectively.

In order to compare the computational method it is very important to correctly prepare the input file of the problem and perform simulation. A work flow of HydroStar has been explained in figure 4-1(a) & 4-2(b) to get the desired results.

In the first step the (file.txt) must be created which had the sectional coordinate's data to make the (file.hul) and (file.mri) that represent the hydroStateic properties of the investigated yacht e.g. Trim or heel, waterline length and draft with meshing parameters such as type of bow, number of panels, and keel line. These two files were computed in HydroStar to get the consistent mesh with diffraction and radiation calculation.it is al so possible in HydroStar to insert the mass properties of yacht with local centre of gravity manually. There is another txt file that was combined in the previous information to compute global load on yacht and elaborated response amplitude operator of the yacht. The time taken by the simulation from 10 minute to 2 hour when I used the processor of Intel(R) Core(TM) i3-2370M CPU @ 2.40 GHz. The time depends upon the number of panels created and number of frequencies step used.

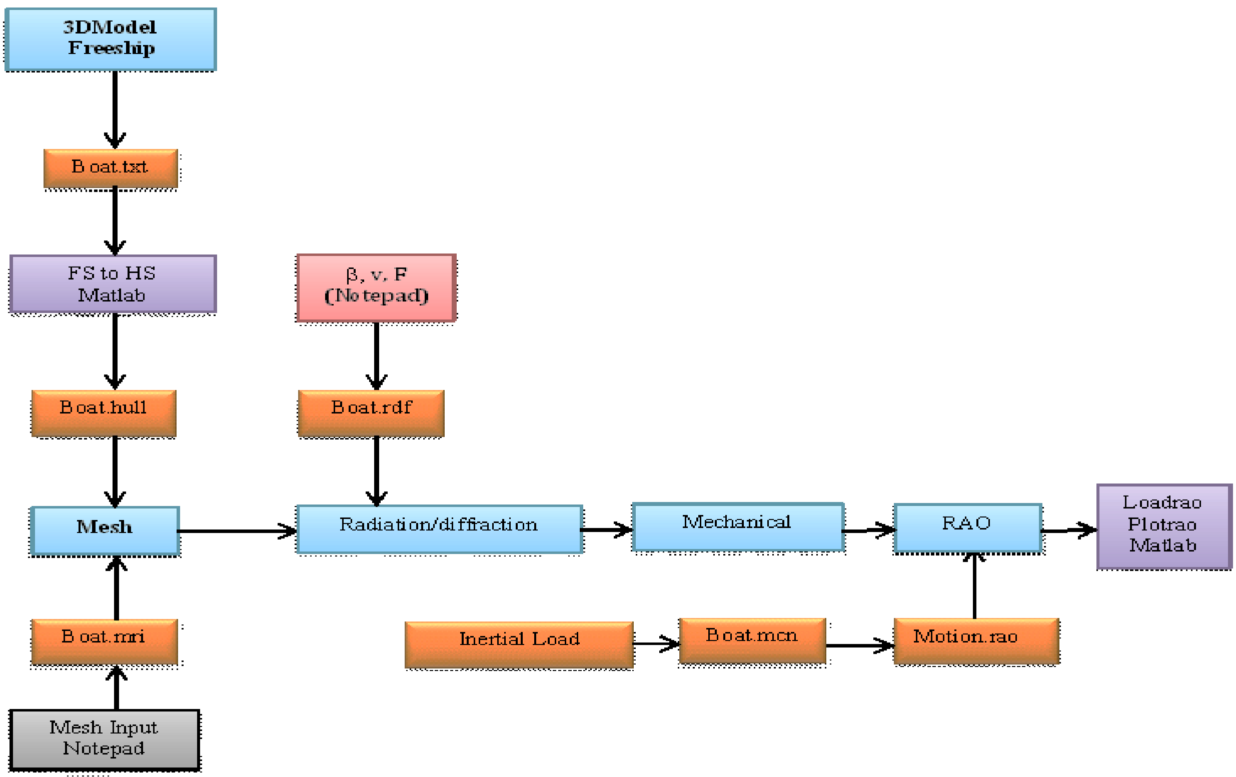


Figure 4-1 Workflow of Hydrostar(a)

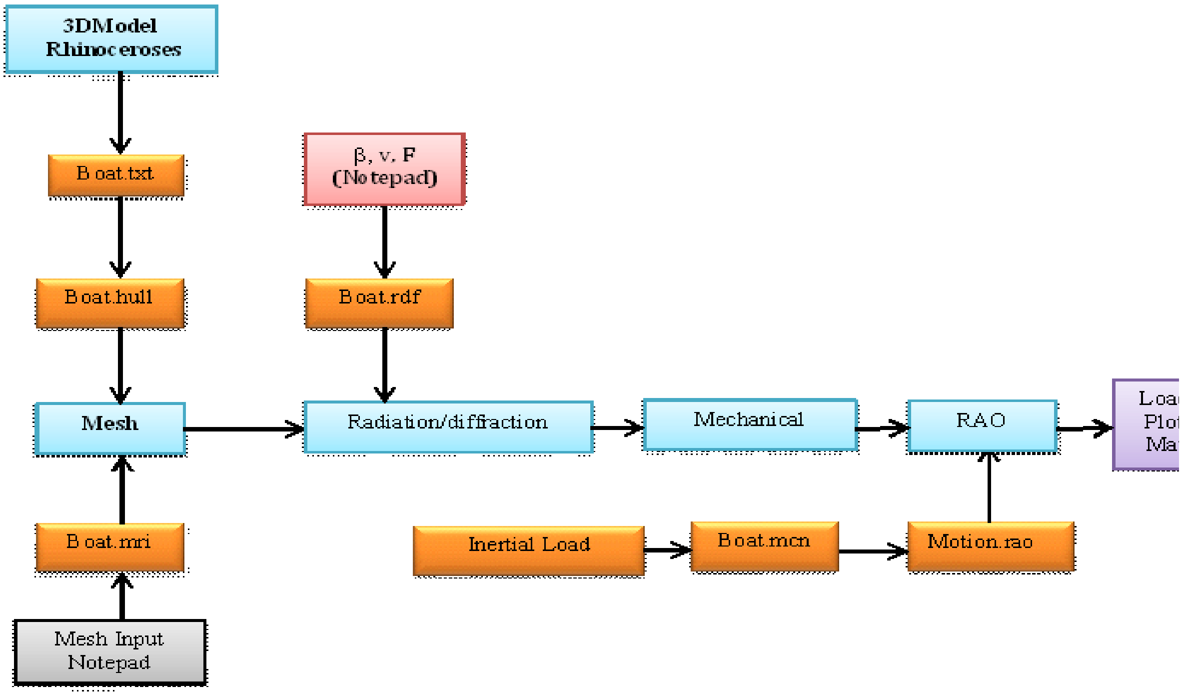


Figure 4-2 Workflow of Hydrostar(b)

4.4 Specifications of 53 and 46 m motor yacht

Seakeeping numerical analysis has been applied to calculate the operability index of the superyachts, having overall length 52.97 and 46.3 m with navigation routes in Mediterranean and Aegean Sea. The following are the dimension of the superyachts.

Table 4-1 Main Parameters of the 53 m motor yacht

Yacht 53	Y
Length overall	52.97 m
Length between perp., Lpp (m)	44.85 m
Beam at waterline, B_{WL} (m)	9.60 m
Draught Fore, T_F (m)	2.700 m
Draught Mean, T_M (m)	2.935 m
Draught Aft, T_A (m)	3.170 m
Displacement, (m)	593 m^3
Block Coefficient, Cb	0.469

Metacentric Height, GM	1.40 m
Radius of Gyration for pitch Iyy	0.245*Lpp
Radius of Gyration for Roll Iyy	0.380* B_{WL}
Natural Roll Motion Period	6.9s

Table 4-2 Main Parameters of the 46 m motor yacht

Yacht 46	**Y**
Length overall	46.3 m
Length between perp., Lpp (m)	41.44 m
Beam at waterline, B_{WL} (m)	9.50 m
Draught Fore, T_F (m)	2.800 m
Displacement, (m)	444 m^3
Radius of Gyration for pitch Iyy	0.245*Lpp
Radius of Gyration for Roll Iyy	0.380* B_{WL}

4.5 Sea States

Table 4-3 Sea States

Sea States		3	4	5
Significant wave height	$\zeta_{w,sig}$	0.88 m	1.88 m	3.25 m
Aegean Sea				
Average Wave Period	T_1	3.5 s	4.5 s	5.3s
Peak Period	Tp	4.2s	5.4s	6.3s
Belonging wave length	λ_{Tp}	27.5 m	45.5m	61.9m
Mediterranean				
Average Wave Period	T_1	4.0 s	5.5 s	6.75 s
Peak Period	Tp	4.8 s	6.6 s	8.1 s

Belonging wave length	λ_{Tp}	35.9 s	68.0 m	102.4 m

4.5.1 Definition of Seaways

In nature the regular waves can be found rarely and RAOs by their own are of little consequence. Stateistical Model can be used to describe the natural seaway in which the ship or vessel operates. To represent the seaways and oscillatory response of the vessel the primary device used are spectral density function or spectrum.

The characteristics of wave for particular area in terms of wave energy distribution w.r.t frequency and direction must be known, the severity of the seas indicated by probability of wave height distribution as well. In fig 4-3 & 4-4 spectral density function with respect to wave frequency and sea State, based on Jonswap formulation has been presented.

4.5.2 JONSWAP Spectrum Mediterranean Sea

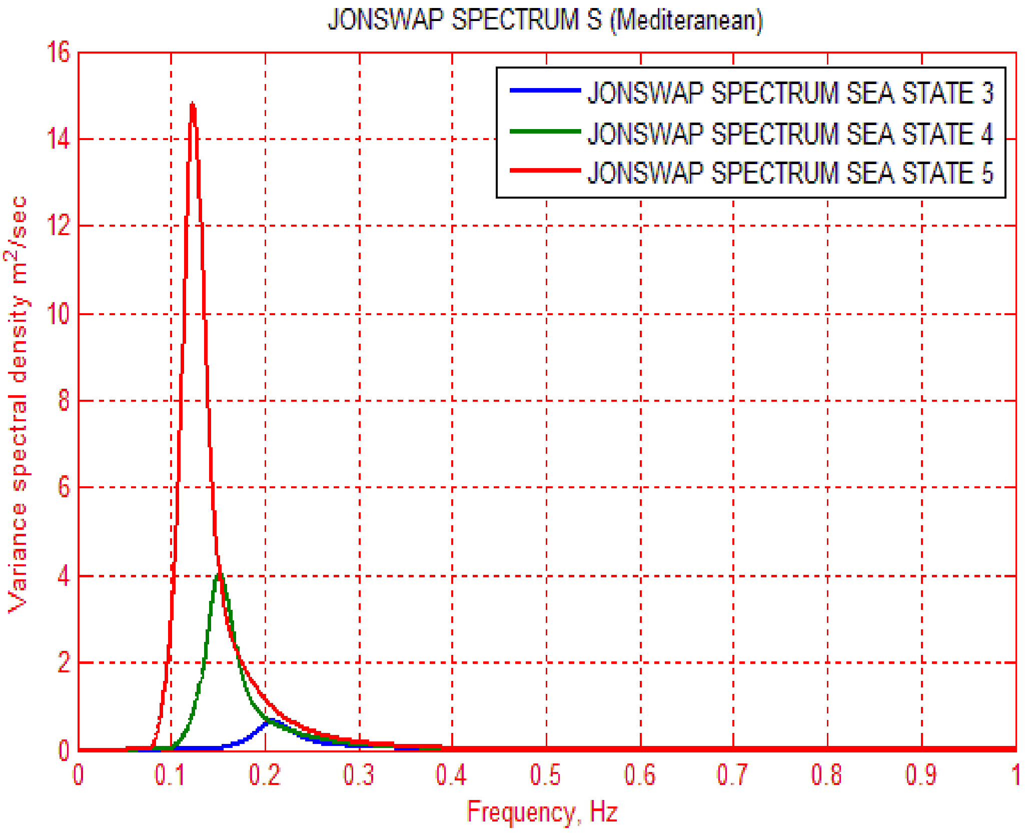


Figure 4-3 JONSWAP at sea State 3,4 and 5 (Mediterranean)

4.5.3 JONSWAP Spectrum Aegean Sea

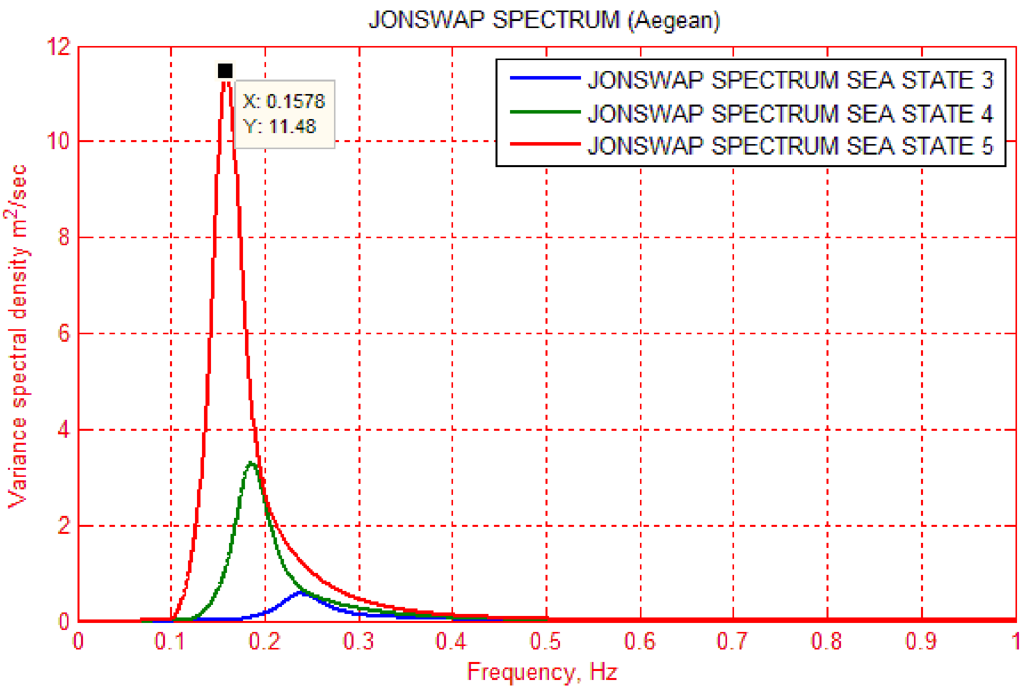


Figure 4-4 JONSWAP at sea State 3,4 and 5 (Aegean)

4.5.4 Response Amplitude Operator (RAO) by Hydrostar

In first step the yacht model of 53 and 46 meter converted into sections by using the modelling software rhinoceros and extracted the coordinate of each section in terms of Txt file.

In second step the geometry input files for Hydrostar created and it includes fb53.hul which contained the coordinates of each section in a specific format while fb53.mri basically indicates hydroStateic properties of the yacht e.g. trim, draft and water line length and meshing parameters e.g. knuckle points, type of bow and stern, total number of panels. The fb53.hul and fb53.mri were used in Hydrostar to create the mesh on the immersed volume of yacht model to make environment to get the hydroStateic result about mesh which would be used to

calculate the radiation or diffraction.

After defining all parameters in fb53.hul and fb53.mri the mesh was created by using the hsmsh –ship fb53 command and read that mesh by hslec myship.hst and hschk is use to check either mesh is ok or not. If mesh is ok the Hydrostar will notify that your mesh is ok and now you can proceed further. To visualise the mesh hvisu command can be used. The hydroStateic result about mesh can be checked by hState command.

For radiation or diffraction calculation the fb53.rdf file need to be created in which wave frequencies, headings forward speed and water depth was specified. For the computation of calculation hsrdf fb53.rdf command was used. The mechanical properties and mass distribution can be specified in massdistribution.weld file and hState massdistribution.weld gives mechanical results in myship_wld.don and the result from it pasted in fb53.mcn file or it can be created manually to solve the equation of motion by using hsmcn fb53.mcn. Response amplitude operator RAO was extracted by using motion.rao and same procedure was used to extract RAO for 46 meter motor yacht. The graphical steps are shown in figure 4-2(b).The figure 4-6 represents the 53 meter motor yacht model of on which the seakeeping analysis has been performed.

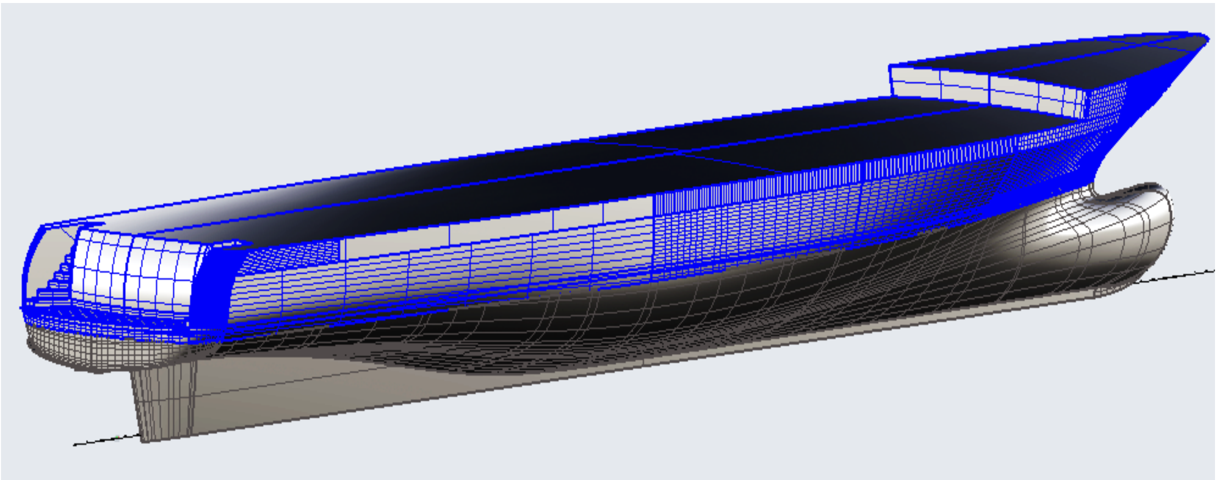


Figure 4-5 motor yacht model 53 meter in length

The figure 4-7 represents the coordinates of the sections created by rhinoceroses of the 53 meter motor yacht.

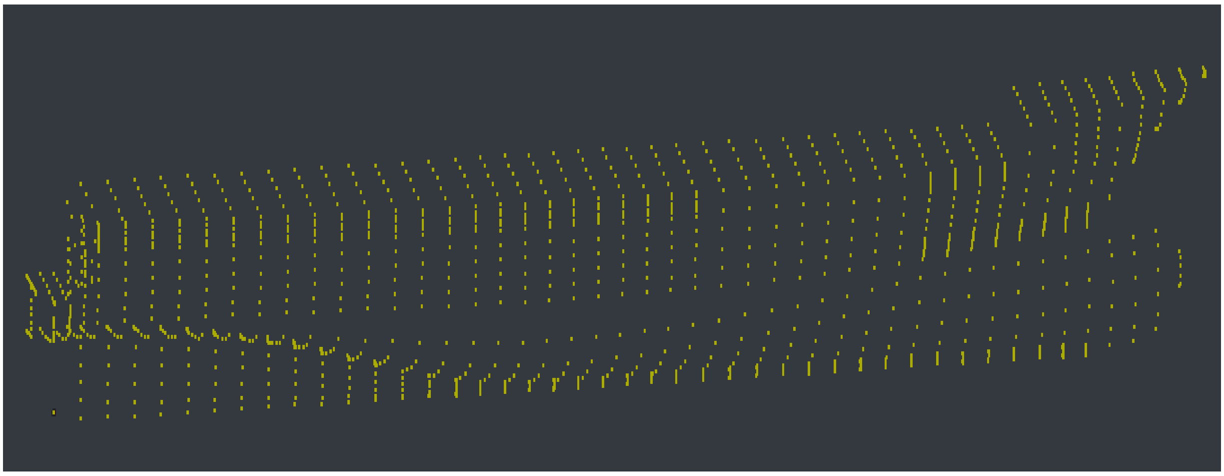


Figure 4-6 motor yacht model 53 meter in length Sections

The mesh generation by using Hydrostar can be visualized in figure 4-8 & 4-9.

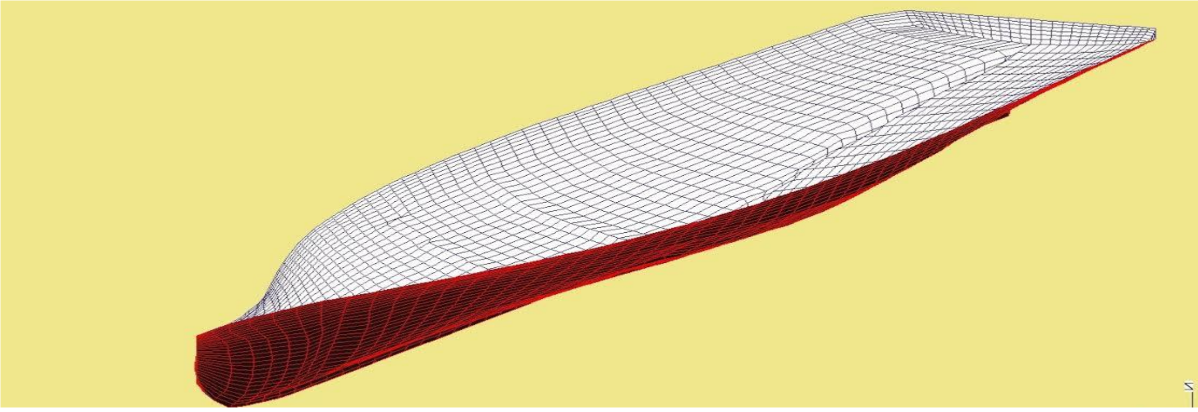


Figure 4-7 motor yacht model 53 meter in length mesh visualization

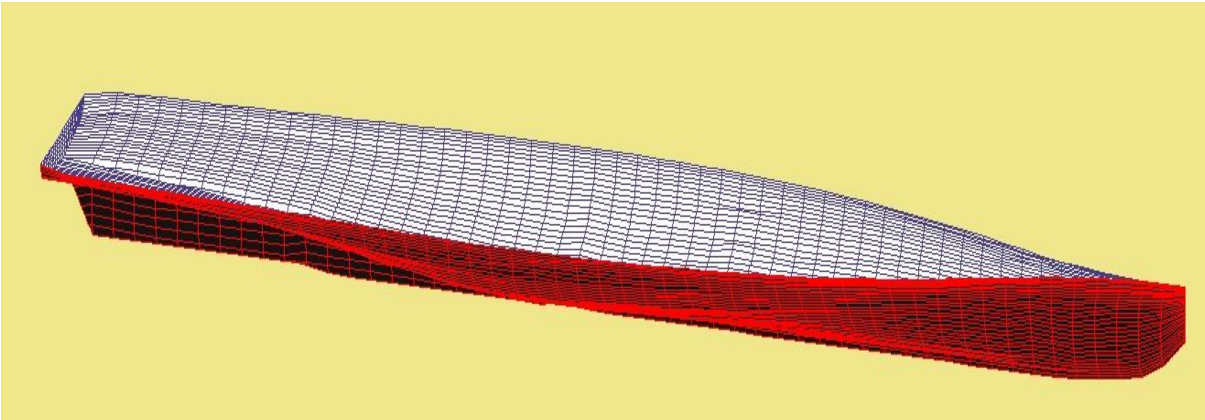


Figure 4-8 motor yacht model 53 meter in length mesh visualization

The figure 4-10 represents the 46 meter motor yacht model of on which the seakeeping analysis has been performed

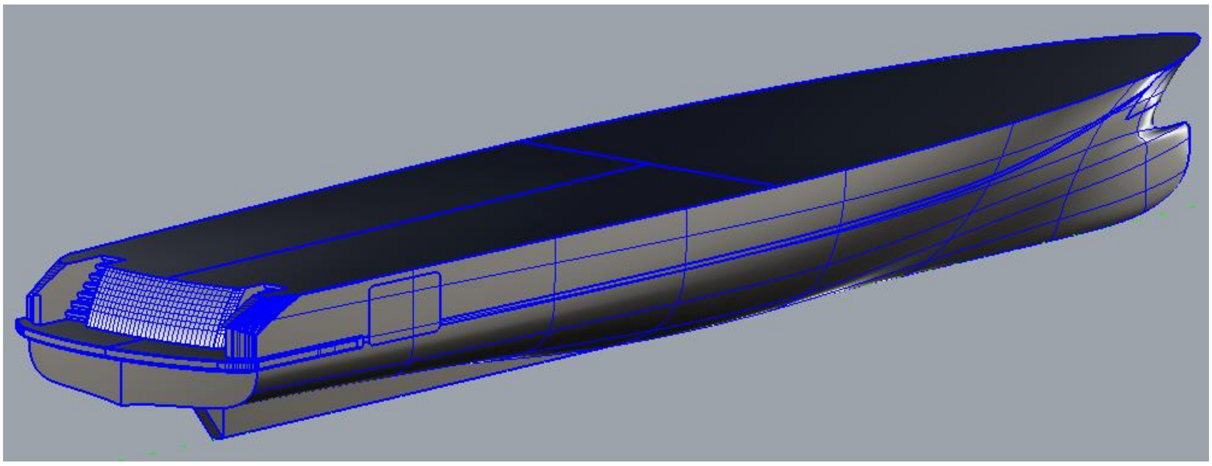


Figure 4-9 motor yacht model 46 meter in length

The figure 4-11 represents the coordinates of the sections created by rhinoceroses of the 46 meter motor yacht.

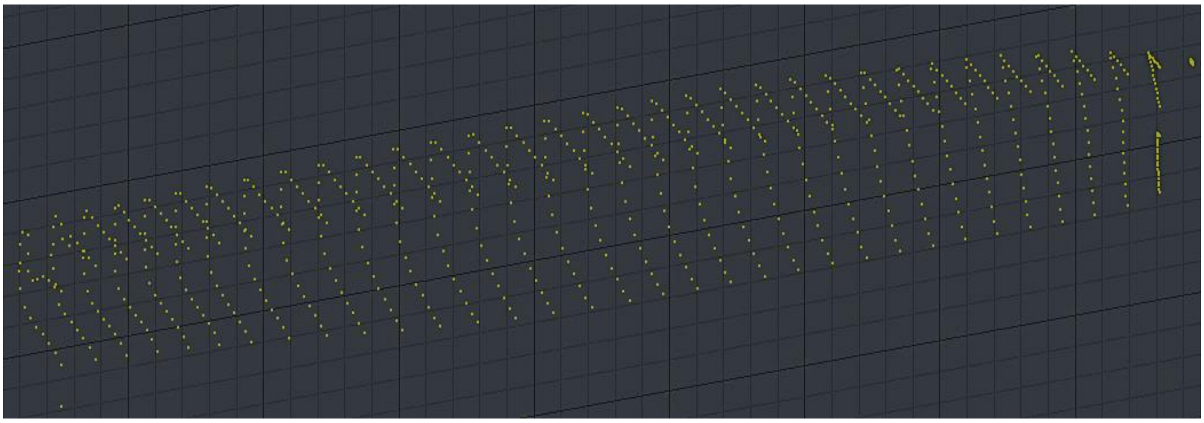


Figure 4-10 motor yacht model 46 meter in length Sections

The mesh generation by using Hydrostar can be visualized in figure 4-12

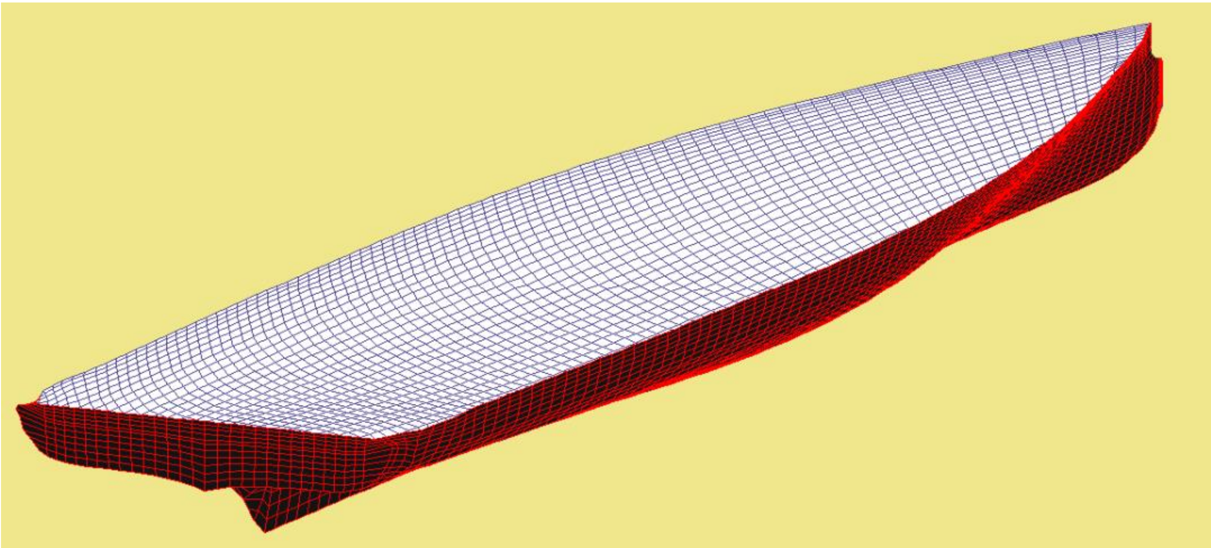


Figure 4-11 motor yacht model 46 meter in length mesh visualization

4.6 Effect of Headings and Velocity on ship motion under regular wave

4.6.1 Transfer Functions of Absolute Motions

To calculate the seakeeping performance of the vessel, the first step is to calculate the ship response transfer function of the main degree of freedom of ship for all heading angles in regular waves.

4.6.1.1 53 meter motor yacht

4.6.1.2 Influence of Heading and velocity on Heave

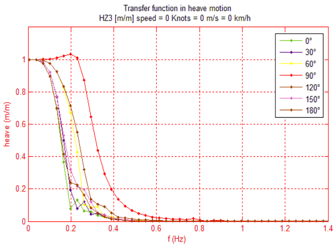


Figure 4-12 Heave Transfer Function at 0 knots

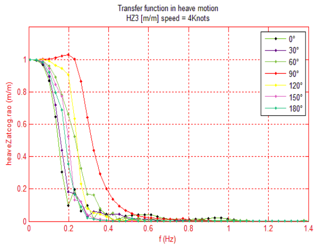


Figure 4-13 Heave Transfer Function at 4 knots

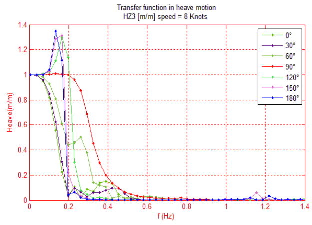


Figure 4-14 Heave Transfer Function at 8 knots

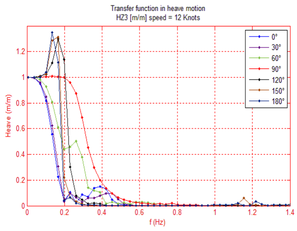


Figure 4-15Heave Transfer Function at 12 knots

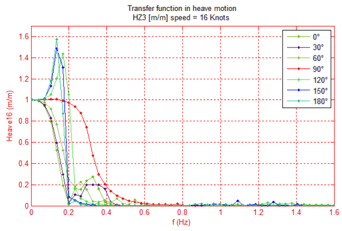


Figure 4-16 Heave Transfer Function at 16 knots

It is observed that the heave amplitude reach to unit value at each heading and heave increase maximum from 90 to 120 degree of heading

4.6.1.3 Influence of Heading and velocity on Pitch

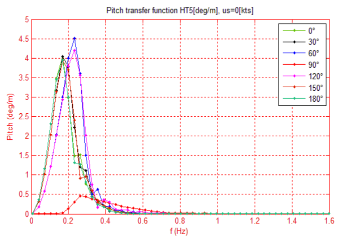


Figure 4-17Pitch Transfer Function at 0 knots

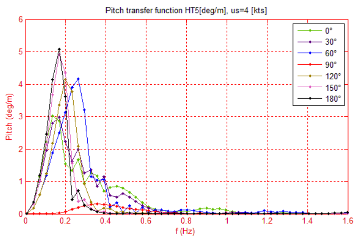


Figure 4-18 Pitch Transfer Function at 4 knots

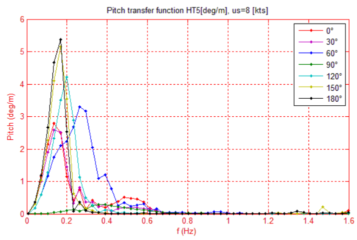


Figure 4-19 Pitch Transfer Function at 8 knot

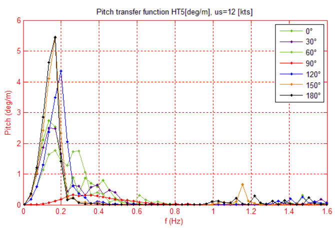


Figure 4-20 Pitch Transfer Function at 12 knots

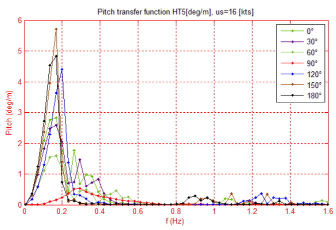


Figure 4-21 Pitch Transfer Function at 16 knots

The maximum pitch motion amplitude is obtained in the heading angles of 60, 120, 150, and 180 degree while the pitch motion at 90 degree does not occur.

4.6.1.4 Influence of Heading and velocity on Roll

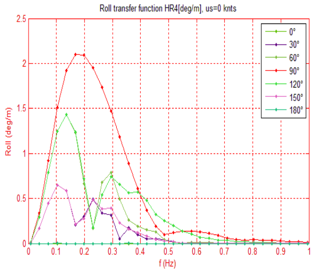


Figure 4-22 Roll Transfer function at 0 knots

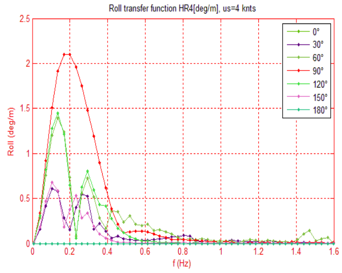


Figure 4-23 Roll transfer function HR4[deg/m], us=4 knots

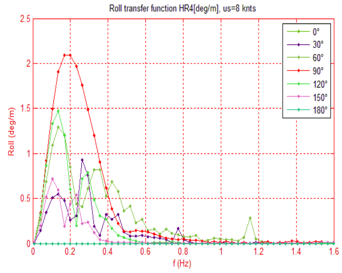


Figure 4-24 Roll transfer function HR4[deg/m], us=8 knots

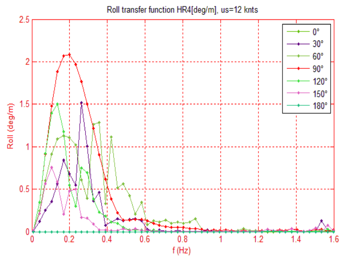


Figure 4-25 Roll transfer function HR4[deg/m], us=12 knots

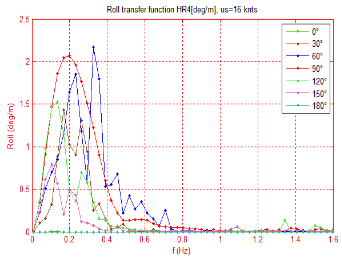


Figure 4-26 Roll transfer function HR4[deg/m], us=16 knots

The transfer function of the roll motion has maximum values in headings 60, 90and 120 degree without viscous damping while we are considering the radiation hydrodynamic damping the roll motion is almost zero at heading 180 degree.

4.6.2 Derived Ship Transfer Functions

Drive responses of ship have been calculated for different headings and forward speeds on a specific location.

Table 4-4 Location of different fixed positions under consideration

Position	X [m] In front of AP	Y [m] From Centreline	Z[m] Above Base
Owner's cabin	36.80	0	6.90
Saloon	12.65	0	6.90
Bridge	28.43	0	9.50

4.6.2.1 Influence of Heading and velocity on Vertical acceleration at owner's cabin

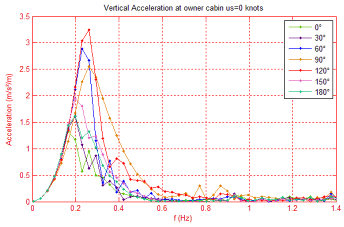


Figure 4-27 Vertical acceleration at owner cabin at 0 knots

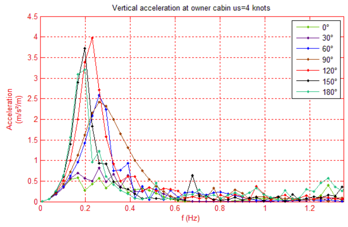


Figure 4-28 Vertical acceleration at owner cabin at 4 knots

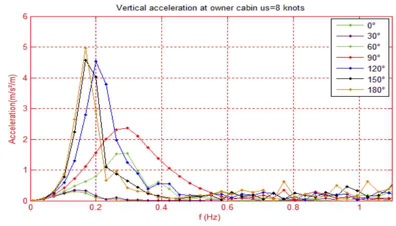


Figure 4-29 Vertical acceleration at owner cabin at 8 knots

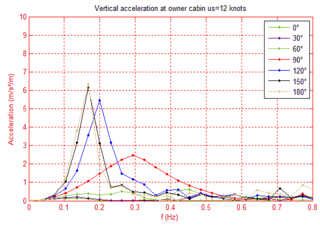


Figure 4-30 Vertical acceleration at owner cabin at 12 knots

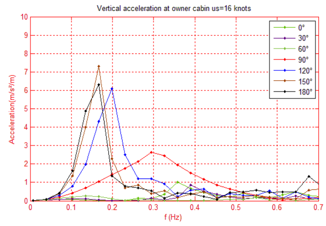


Figure 4-31 Vertical acceleration at owner cabin at 16 knots

Great amplification in vertical acceleration at heading 120, 150, and 180 degree has been noticed, while at 0, 30, and 60 degree there is no amplification in vertical acceleration so to navigate yacht in these heading are recommended for the comfort of the owner.

4.6.2.2 Influence of Heading and velocity on Vertical acceleration at bridge

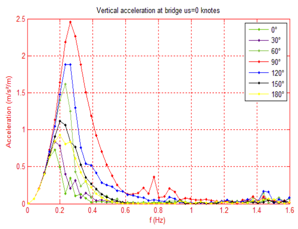


Figure 4-32 Vertical acceleration at Bridge at 0 knots

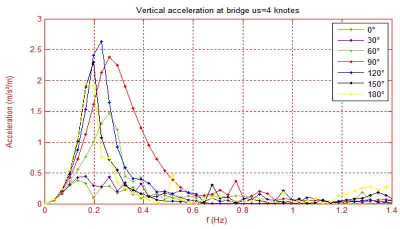


Figure 4-33 Vertical acceleration at Bridge at 4 knots

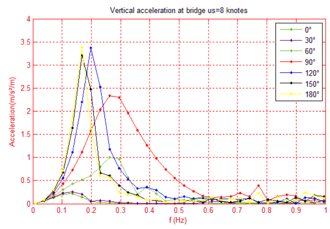


Figure 4-34 Vertical acceleration at Bridge at 8 knots

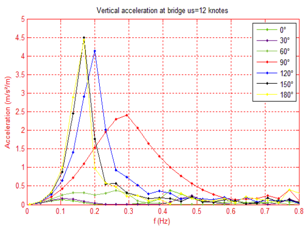


Figure 4-35 Vertical acceleration at Bridge at12 knots

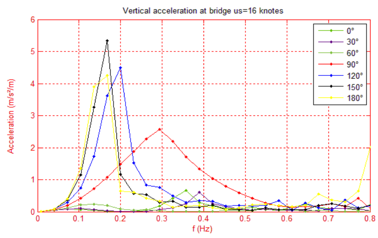


Figure 4-36 Vertical acceleration at Bridge at 16 knots

Great amplification in vertical acceleration at heading 120, 150, and 180 degree has been noticed, while at 0, 30, and 60 degree there is no amplification in vertical acceleration so to navigate yacht in these heading are recommended for the comfort of the Crew.

4.6.2.3 Influence of Heading and velocity on Vertical acceleration at saloon

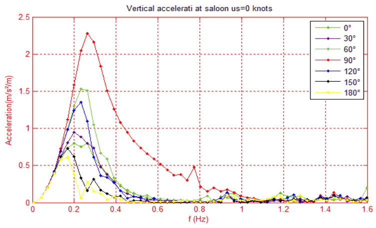


Figure 4-37 Vertical acceleration at Saloon at 0 knots

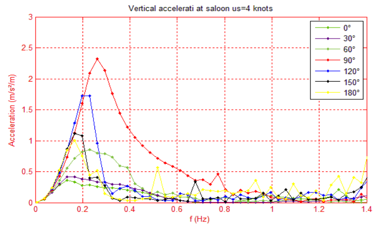


Figure 4-38 Vertical acceleration at Saloon at 4 knots

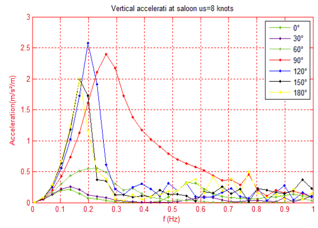


Figure 4-39 Vertical acceleration at Saloon at 8 knots

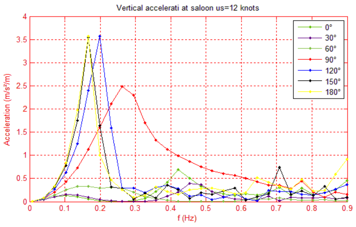


Figure 4-40 Vertical acceleration at Saloon at 12 knots

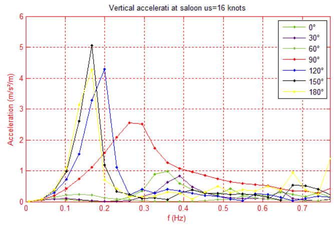


Figure 4-41 Vertical acceleration at Saloon at 16 knots

It is noticed that the great amplification in vertical acceleration at heading 120, 150, and 180 degree has been noticed, while at 0, 30, and 60 degree there is no amplification in vertical acceleration so to navigate yacht in these heading are recommended for the comfort of the saloon.

4.6.2.4 Influence of Heading and velocity on Lateral acceleration at bridge

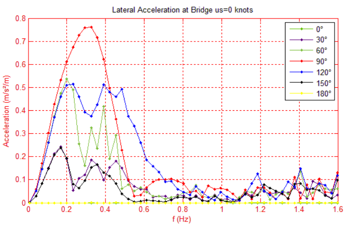


Figure 4-42 Lateral acceleration at Bridge at 0 knots

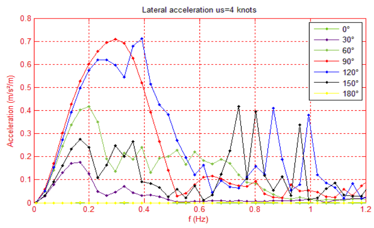


Figure 4-43 Lateral acceleration at Bridge at 4 knots

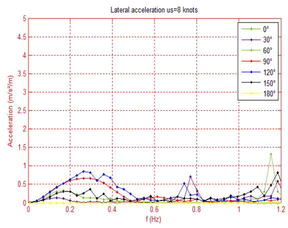


Figure 4-44 Lateral acceleration at Bridge at 8 knots

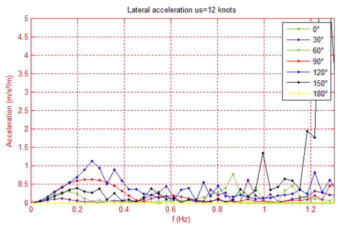


Figure 4-45 Lateral acceleration at Bridge at 12 knots

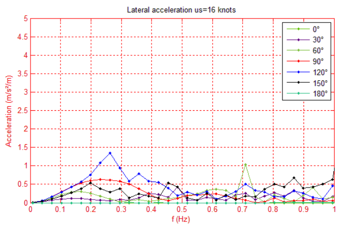


Figure 4-46 Lateral acceleration at Bridge at 16 knots

4.6.3 46 meter motor yacht

4.6.3.1 Influence of Heading and velocity on Heave

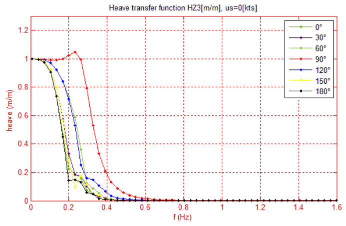


Figure 4-47 Heave Transfer Function at 0 knots

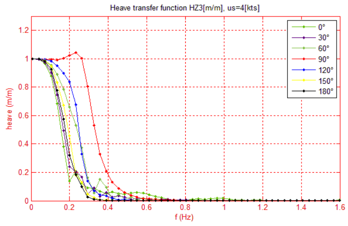


Figure 4-48 Heave Transfer Function at 4 knots

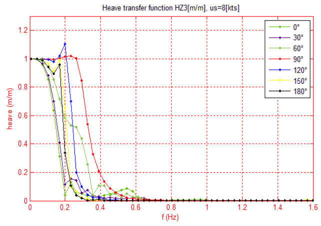


Figure 4-49 Heave Transfer Function at 8 knots

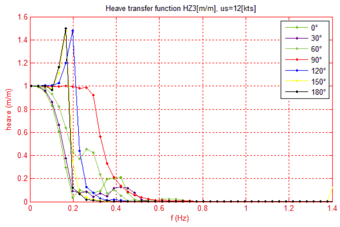


Figure 4-50 Heave Transfer Function at 12 knots

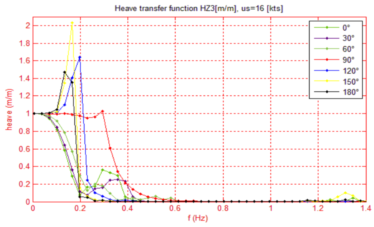


Figure 4-51 Heave Transfer Function at 16 knots

It is observed that the heave amplitude reach to unit value at each heading and heave increase maximum from 90 to 150 degree of heading.

4.6.3.2 Influence of Heading and velocity on Pitch

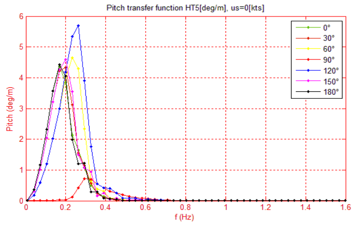


Figure 4-52Pitch Transfer Function at 0 knots

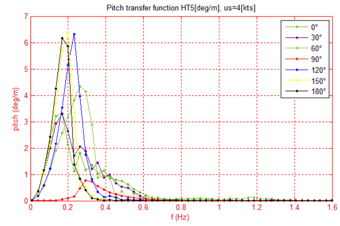


Figure 4-53 Pitch Transfer Function at 4 knots

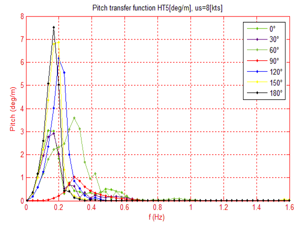


Figure 4-54 Pitch Transfer Function at 8 knots

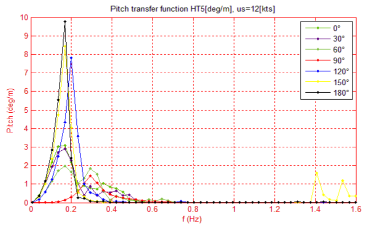


Figure 4-55 Pitch Transfer Function at 12 knots

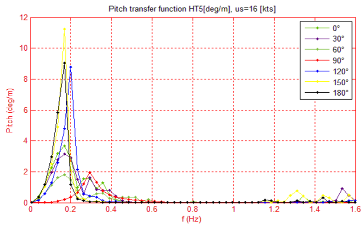


Figure 4-56 Pitch Transfer Function at 16 knots

The maximum pitch motion amplitude is obtained in the heading angles of 60, 120, 150, and 180 degree while the pitch motion at 90 degree does not occur.

4.6.3.3 Influence of Heading and velocity on Roll

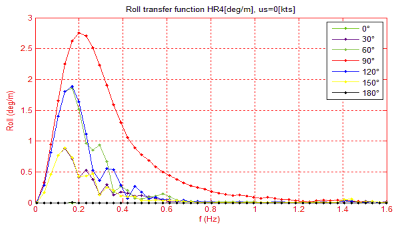


Figure 4-57 Roll Transfer function at 0 knots

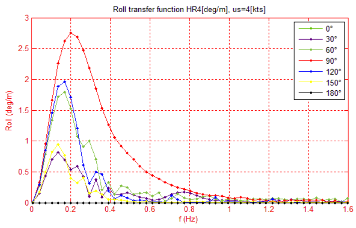


Figure 4-58 Roll transfer function HR4[deg/m], us=4 knots

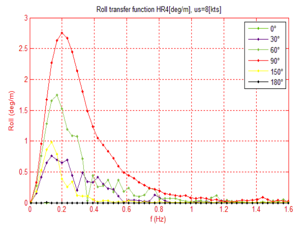


Figure 4-59 Roll transfer function HR4[deg/m], us=8 knots

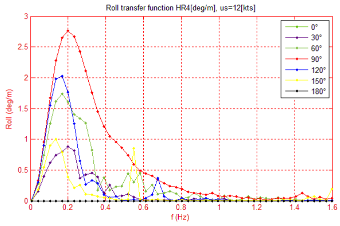


Figure 4-60 Roll transfer function HR4[deg/m], us=12 knots

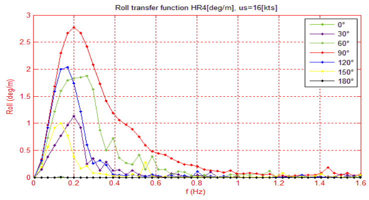


Figure 4-61 Roll transfer function HR4[deg/m], us=16 knots

The transfer function of the roll motion has maximum values in headings 60, 90and 120 degree without viscous damping while we are considering the radiation hydrodynamic damping the roll motion is almost zero at heading 180 degree.

4.6.4 Derived Ship Transfer Functions

Drive responses of ship have been calculated for different headings and forward speeds on a specific location.

Table 4-5 Location of different fixed positions under consideration

Position	X [m] In front of AP	Y [m] From Centreline	Z[m] Above Base
Owner's cabin	32.85	0.0	4.407
Saloon	13.789	0	4.407
Bridge	28.6	0	6.905

4.6.4.1 Influence of Heading and velocity on owner's cabin

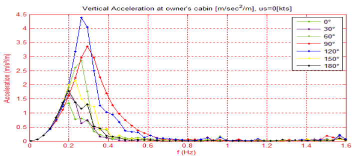


Figure 4-62 Vertical acceleration at owner cabin at 0 knots

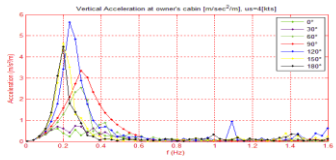


Figure 4-63 Vertical acceleration at owner cabin at 4 knots

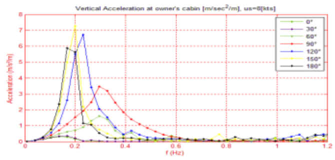


Figure 4-64 Vertical acceleration at owner cabin at 8 knots

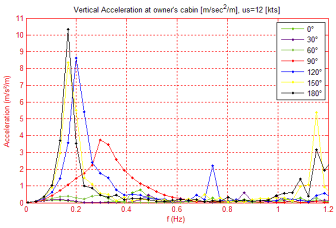


Figure 4-65 Vertical acceleration at owner cabin at 12 knots

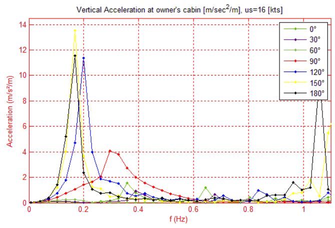


Figure 4-66 Vertical acceleration at owner cabin at 16 knots

It has been observed that the vertical acceleration at heading 120, 150, and 180 degree has been noticed, while at 0, 30, and 60 degree there is no amplification in vertical acceleration so to navigate yacht in these heading are recommended for the comfort of the owner cabin.

4.6.4.2 Influence of Heading and velocity on bridge

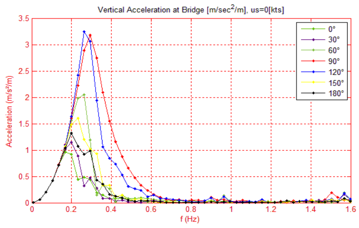


Figure 4-67 Vertical acceleration at Bridge at 0 knots

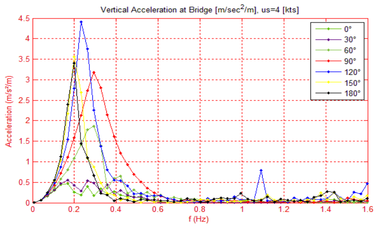


Figure 4-68 Vertical acceleration at Bridge at 4 knots

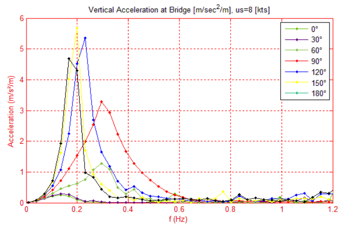


Figure 4-69 Vertical acceleration at Bridge at 8 knots

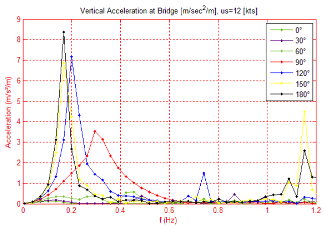


Figure 4-70 Vertical acceleration at Bridge at12 knots

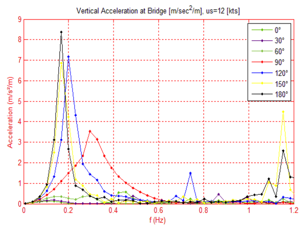


Figure 4-71 Vertical acceleration at Bridge at 16 knots

It is noticed that the amplification in vertical acceleration at heading 120, 150, and 180 degree, while at 0, 30, and 60 degree there is no amplification in vertical acceleration, to navigate yacht in these heading are recommended for the comfort of the crew in bridge.

4.6.4.3 Influence of Heading and velocity on saloon

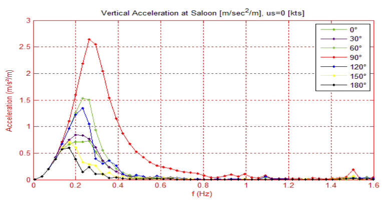


Figure 4-72 Vertical acceleration at Saloon at 0 knots

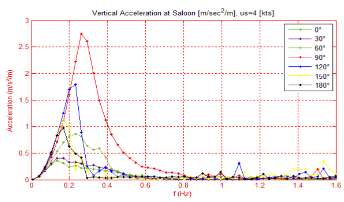


Figure 4-73 Vertical acceleration at Saloon at 4 knots

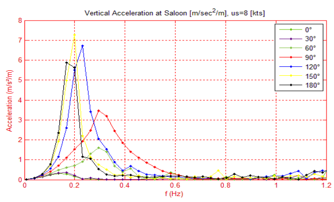


Figure 4-74 Vertical acceleration at Saloon at 8 knots

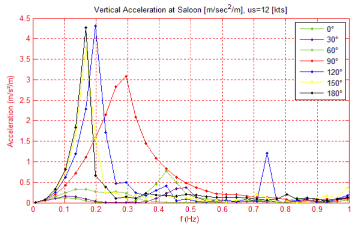


Figure 4-75 Vertical acceleration at Saloon at 12 knots

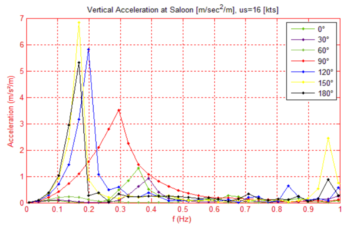


Figure 4-76 Vertical acceleration at Saloon at 16 knots

Amplification in vertical acceleration at heading 120, 150, and 180 degree has been noticed, while there is no amplification at 0, 30, and 60 degree in vertical acceleration for the comfort of the saloon.

4.6.4.4 Influence of Heading and velocity on Lateral acceleration at bridge

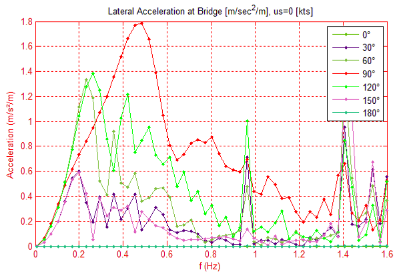


Figure 4-77 Lateral acceleration at Bridge at 0 knots

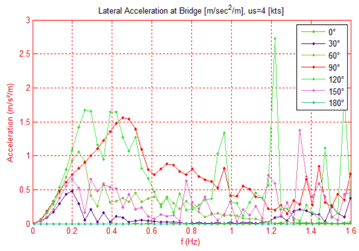


Figure 4-78 Lateral acceleration at Bridge at 4 knots

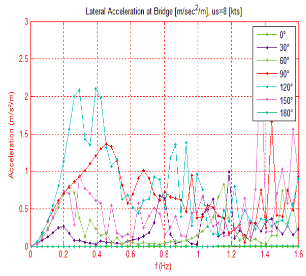


Figure 4-79 Lateral acceleration at Bridge at 8 knots

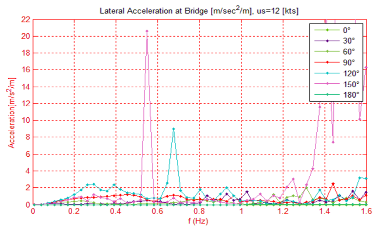


Figure 4-80 Lateral acceleration at Bridge at 12 knots

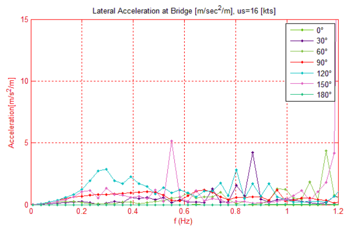


Figure 4-81 Lateral acceleration at Bridge at 16 knots

4.6.5 Effect of the forward speed

It is known that when ship advances with forward speed, boat experiences waves of different frequencies, which is called the encounter frequency.

$$\omega e = \omega - \omega 2V/g \ cos\beta \tag{4.20}$$

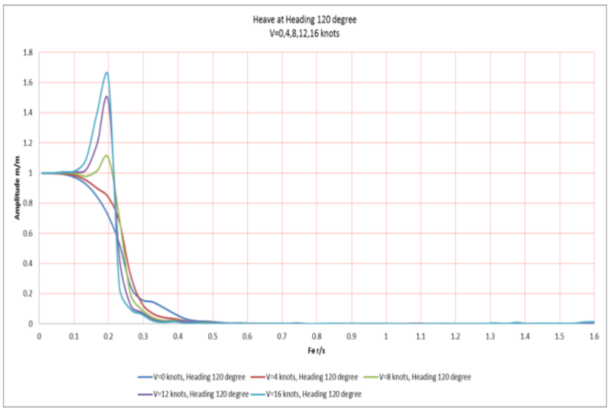


Figure 4-82 Forward Speed influence on heave

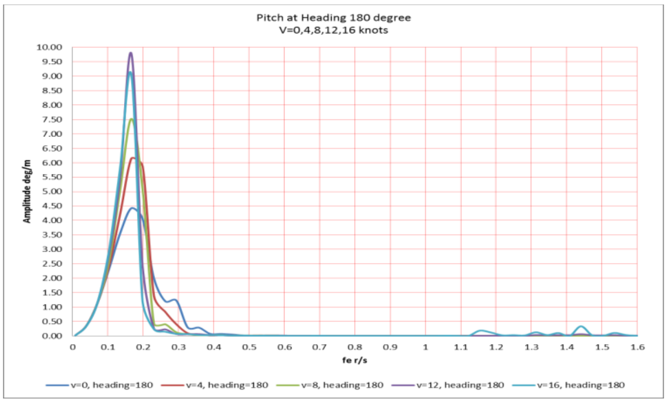


Figure 4-83 Forward Speed influence on Pitch

The effect of forward speed is clearly visible from the figure 4-82 and 4-83.the maximum effect of forward speed in heave and pitch has been observed near the resonance while increasing the velocity. The phenomenon can be explained like, the energy content increased due to forward speed and the boat become more excited in the range of low frequency and resonance one.

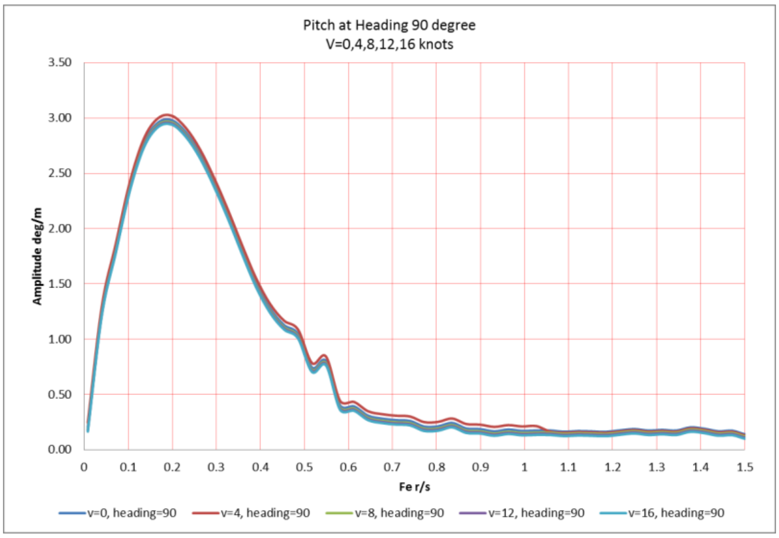


Figure 4-84 Forward Speed influence on Roll

It has been observed that the forward speed does not enhance the rotation and corresponding natural period. But the non-linear and quadratic effects the roll response overall.

4.6.6 Effect of Damping

To consider the non-linearity of the damping force, especially in roll motion it is common to add linearized viscous damping term. For the sake of simplicity the term fraction of critical damping is taken. $B\_ = nBcr$

The following is the expression

$$(-\omega 2[M + A(\omega)] + i\omega[B(\omega) + B\_] + [K])X = F(\omega) \quad 4.21$$

Where:

$$B\_ = nBcr = n \cdot 2\sqrt{(M + A(\omega))} \cdot K \quad 4.22$$

Hydrostar computation allows us to insert the percentage of critical damping. The suggested percentage of the critical damping by HydroStar Manual 8 percent has been used in the presented thesis.

Chapter 5
Results and Discussion

Results and discussion

The calculation results are shown in the Cartesian diagram. There are several curves in each diagram for different speed under consideration. The x-axis (abscissa) in each diagram represents the relative course angle in which 0 degree is the means stern sea, 180 degree head seas and 90 degree represent the mean beam seas coming from the starboard. The y-axis (ordinate) in each diagram for motion and acceleration represents the significant amplitude of the ship responses that are the mean values of the highest one third response amplitude.

There is red line in each diagram that represents the performance criteria for respective ship response. The main source of criteria on motion sickness is the International Standard ISO 2631(ISO 2631-3, 1985) and (Odabas¸ı et al., 1991).

Significant amplitude for Roll motion = 6 degree

Significant amplitude for Pitch motion = 3 degree

Significant amplitude for vertical acceleration= 0.20g

Significant amplitude for Lateral acceleration = 0.15g

A performance criterion on 53 and 46 meter motor yacht has been checked against all operational condition under consideration.

- Aegean and Mediterranean Seas
    - Sea State 3
    - Sea State 4
    - Sea State 5

Table 5-1Result Summary of 53 meter Yacht by Hydrostar Computation

Aegean Sea						
	Roll Motion Limit Criteria 6 degree	Pitch Motion Limit Criteria 6 degree	Vertical Acc. Owners Cabin Limit Criteria 0.2g	Vertical Acc. Bridge Limit Criteria 0.2g	Vertical Acc. Saloon Limit Criteria 0.2g	Lateral Acc. Bridge Limit Criteria 0.15g
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)
Sea State 4	Satisfied (Us>4 knt)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us<4 knt)	Satisfied (Us>8 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us <16 knt)
Mediterranean Sea						
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)
Sea State 4	Satisfied (Us>4 knt)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us<4 knt)	Satisfied (Us>8 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us <16 knt)

It is observed that in Aegean and Mediterranean sea State 3 the yacht does not have any restriction to operate, while in sea State 4 and 5 the standard limit criteria for comfort has been breached and restricted to operate in these operational areas.

Table 5-2 Result Summary of 53 meter Yacht by HSVA Computation Technique

Aegean Sea						
	Roll Motion Limit Criteria 6 degree	Pitch Motion Limit Criteria 6 degree	Vertical Acc. Owners Cabin Limit Criteria 0.2g	Vertical Acc. Bridge Limit Criteria 0.2g	Vertical Acc. Saloon Limit Criteria 0.2g	Lateral Acc. Bridge Limit Criteria 0.15g
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)
Sea State 4	Satisfied (Us>4 knt)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us<4 knt)	Satisfied (Us>8 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us <16 knt)
Mediterranean Sea						
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (all Us and β)
Sea State 4	Satisfied (Us>4 knt)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us<4 knt)	Satisfied (Us>8 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Satisfied (Us <16 knt)

The table 5-1 & 5-2 represent the computational result by HydroStar and HSVA Hamburg. By analysing the result of both computations it has been observed that both computational techniques are concurrent.

Table 5-3Result Summary of 46 meter Yacht by Hydrostar Computation

Aegean Sea						
	Roll Motion Limit Criteria 6 degree	Pitch Motion Limit Criteria 6 degree	Vertical Acc. Owners Cabin Limit Criteria 0.2g	Vertical Acc. Bridge Limit Criteria 0.2g	Vertical Acc. Saloon Limit Criteria 0.2g	Lateral Acc. Bridge Limit Criteria 0.15g
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (Us < 12 knt)	Satisfied (Us < 16 Knt)	Satisfied (Us < 12 knt)	Satisfied (all Us and β)
Sea State 4	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (Us>4 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)
Mediterranean Sea						
Sea State 3	Satisfied (all Us and β)	Satisfied (all Us and β)	Satisfied (Us < 12 knt)	Satisfied (Us < 16 Knt)	Satisfied (Us < 12 knt)	Satisfied (all Us and β)
Sea State 4	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (Us>4 knt)	Satisfied (all Us and β)
Sea State 5	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)	Dissatisfied (all Us and β)

It is observed that in Aegean and Mediterranean Sea State 3 the yacht does not have any restriction to operate but there is a discomfort observed in higher speed. In sea State 4 and 5 the standard limit criteria for comfort has been breached and restricted to operate in these operational areas.

5.1 Conclusion

5.1.1 Sea State 3

It has been observed that the 53 meter motor yacht has no restriction to operate in Aegean and Mediterranean Sea. It is observed that the vertical acceleration at different positions is under the ISO performance criteria, the acceleration especially the vertical one impact on the human body and cause motion sickness. In this sea State the desire comfort for the owner cabin, bridge and saloon has been achieved.

5.1.2 Sea State 4

In Aegean and Mediterranean Sea State 4, significant amplitude of pitch motion, vertical and lateral acceleration shows the amplification in results and overstepped from the defined ISO limiting values of performance criteria. The owner cabin is situated in the fore part of the yacht and has maximum value of the vertical acceleration. It has been observed that the great impact on the human body which cause the motion sickness is due to the vertical acceleration. The roll motion is overstepped from the defined limits from slow to moderate speed while in high speed it is under the limit criteria it might be possible that at slow and moderate speed the roll motion cross the limit criteria due to the poor performance of fins stabilisers in this operational situations. The lateral acceleration is under the limit when it operates in sea State 4 of Aegean and Mediterranean seas. By considering the results the operability of the 53 metre motor yacht is restricted in Aegean and Mediterranean Sea State 4 because of motion sickness for the owner, crew and guests.

5.1.3 Sea State 5

The relatively short seaway period produce steep waves which lead to the distinct pitch motion and vertical acceleration responses. Peak periods of sea State 5 are also close to natural yacht's roll motion which excites the roll motion and lateral accelerations near resonance condition. It has been observed that the operability of 53 m motor yacht is restricted in Aegean Sea State 5. The seakeeping performance in Mediterranean is relatively better than Aegean Sea because of relatively less pitch motion and vertical acceleration and smaller roll motion and lateral acceleration.

5.1.4 Sea State 3

The 46 meter motor yachts has also no restriction to operate either in Aegean and Mediterranean sea at a speed less than 12 knots, above this speed it has been observed that the desired comfort in owner cabin, bridge and saloon does not achieve. The vertical acceleration obtained in 46 meter yacht at high speed overstepped the limit criteria which cause an impact on human body and produce motion sickness on board because the motion sickness index is directly related to the vertical acceleration at a specific position.

5.1.5 Sea State 4

The result shows that the operability of 46m motor yacht is restricted in sea State 4 in both Aegean and Mediterranean Sea because of large pitch and vertical accelerations. The highest value of vertical acceleration found in the owner’s cabin which is in the fore area of the yacht. The roll motion of 46 m yacht is overstepped from the defined limits from slow to moderate speed while in high speed it is under the limit criteria in both Aegean and Mediterranean Sea. The roll motion of 46 meter yacht in sea State 4 cross the limits in all speed in Aegean Sea while in Mediterranean at high speed it is under limiting value. The amplification of the Roll motion caused may be due to poor working of fins stabilizer.

5.1.6 Sea State 5

It has been observed that the operability of 46 m motor yacht is fully restricted in Sea State 5 of Aegean and Mediterranean seas. There is a great amplification in roll and pitch motion, vertical and lateral acceleration and overstepped the Limiting Criteria which cause the discomfort of the crew, guest and owner.

The significant amplitude of roll and pitch motion, vertical and lateral acceleration computed by HydroStar concurrent to the HSVA Hamburg Computation.

The results are given in the following diagrams.

5.2 53 m yacht Responses to Irregular Waves

5.3 Aegean Sea State 3

5.3.1 Roll Motion (Aegean Sea State 3)

Performance Criteria Significant roll motion amplitude <= 6 degree

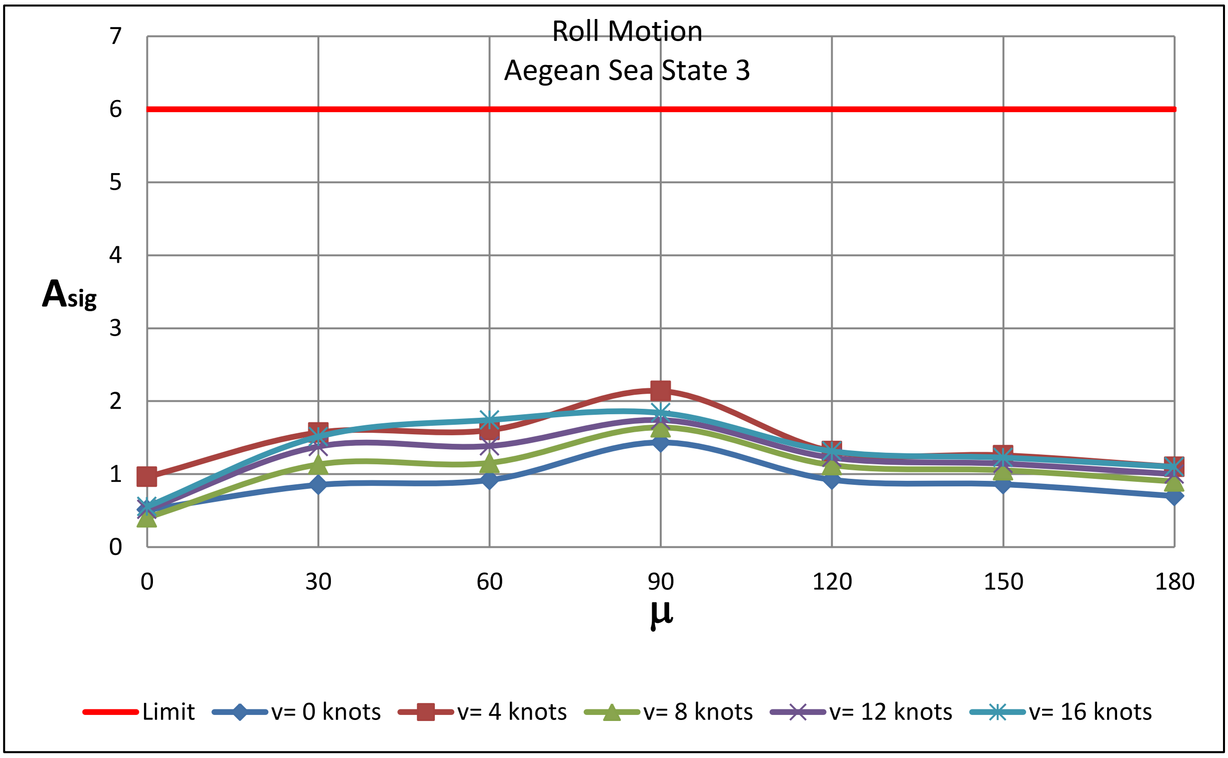


Figure 5-1 Significant roll motion amplitude

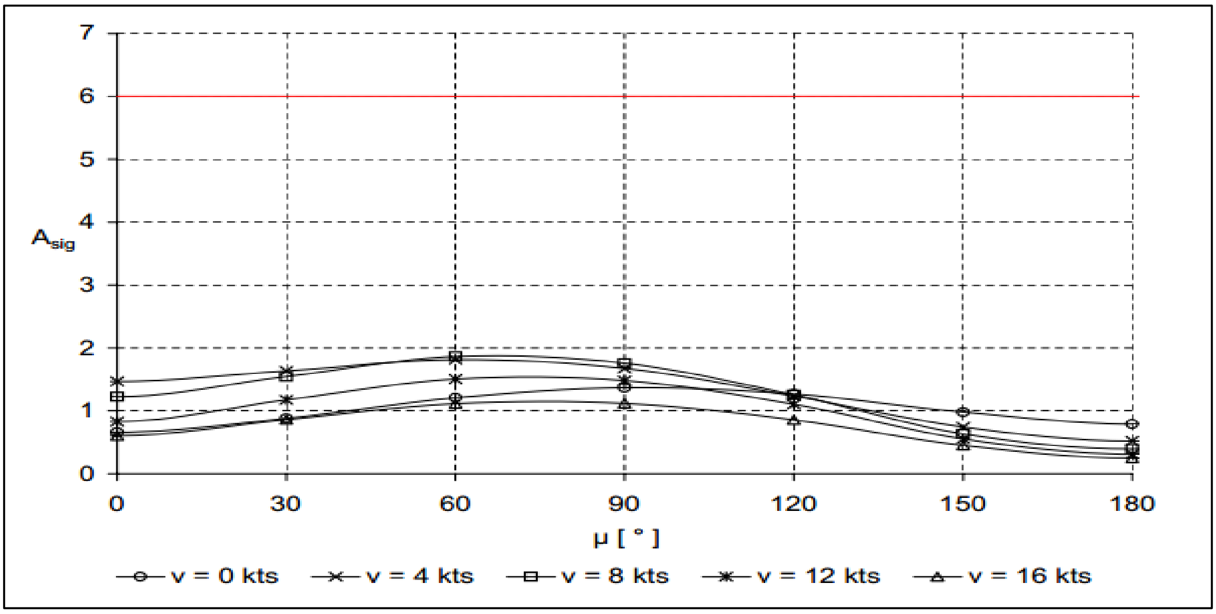


Figure 5-2 HSVA Significant roll motion amplitude

The computed significant amplitude for roll motion satisfy the performance criteria and have maximum values from 60 to 90 degree headings which is obvious that the roll motion at 90 degree presume to be maximum.

5.3.2 Pitch Motion (Aegean Sea State 3)

Performance Criteria   Significant pitch motion amplitude <= 3 degree

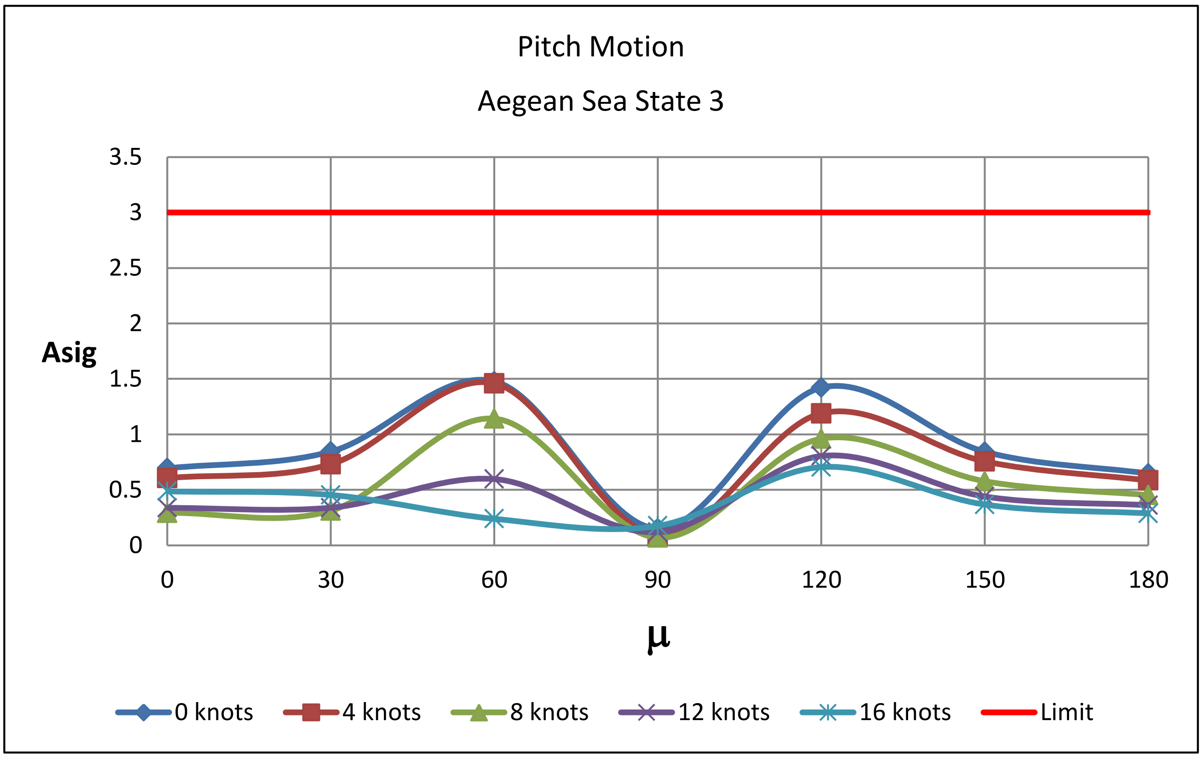


Figure 5-3 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

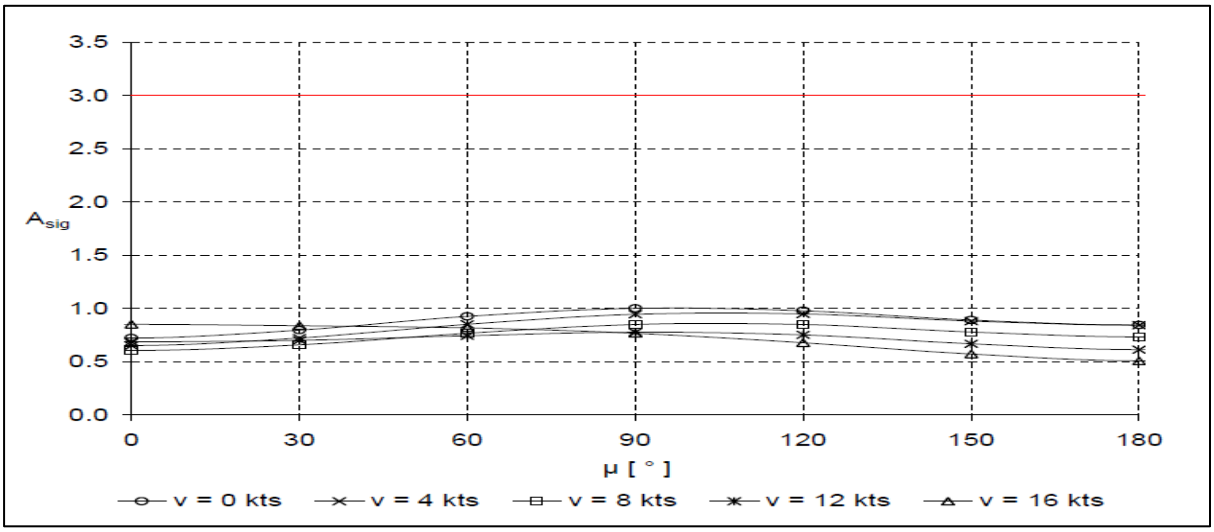


Figure 5-4 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

The computed significant amplitude for pitch motion satisfy the performance criteria at all speeds, headings and have minimum amplitude at 90 degree headings which is obvious that the Pitch motion at 90 degree presume to be minimum.

5.3.3 Vertical acceleration at owner's cabin (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

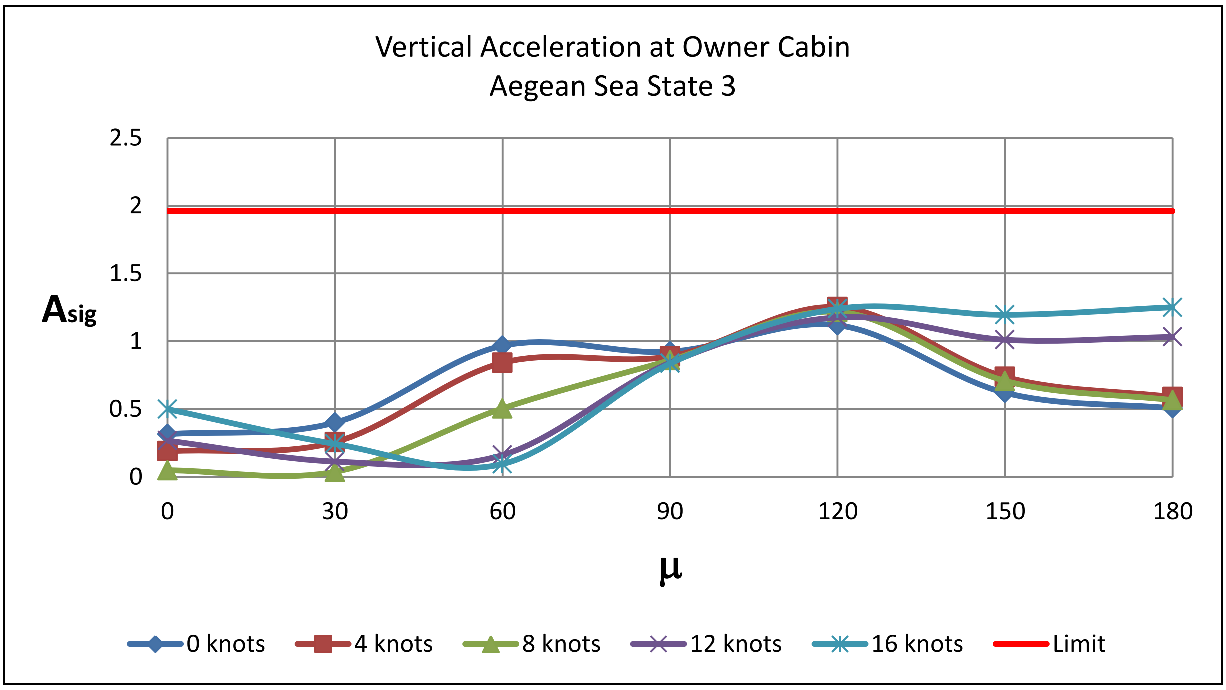


Figure 5-5 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

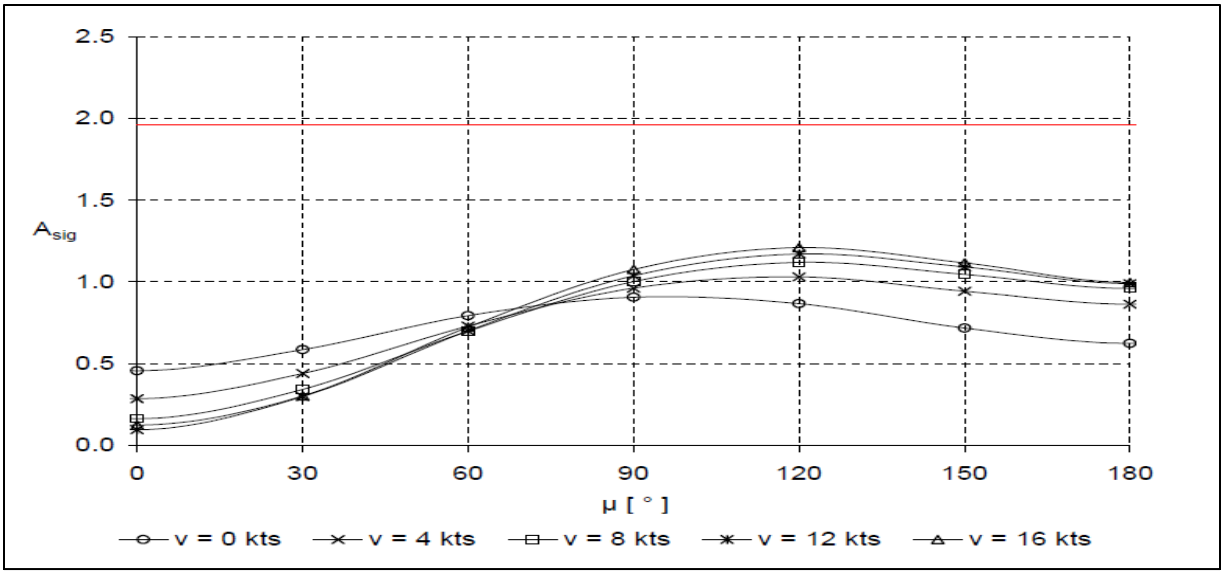


Figure 5-6 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in owner cabins satisfies the performance criteria at all speeds and headings. At heading 0, 30 and 60 the maximum comfort can be achieved because there is less amplification of acceleration at these headings.

5.3.4 Vertical acceleration at bridge (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

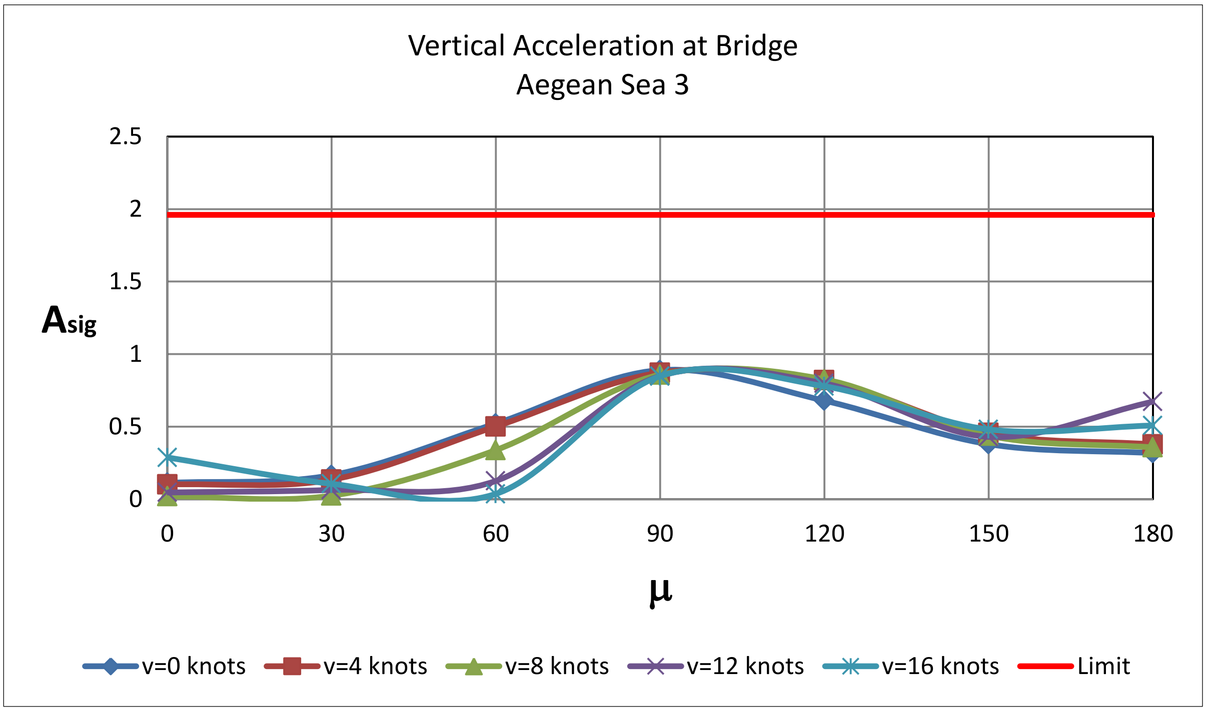


Figure 5-7 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

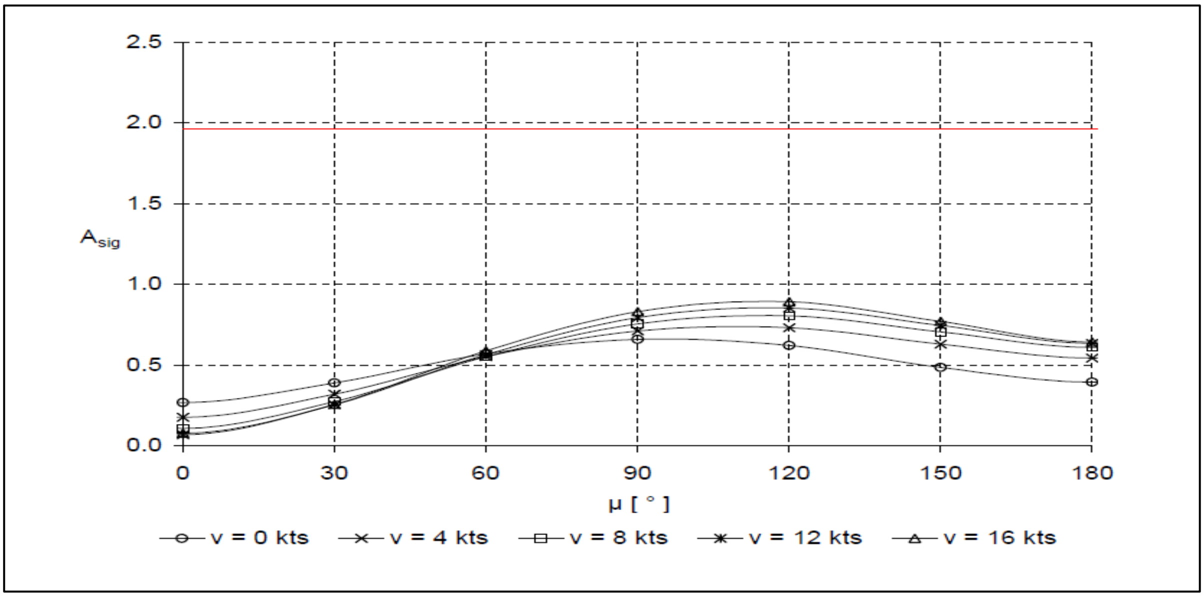


Figure 5-8 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative

course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in Bridge satisfies the performance criteria at all speeds and headings. At 0, 30 and 60 degree the maximum comfort for the crew can be achieved because there is less amplification of acceleration at these headings.

5.3.5 Vertical acceleration at saloon (Aegean Sea State 3)

Performance Criteria   Significant acceleration amplitude <= 0.2g

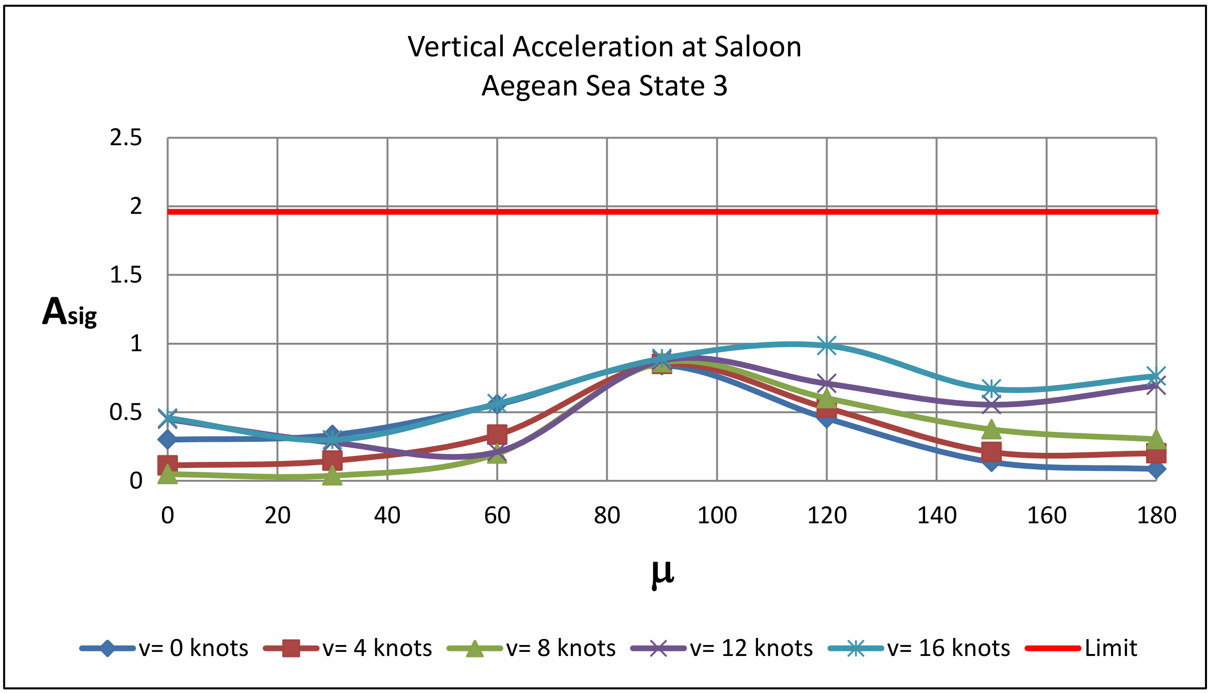


Figure 5-9 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

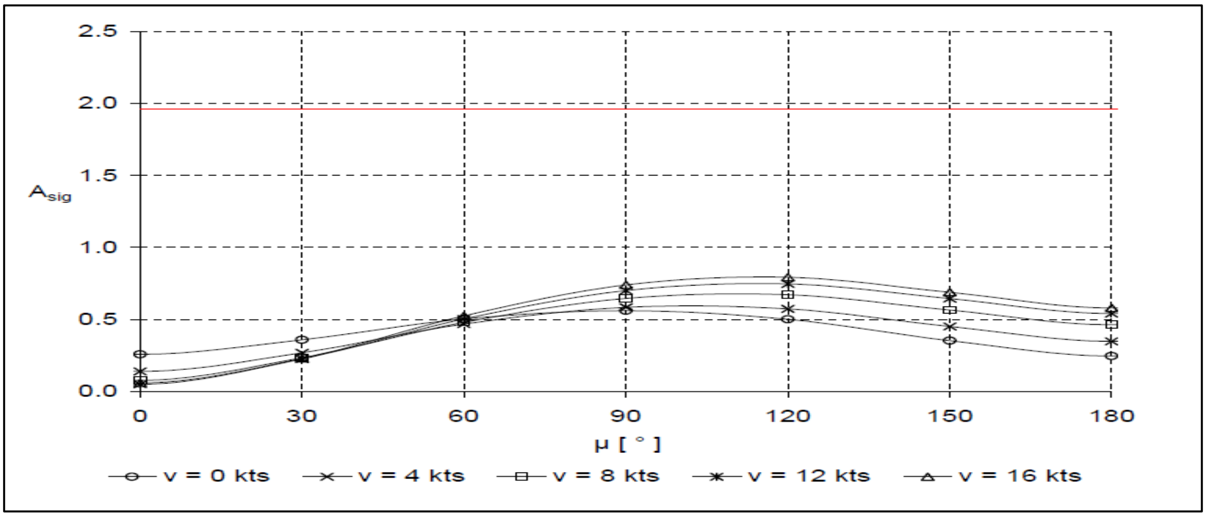


Figure 5-10 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in saloon satisfies the performance criteria at all speeds and headings. At 0, 30 and 60 degree the maximum comfort in saloon can be achieved because there is small amplification of acceleration at these headings.

5.3.6 Lateral acceleration at bridge (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.15g

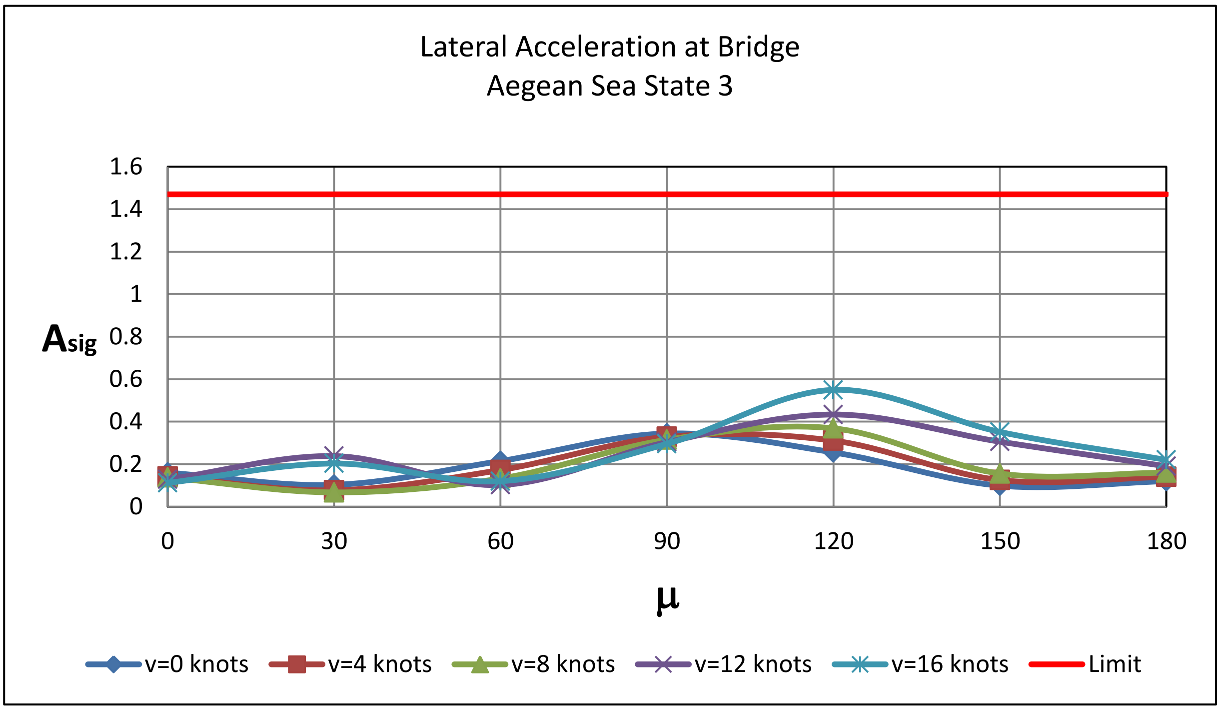


Figure 5-11 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

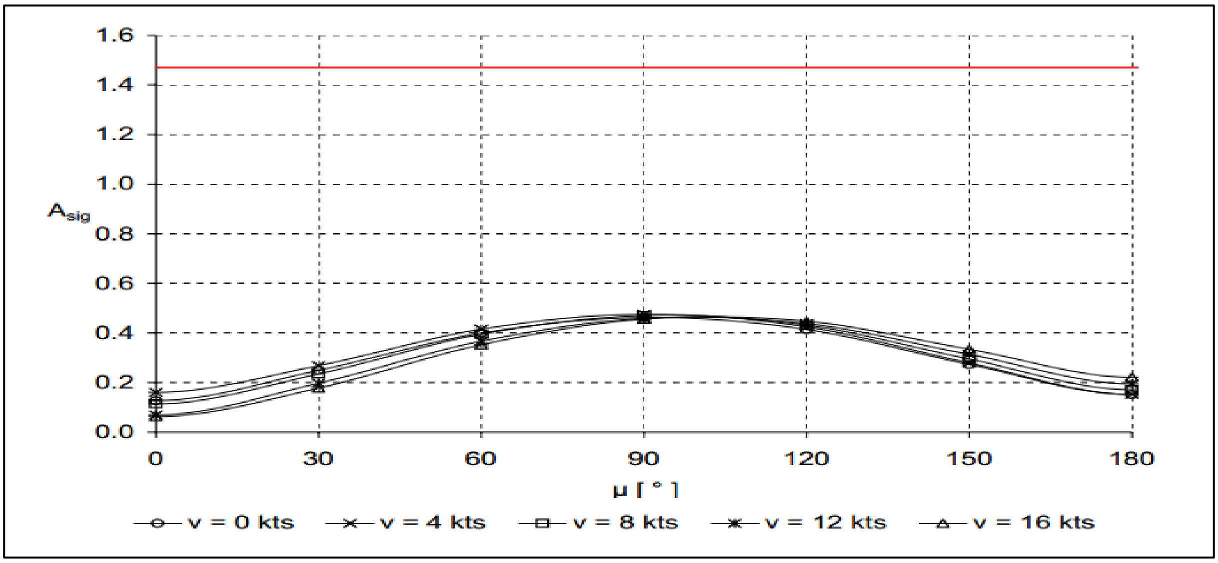


Figure 5-12 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed[m/s]

5.4 Mediterranean Sea State 3

5.4.1 Roll Motion

Performance Criteria — Significant roll motion amplitude <= 6 degree

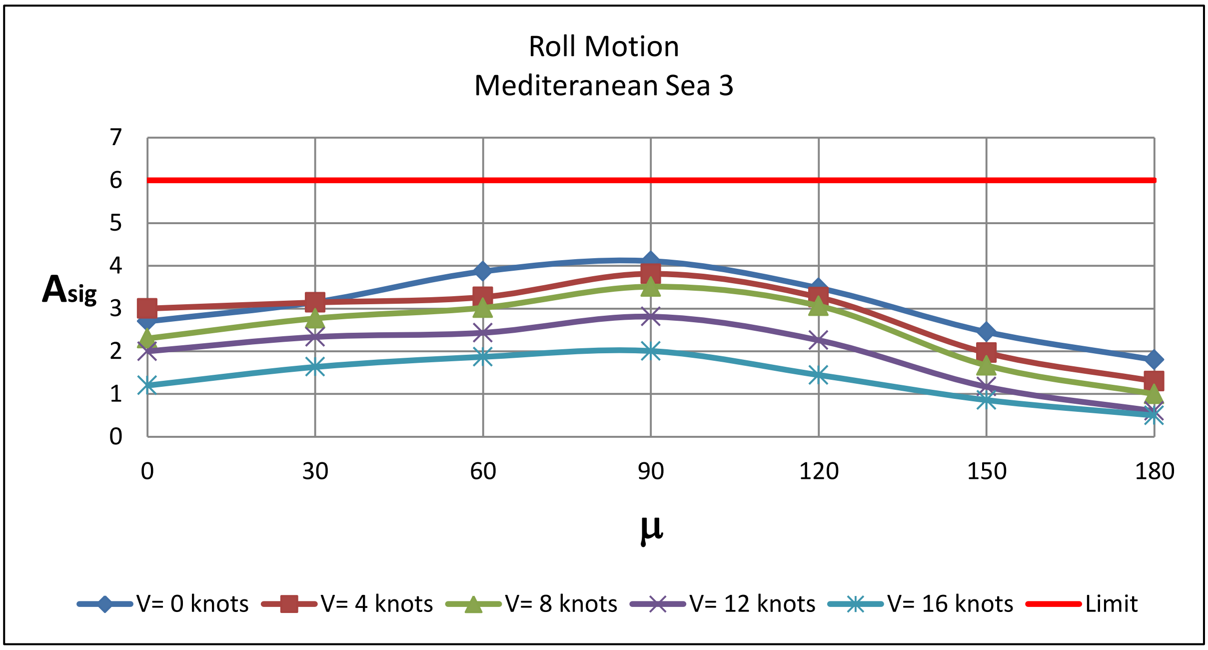


Figure 5-13 **Significant roll motion amplitude**

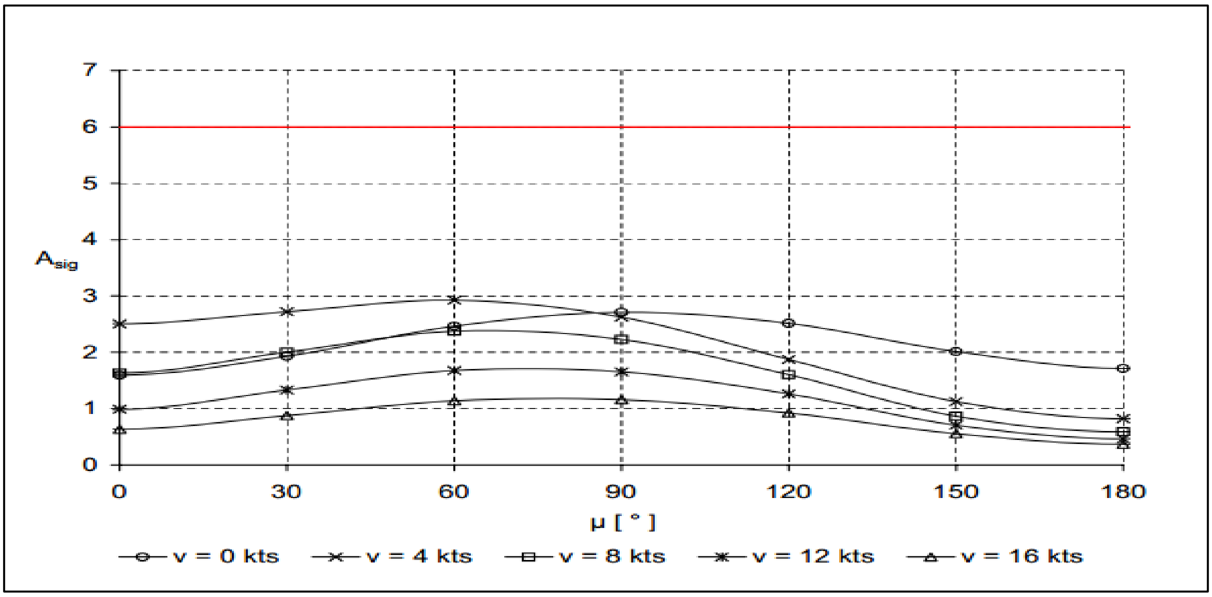


Figure 5-14 HSVA Significant roll motion amplitude

The computed significant amplitude for roll motion satisfy the performance criteria and have maximum values from 60 to 90 degree headings which is obvious that the roll motion at 90 degree presume to be maximum.

5.4.2 Pitch Motion (Mediterranean Sea State 3)

Performance Criteria — Significant pitch motion amplitude <= 3 degree

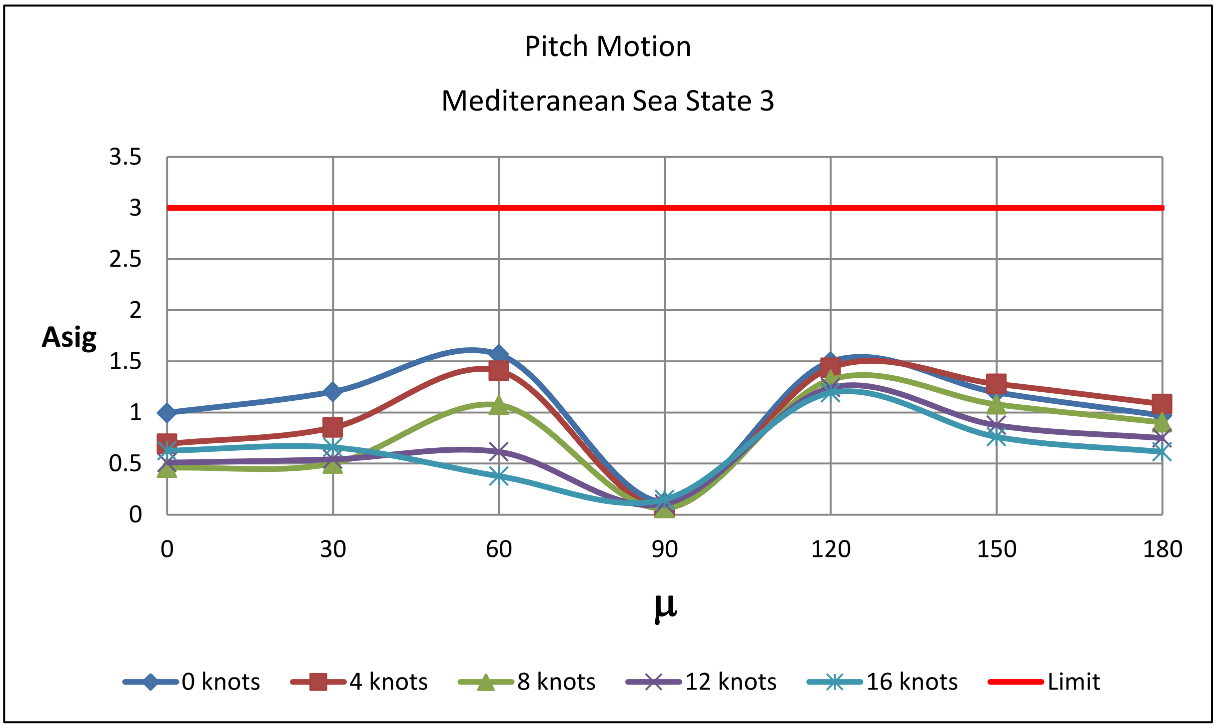


Figure 5-15 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

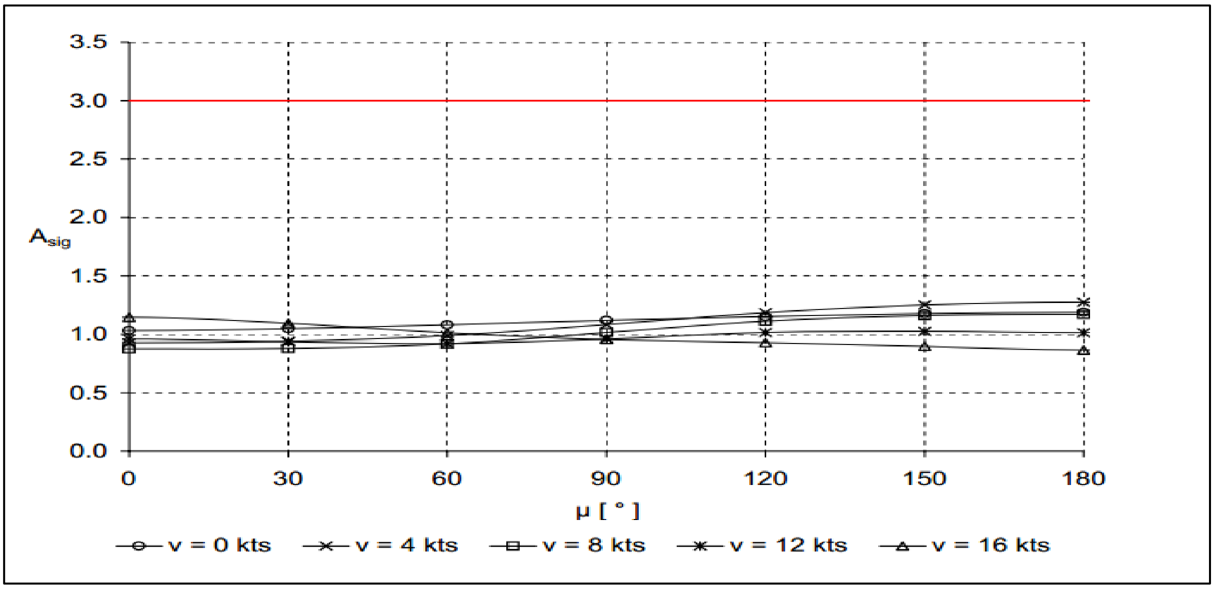


Figure 5-16 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

The computed significant amplitude for pitch motion satisfy the performance criteria at all speeds, headings and have minimum amplitude at 90 degree headings which is obvious that the Pitch motion at 90 degree presume to be minimum.

5.4.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

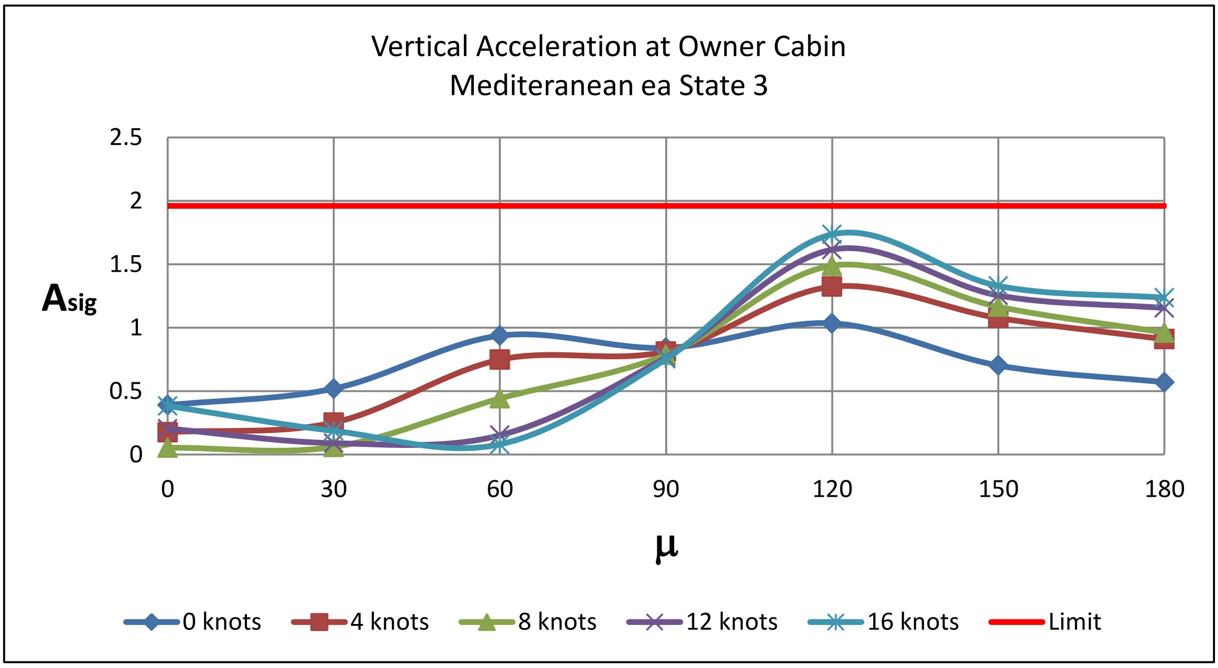


Figure 5-17 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

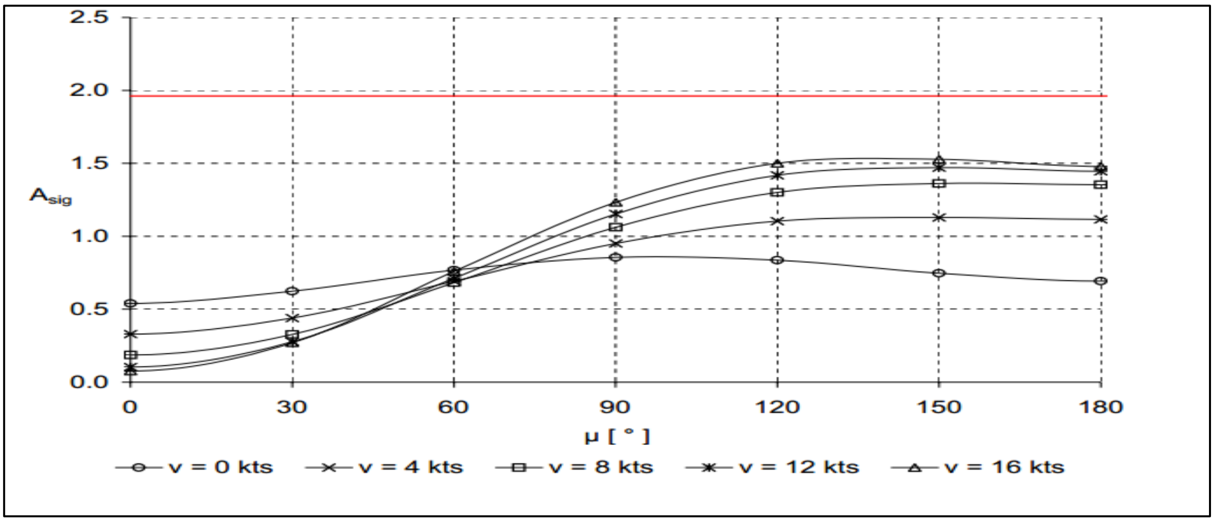


Figure 5-18 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in owner cabins satisfies the performance criteria at all speeds and headings. At heading 0, 30 and 60 the maximum comfort can be achieved because there is small amplification of acceleration at these headings, while at 120 degree great amplification observed but it is under the performance criteria.

5.4.4 Vertical acceleration at bridge (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

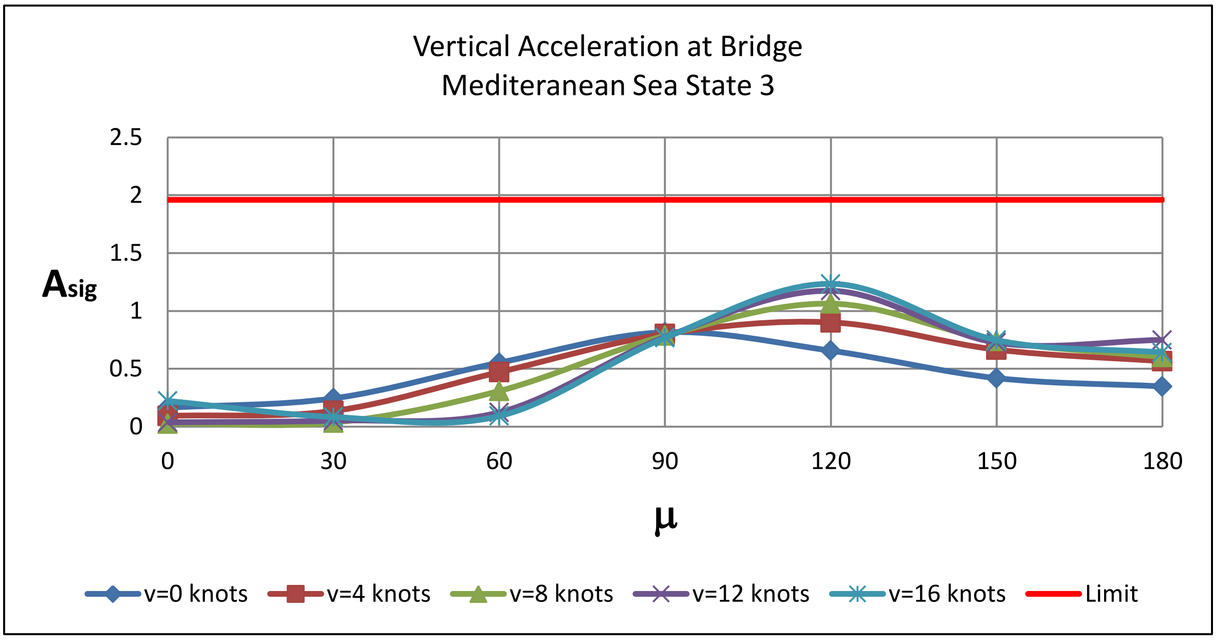


Figure 5-19 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

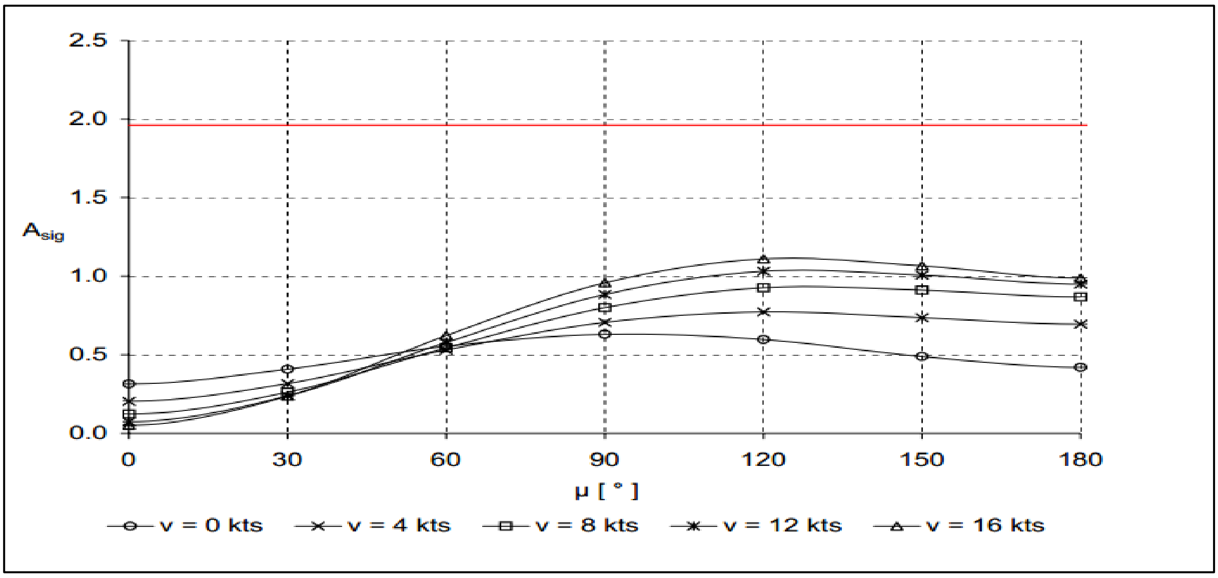


Figure 5-20 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in bridge satisfies the performance criteria at all speeds and headings. At heading 0, 30 and 60 the maximum comfort can be achieved because there is small amplification of acceleration at these headings, while at 120 degree great amplification observed but it is under the performance criteria.

5.4.5 Vertical acceleration at saloon (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

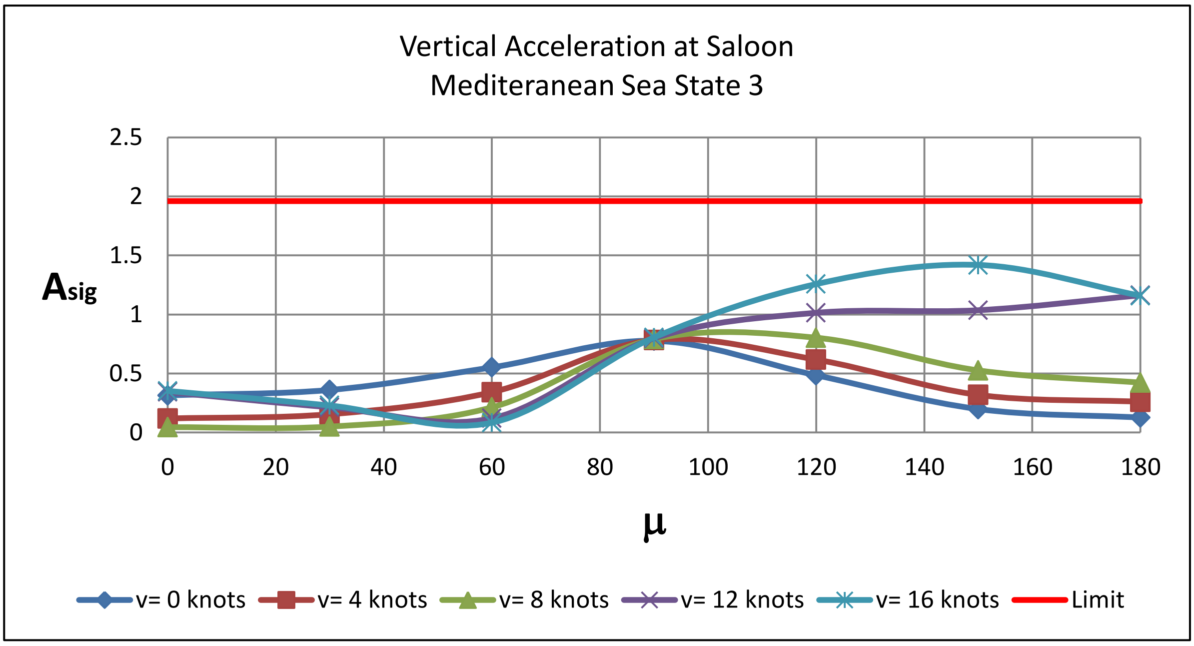


Figure 5-21 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

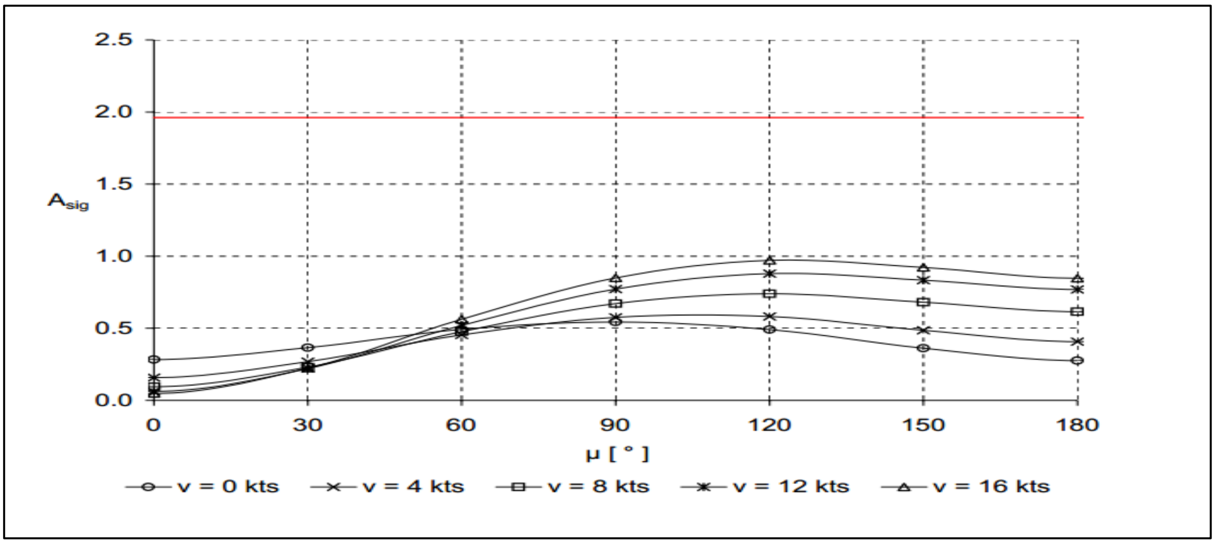


Figure 5-22 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in saloon satisfies the performance criteria at all speeds and headings. At heading 0, 30 and 60 the maximum comfort can be achieved because there is small acceleration at these headings, while the amplification of acceleration is observed in a speed greater than 12 knots and headings above of 90 degree but under the performance criteria.

5.4.6 Lateral acceleration at bridge (Mediterranean Sea State 3)

Performance Criteria   Significant acceleration amplitude <= 0.15g

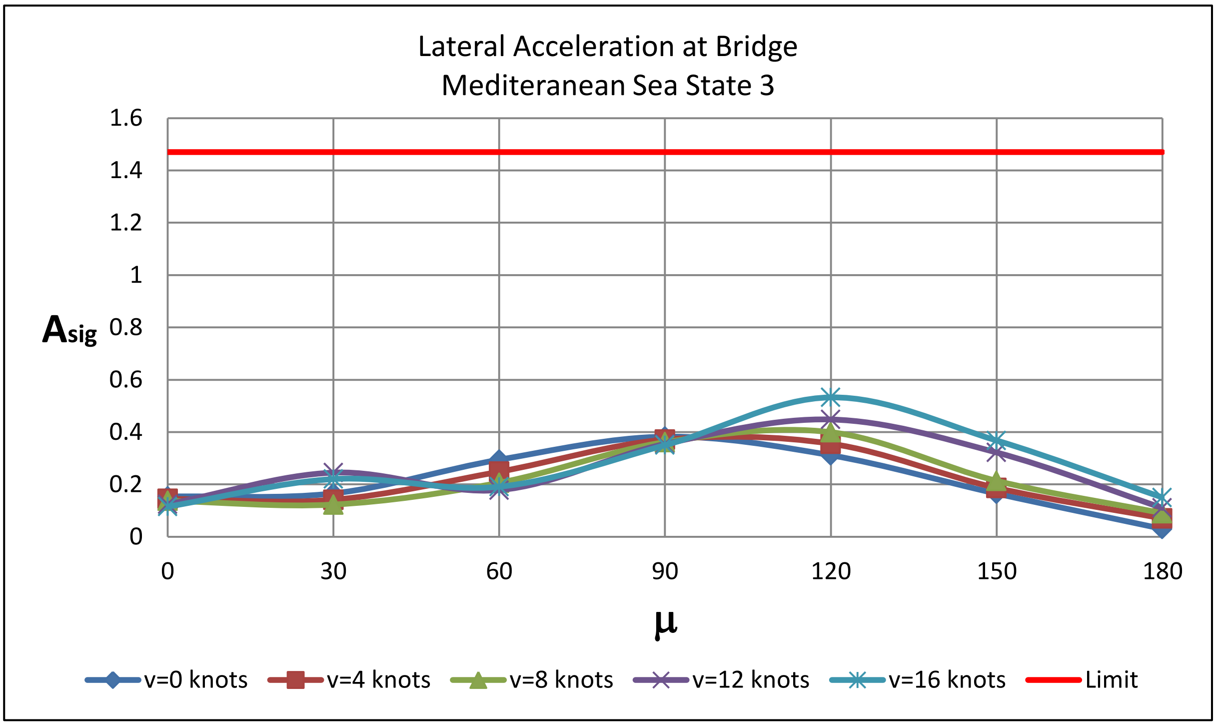


Figure 5-23 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

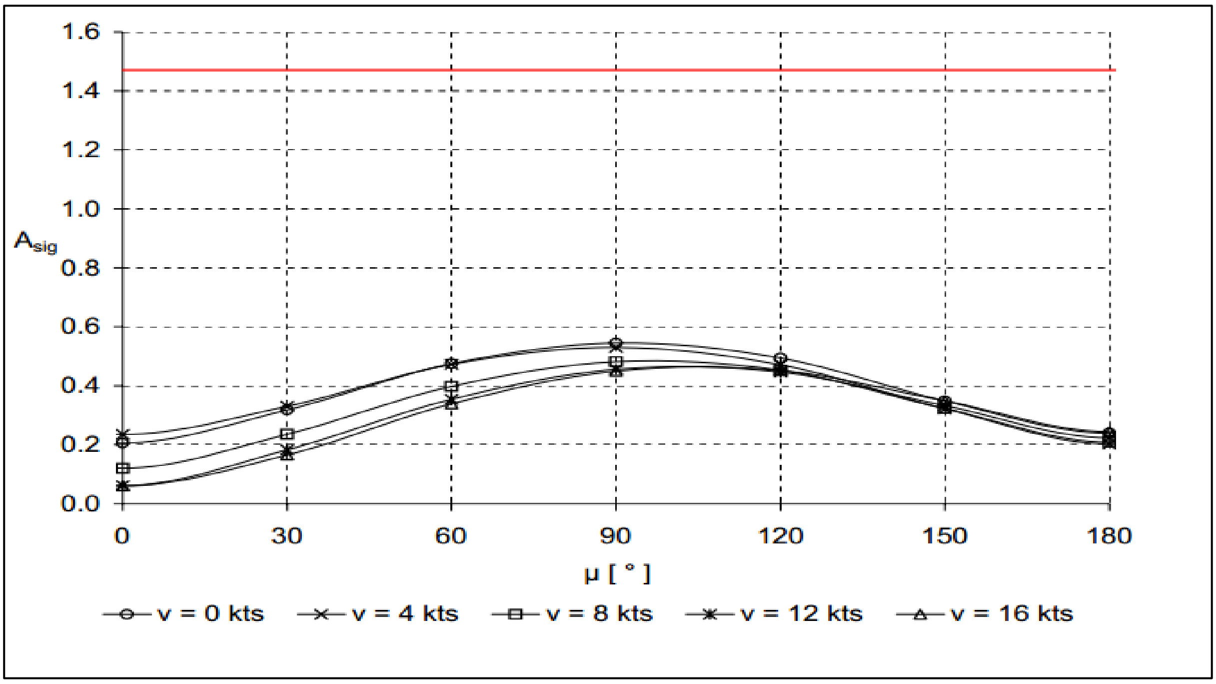


Figure 5-24 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.5 Aegean Sea State 4

5.5.1 Roll Motion (Aegean Sea State 4)

Performance Criteria Significant roll motion amplitude <= 6 degree

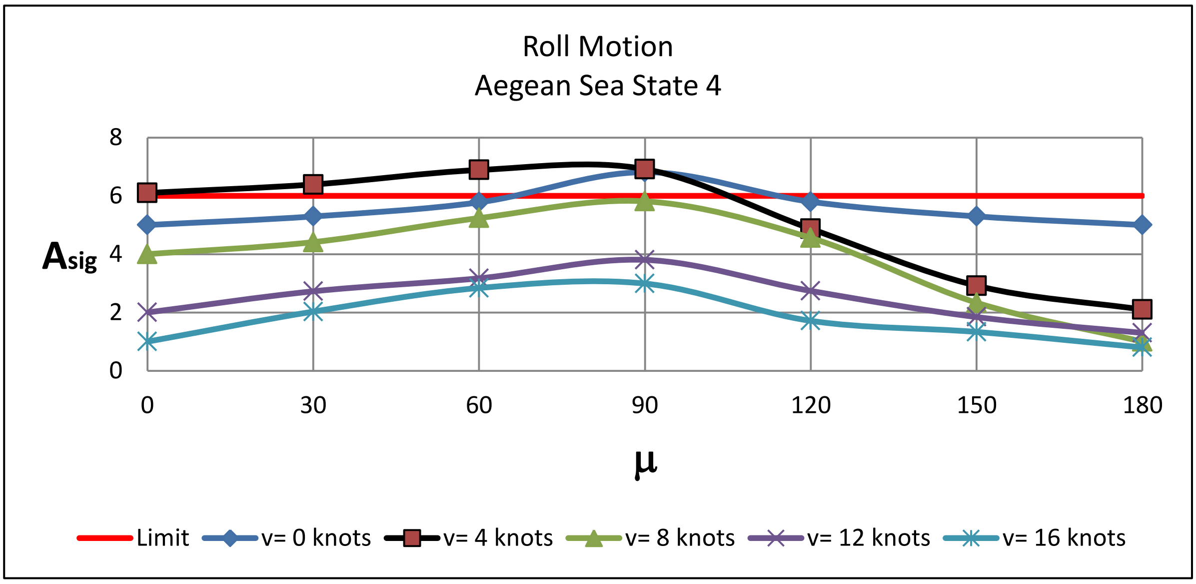


Figure 5-25 Significant roll motion amplitude

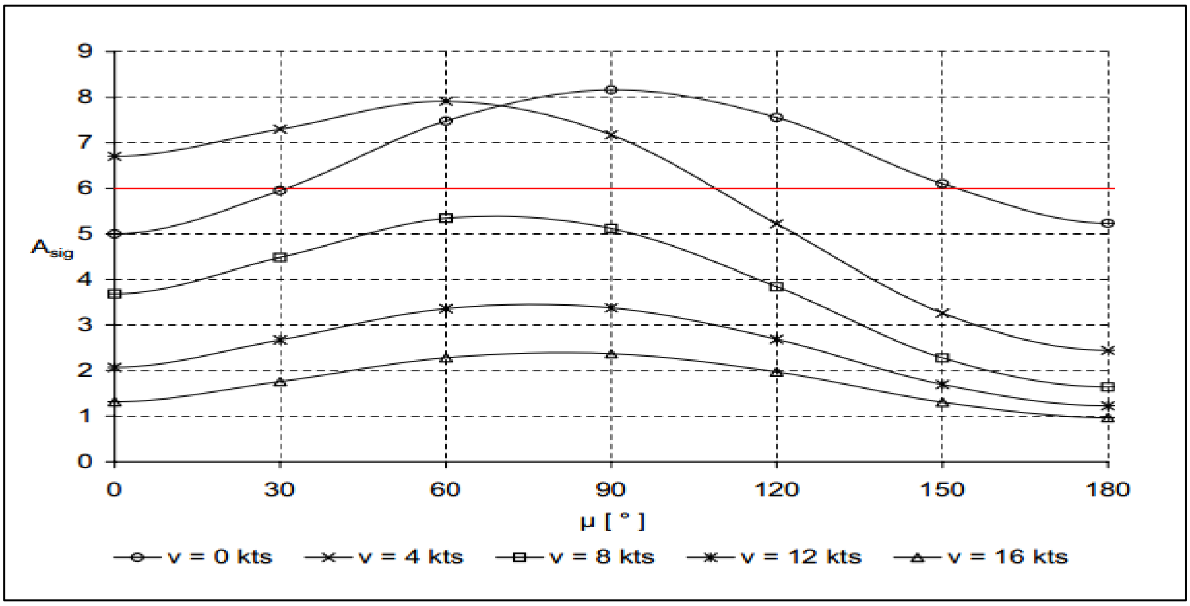


Figure 5-26 HSVA Significant roll motion amplitude

The computed significant amplitude for roll motion satisfies the performance criteria at a speed greater than 4 knots and has maximum values from 60 to 90 degree of headings

5.5.2 Pitch Motion (Aegean Sea State 4)

Performance Criteria — Significant pitch motion amplitude <= 3 degree

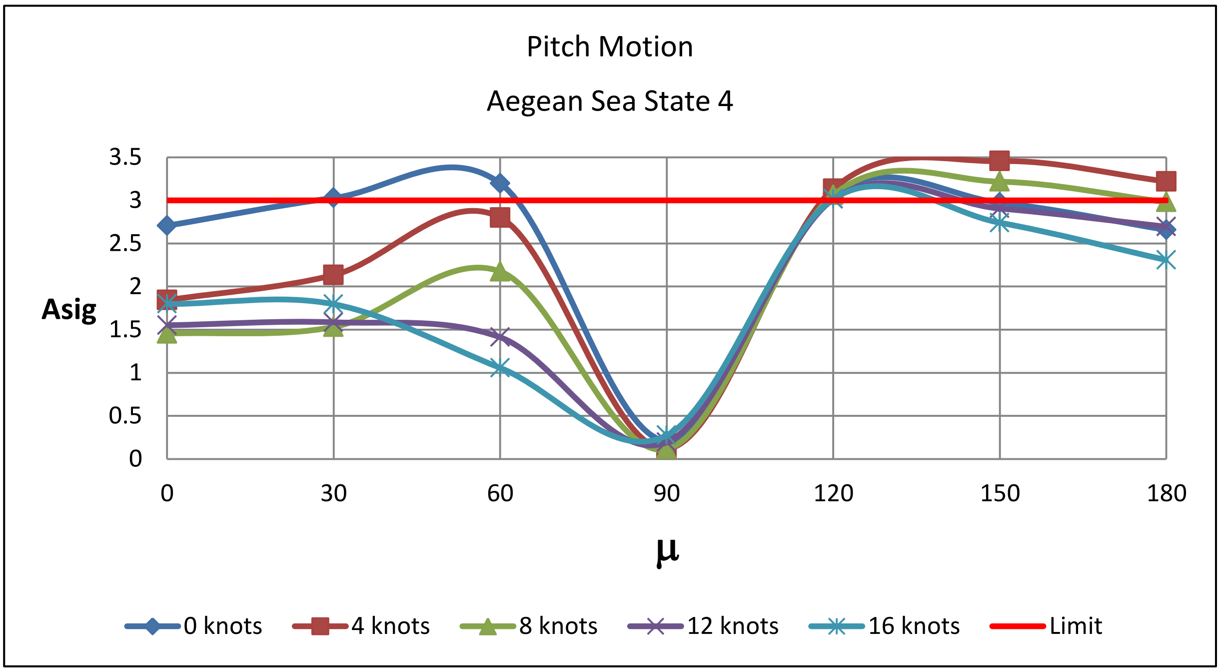


Figure 5-27 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

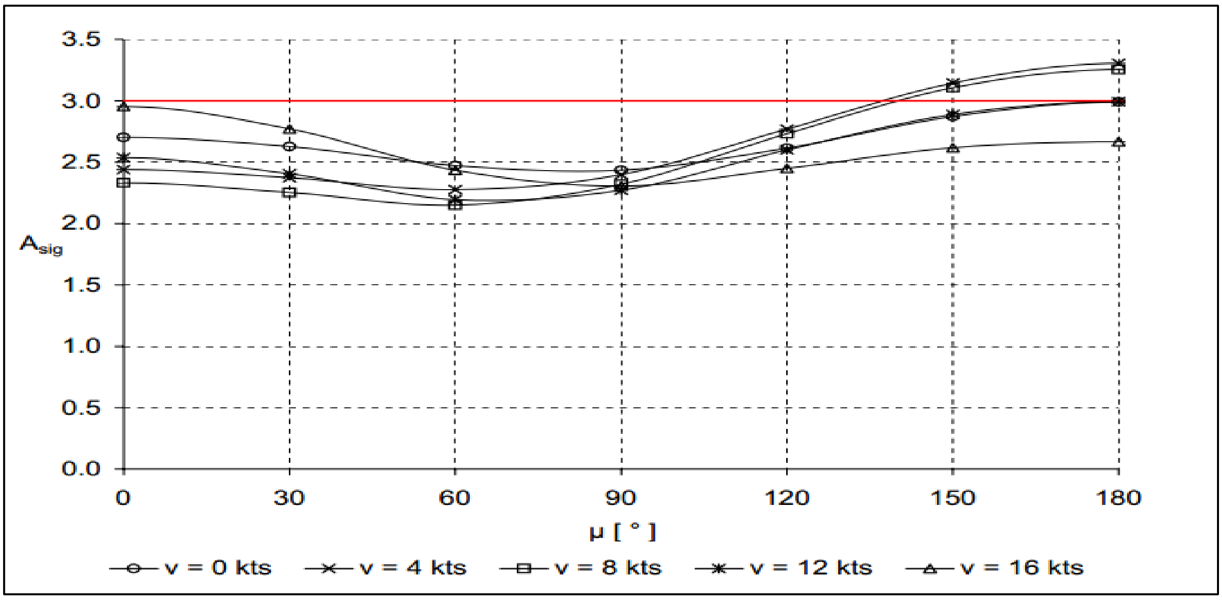


Figure 5-28 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

The computed significant amplitude of pitch motion has amplification and crossing the defined performance criteria in Aegean sea State 4.

5.5.3 Vertical acceleration at owner's cabin (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

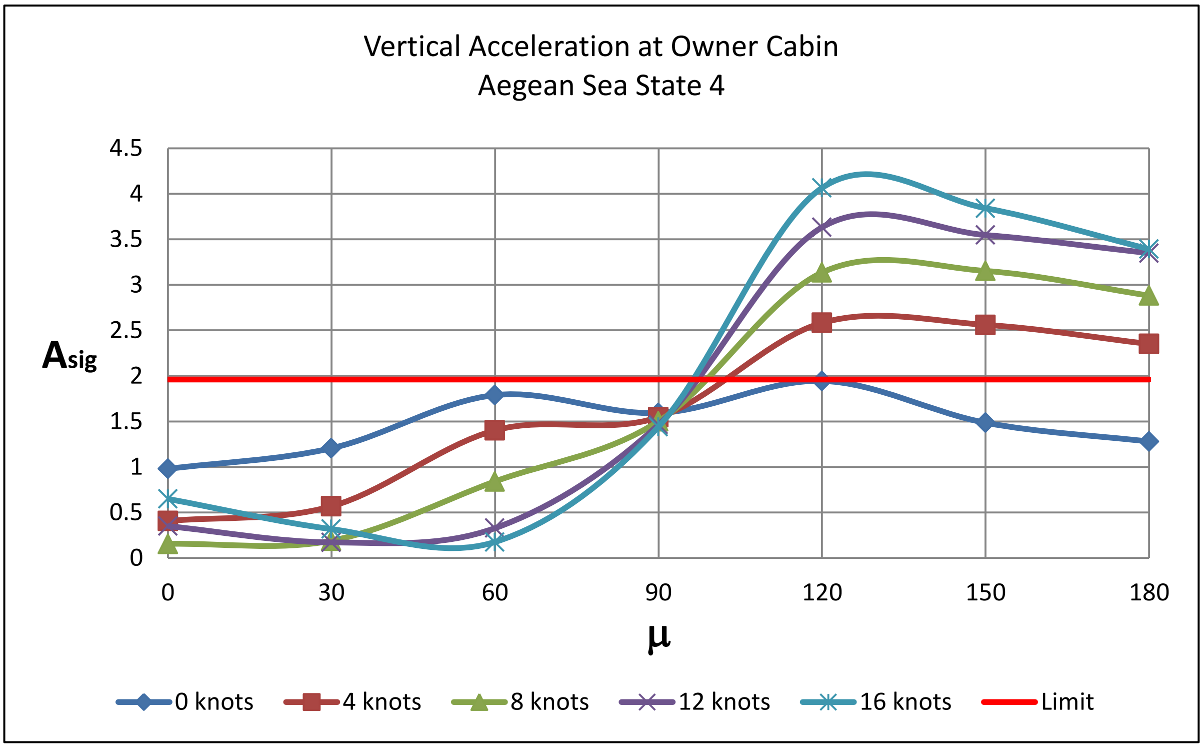


Figure 5-29 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

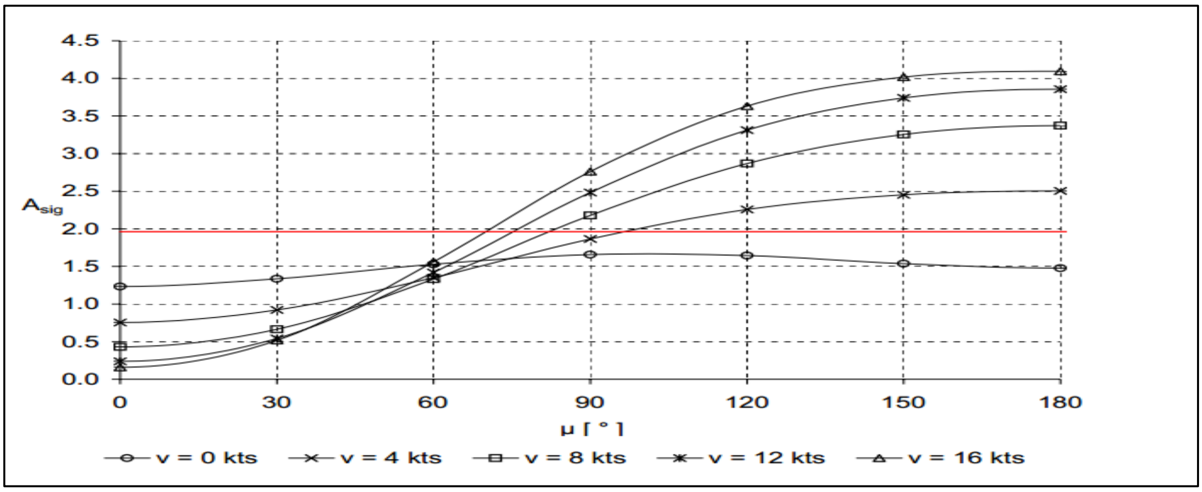


Figure 5-30 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in owner cabins shows the great amplification above 90 degree headings at all speeds. The vertical acceleration has a great impact on the human body and cause motion sickness. This amplification can disturb the comfort of the owner.

5.5.4 Vertical acceleration at bridge (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

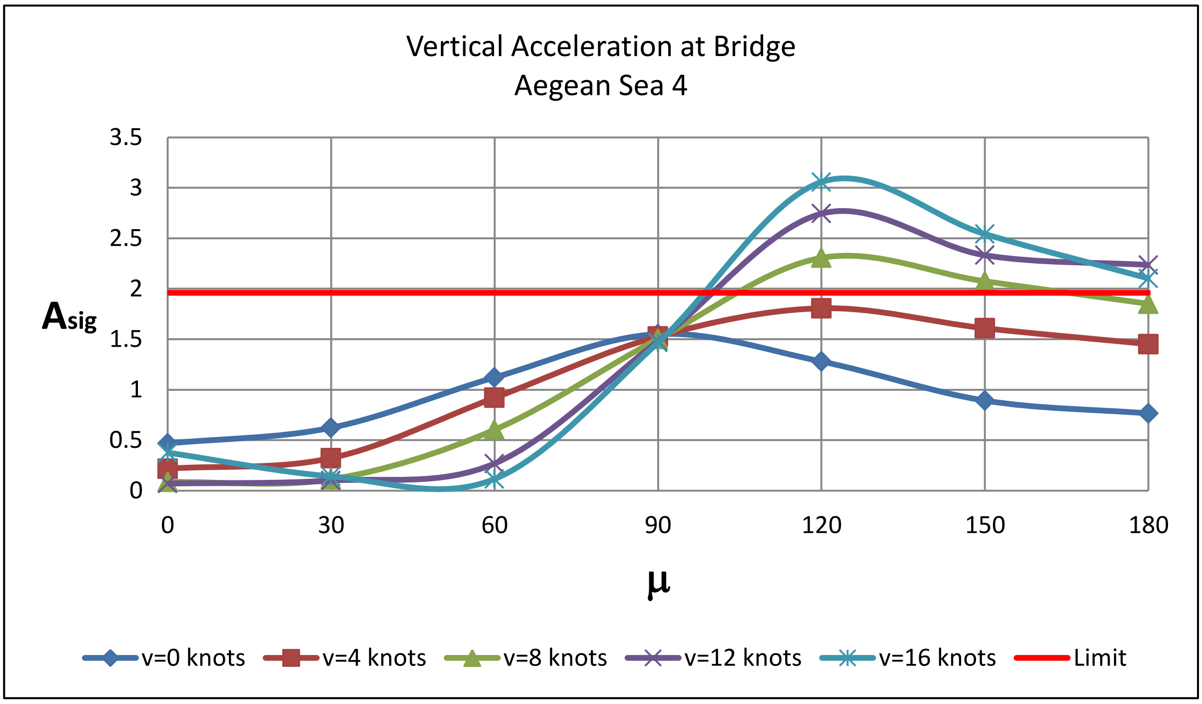


Figure 5-31 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

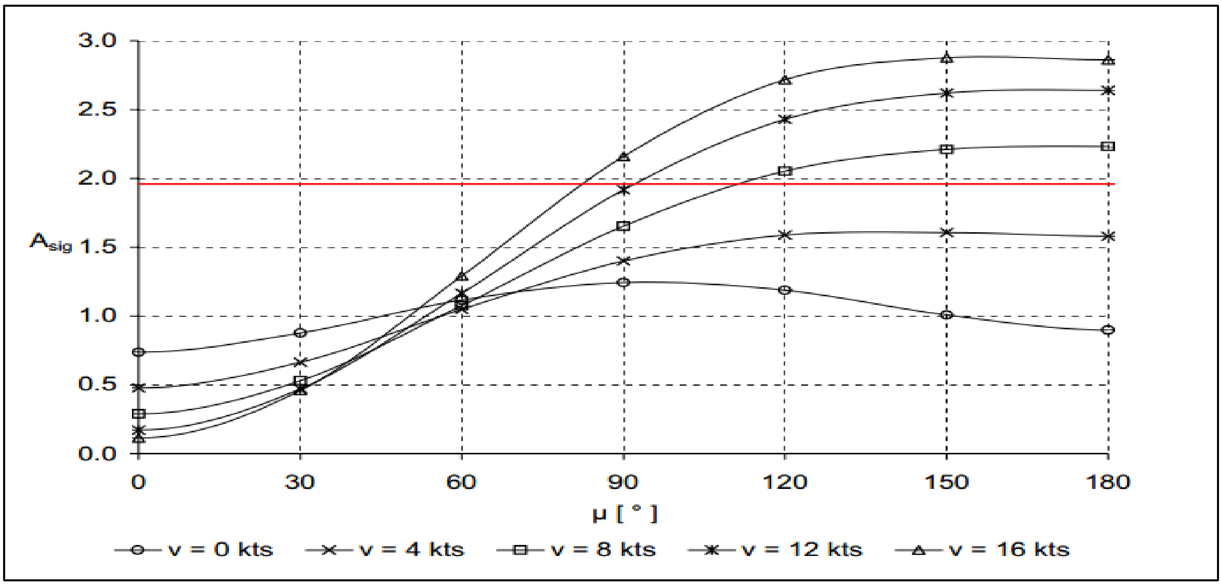


Figure 5-32 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in Bridge shows the great amplification above 90 degree headings in speeds greater than 4 knots. The amplification of vertical acceleration will reduce the comfort of the crew in bridge.

5.5.5 Vertical acceleration at saloon (Aegean Sea State 4)

Performance Criteria   Significant acceleration amplitude <= 0.2g

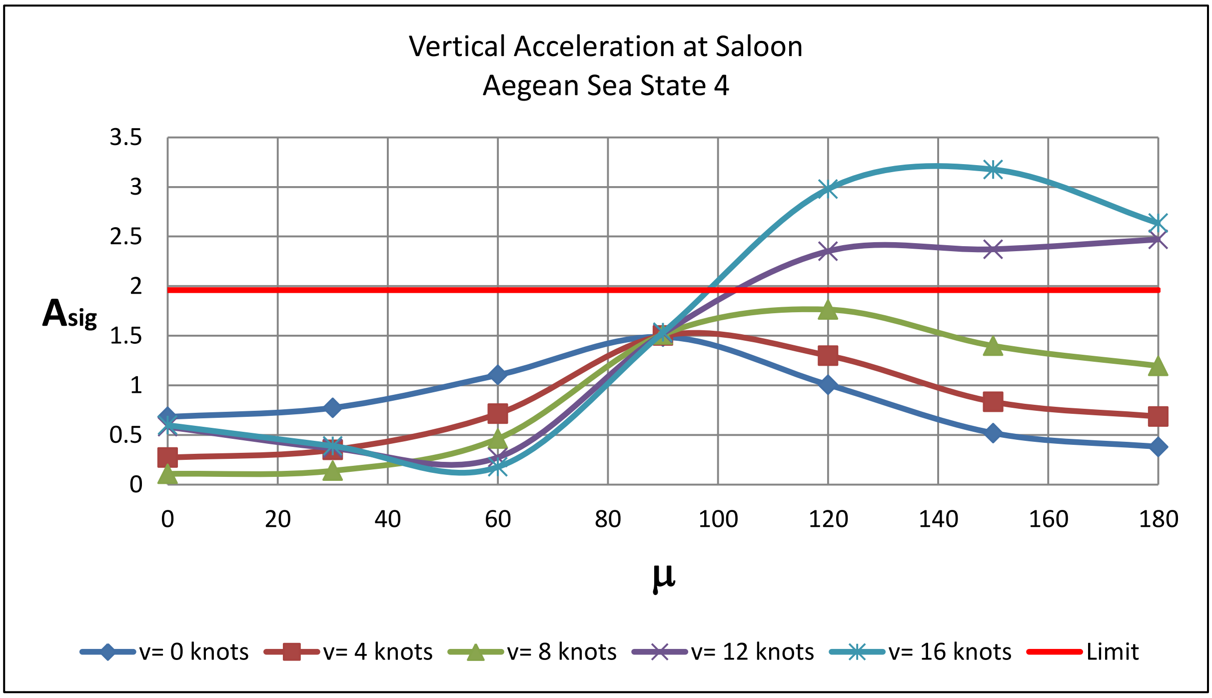


Figure 5-33 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

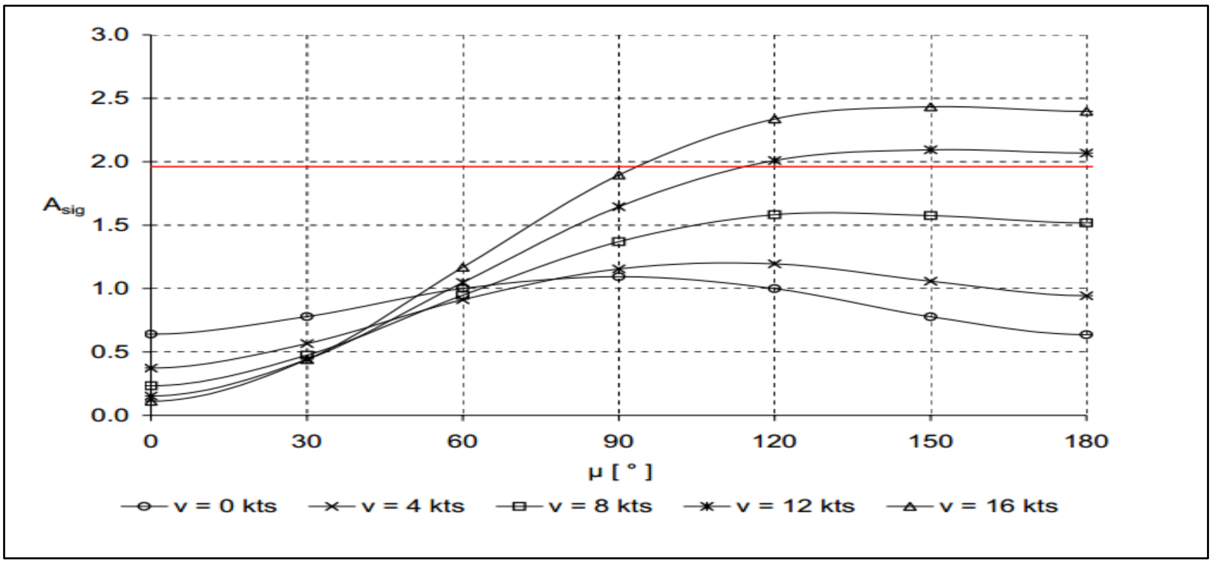


Figure 5-34 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in saloon is crossing the limits defined as performance criteria. The vertical acceleration amplification has a great impact on motion sickness.

5.5.6 Lateral acceleration at bridge (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.15g

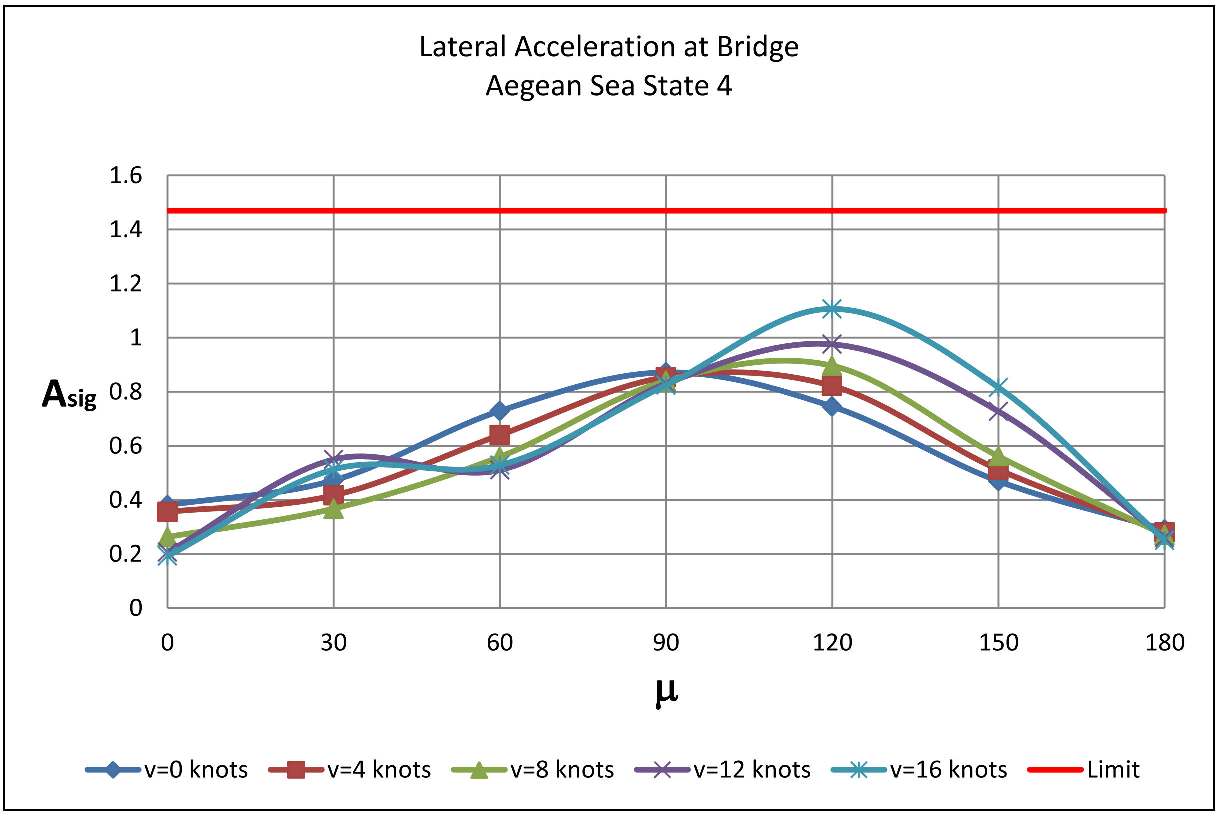


Figure 5-35 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

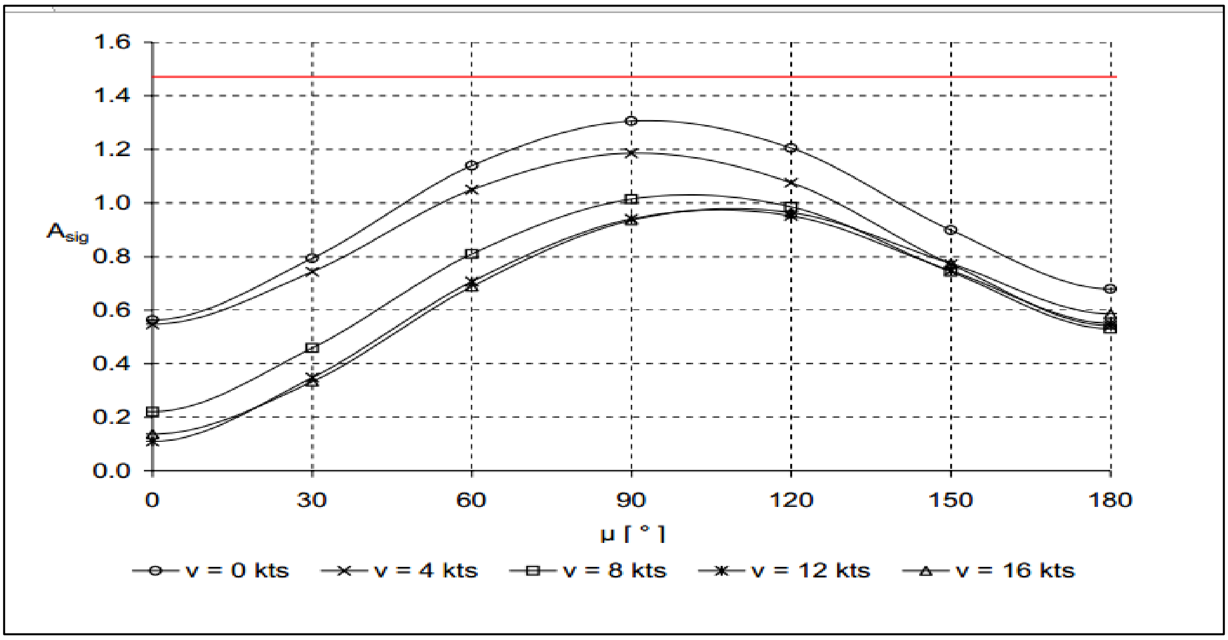


Figure 5-36 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.6 Mediterranean Sea State 4

5.6.1 Roll Motion (Mediterranean Sea State 4)

Performance Criteria Significant roll motion amplitude <= 6 degree

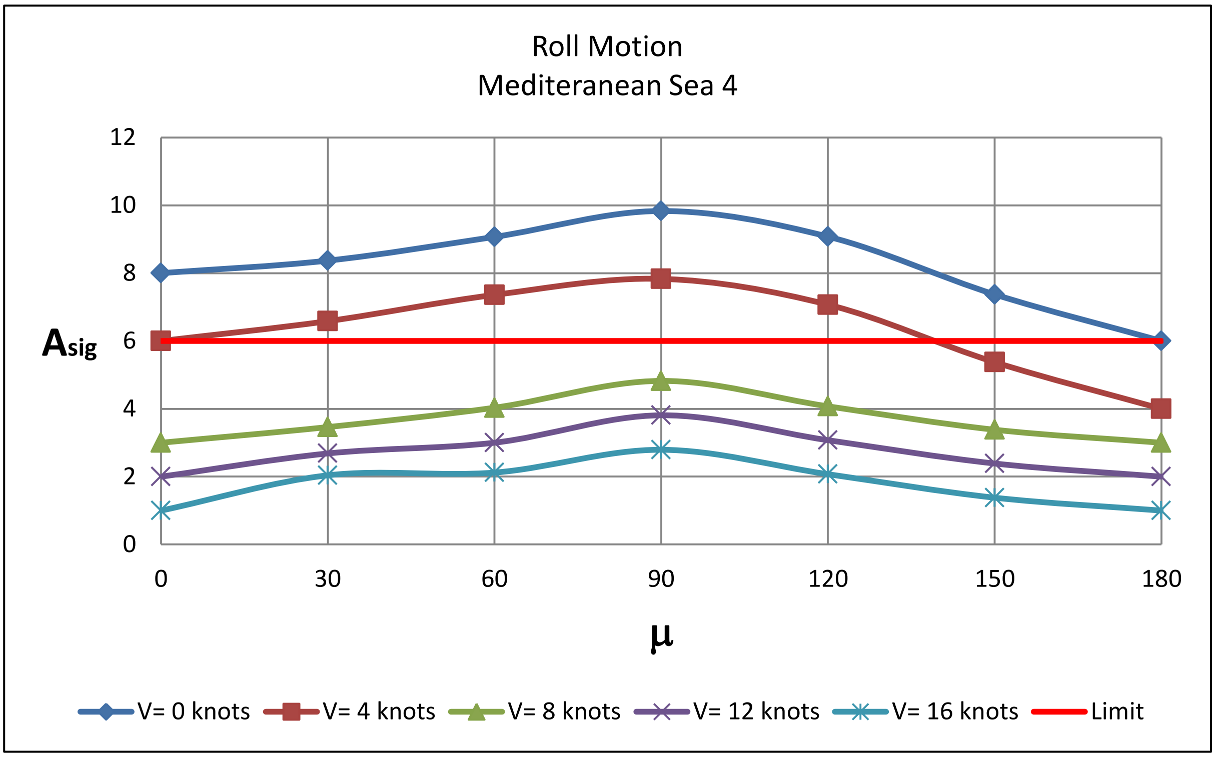


Figure 5-37 Significant roll motion amplitude

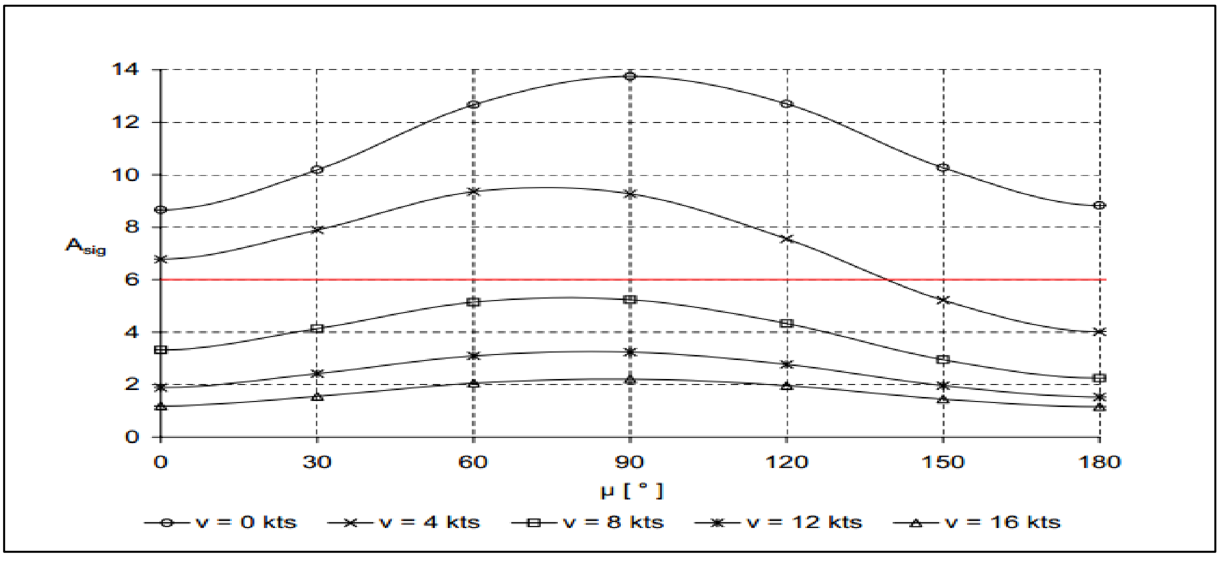


Figure 5-38 HSVA Significant roll motion amplitude

The computed significant amplitude for roll motion overstepped the performance criteria at slow speed. It is may be due to the poor performance of fins and stabilisers.

5.6.2 Pitch Motion (Mediterranean Sea State 4)

Performance Criteria Significant pitch motion amplitude <= 3 degree

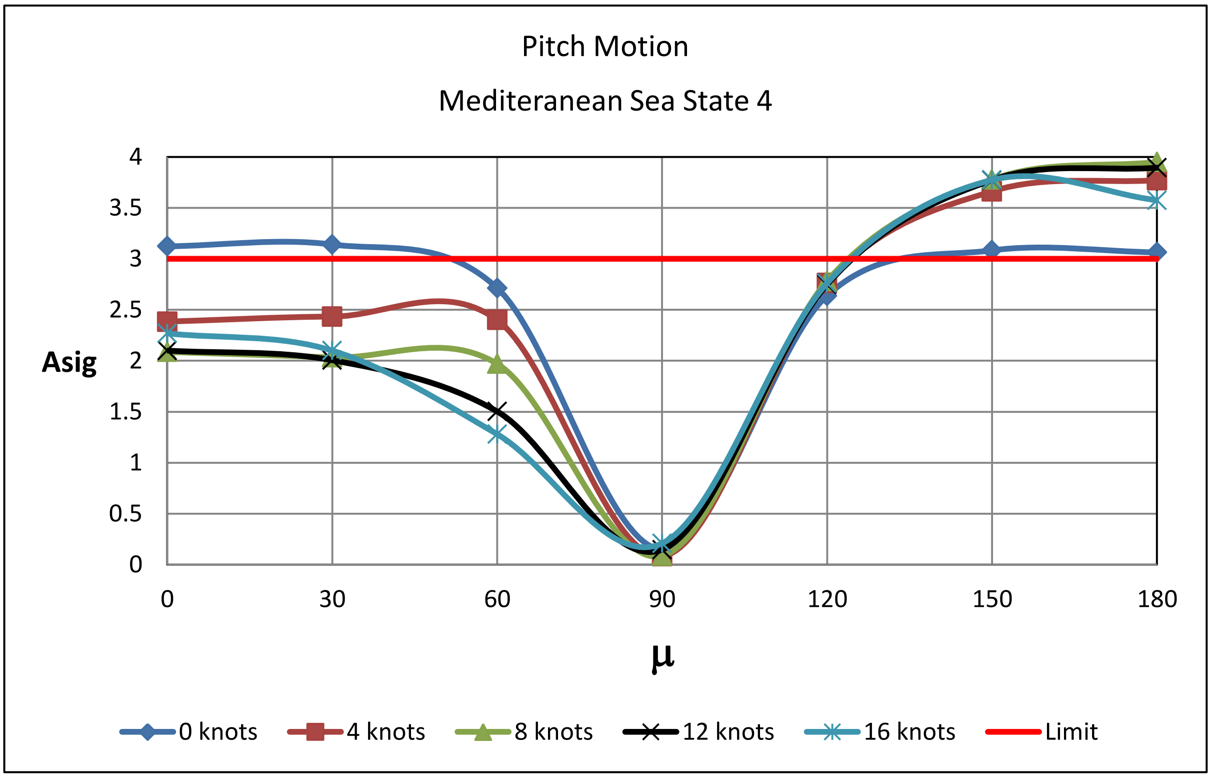


Figure 5-39 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

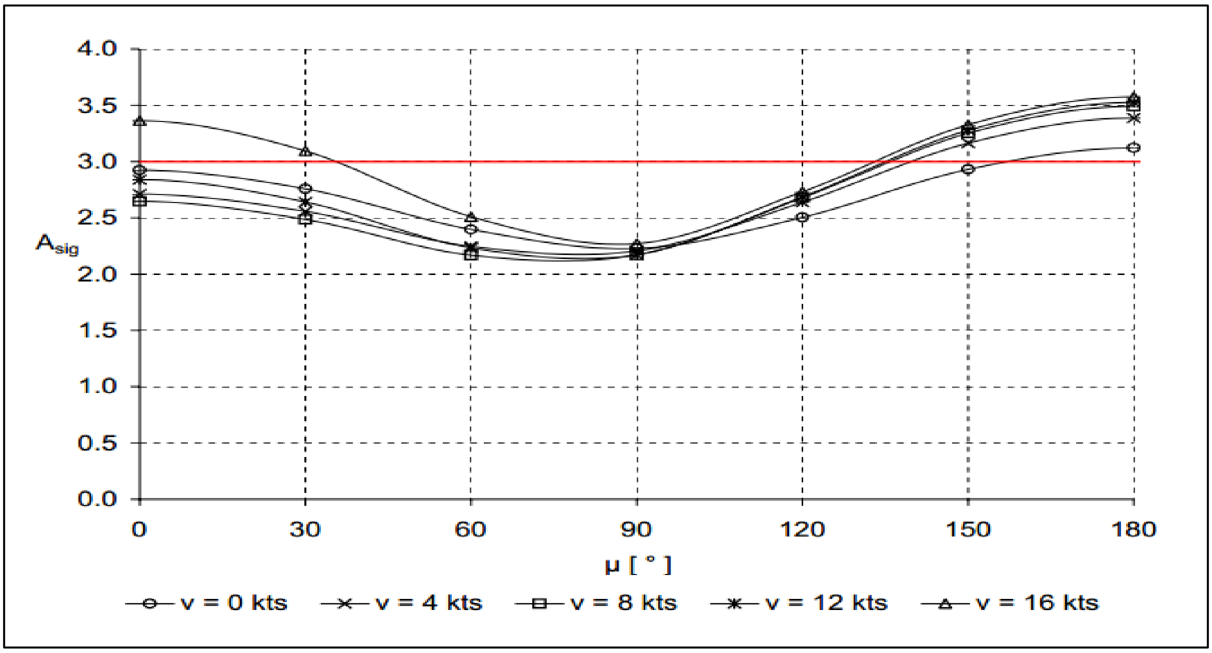


Figure 5-40 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

The computed significant amplitude of pitch motion has amplification and crossing the defined performance criteria in Mediterranean sea State 4.

5.6.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

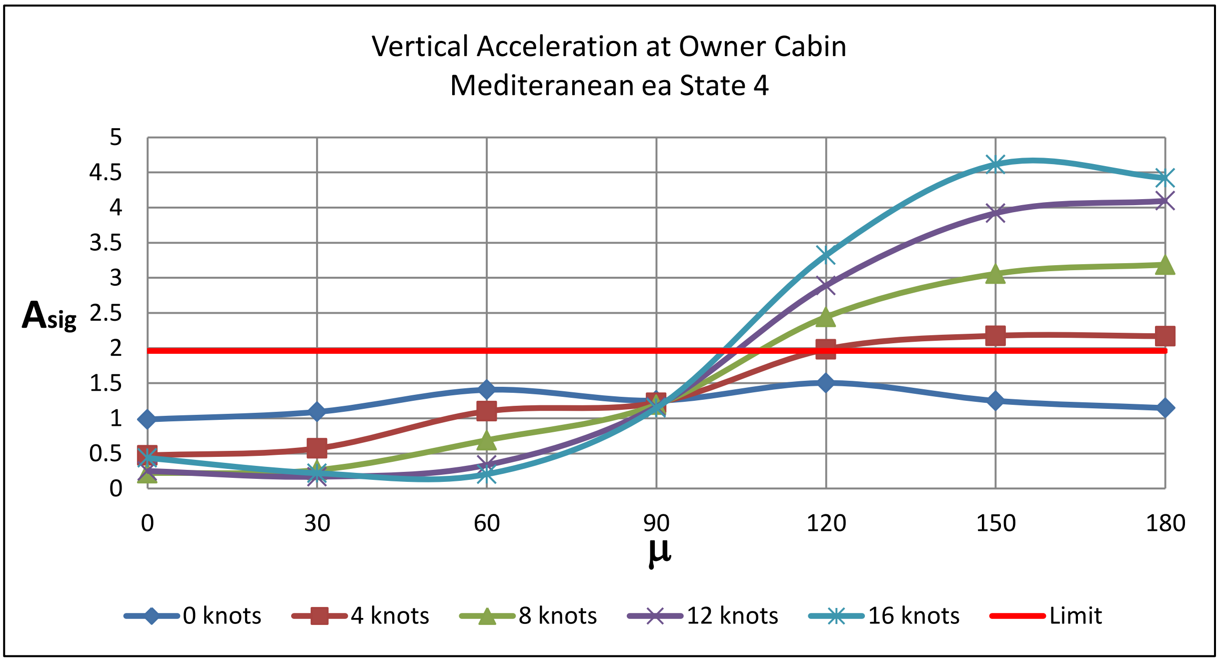


Figure 5-41 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

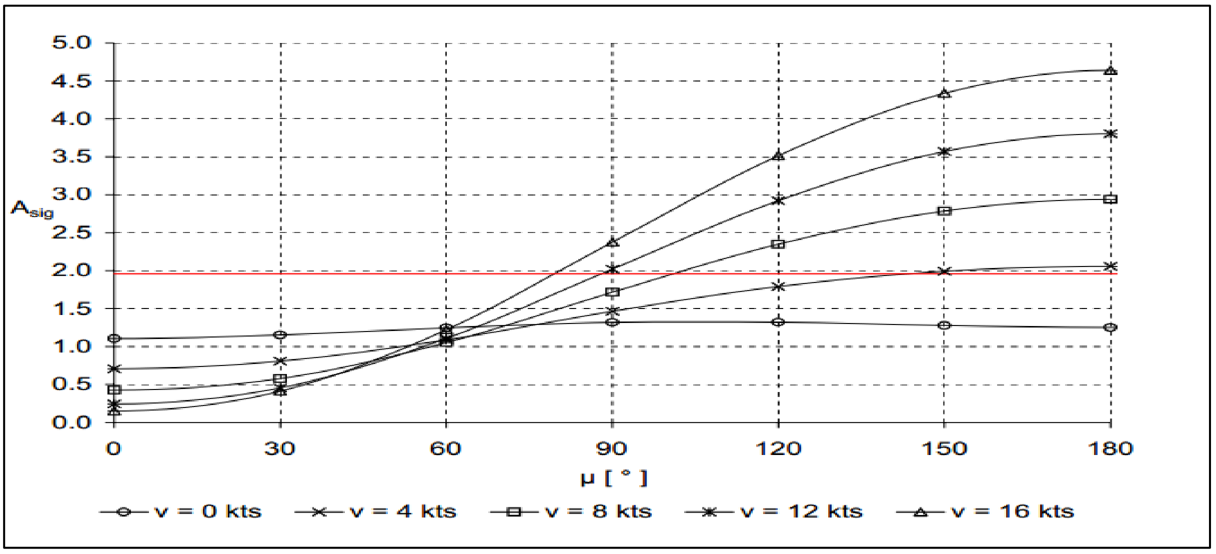


Figure 5-42 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in owner cabins shows the great amplification above 90 degree headings at all speeds. The vertical acceleration has a great impact on the human body and cause motion sickness. This amplification can disturb the comfort of the owner.

5.6.4 Vertical acceleration at bridge (Mediterranean Sea State 4)

Performance Criteria | Significant acceleration amplitude <= 0.2g

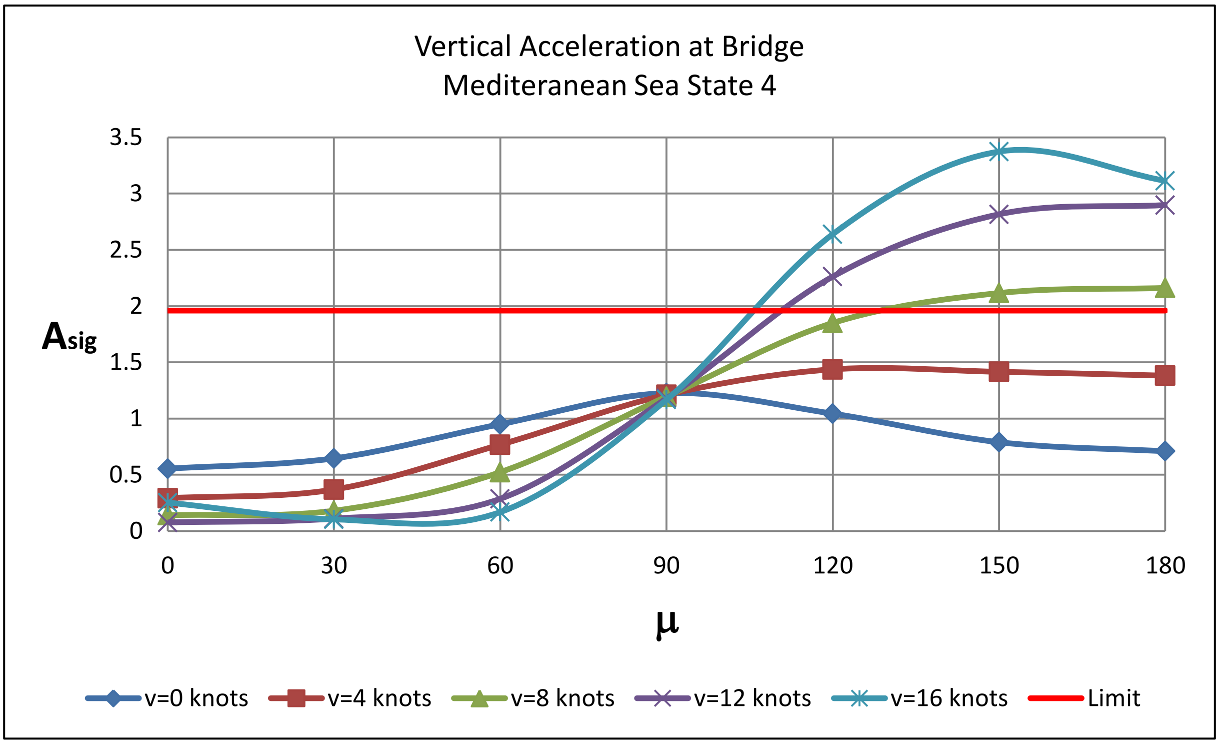


Figure 5-43 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

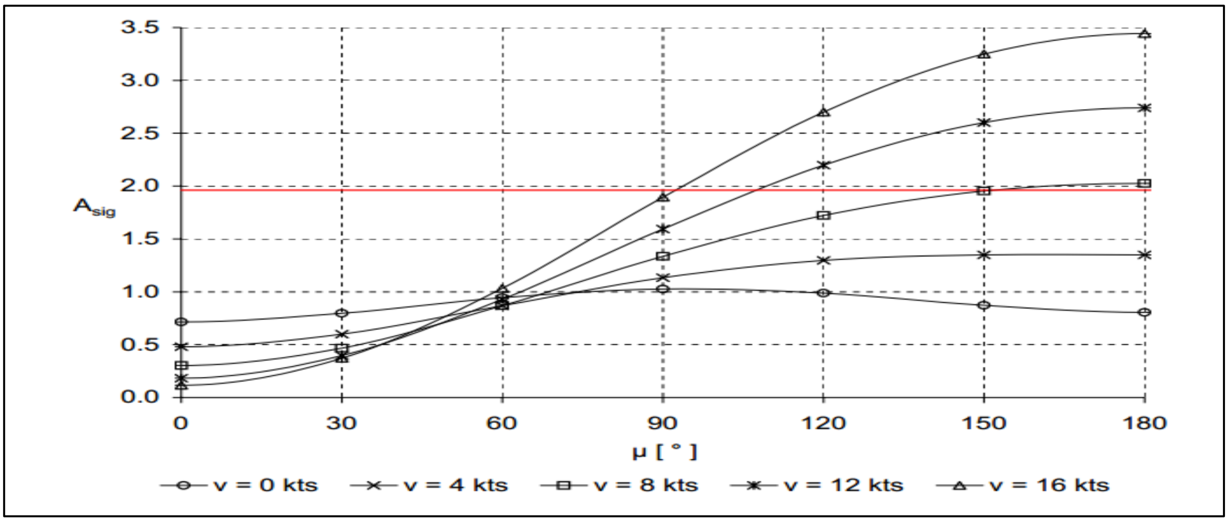


Figure 5-44 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in Bridge shows the great amplification above 90 degree headings in speeds greater than 4 knots. The amplification of vertical acceleration will reduce the comfort of the crew in bridge.

5.6.5 Vertical acceleration at saloon (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

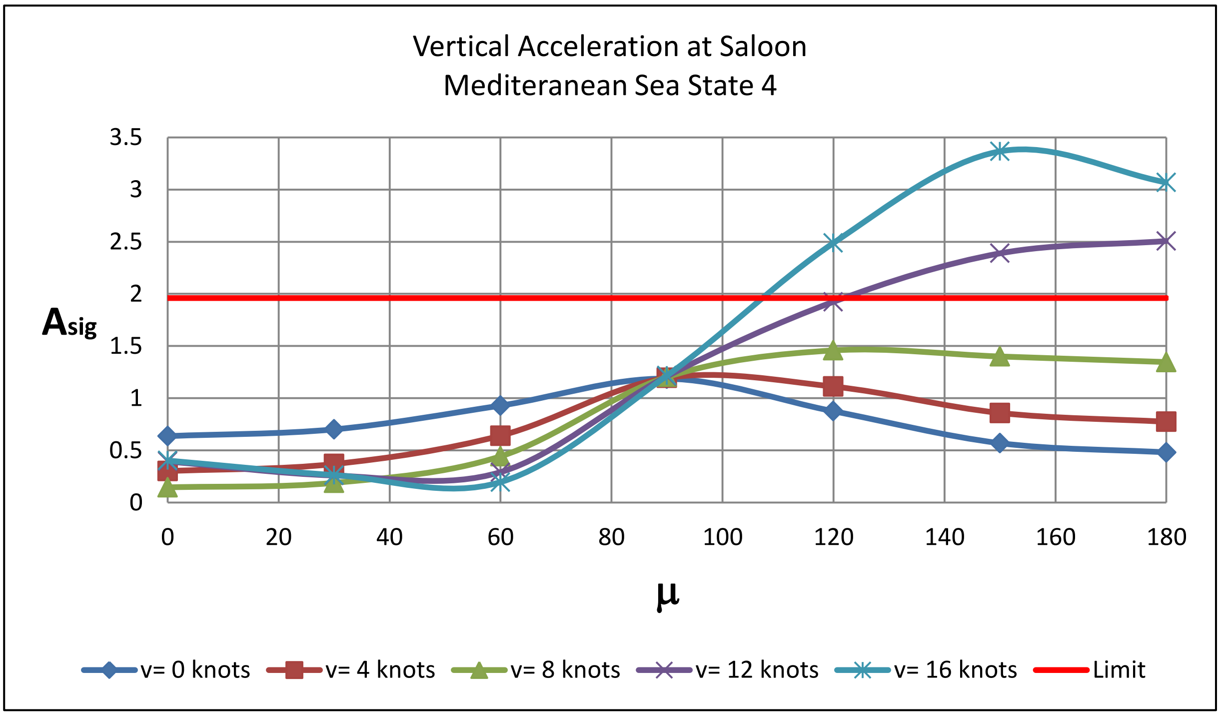


Figure 5-45 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

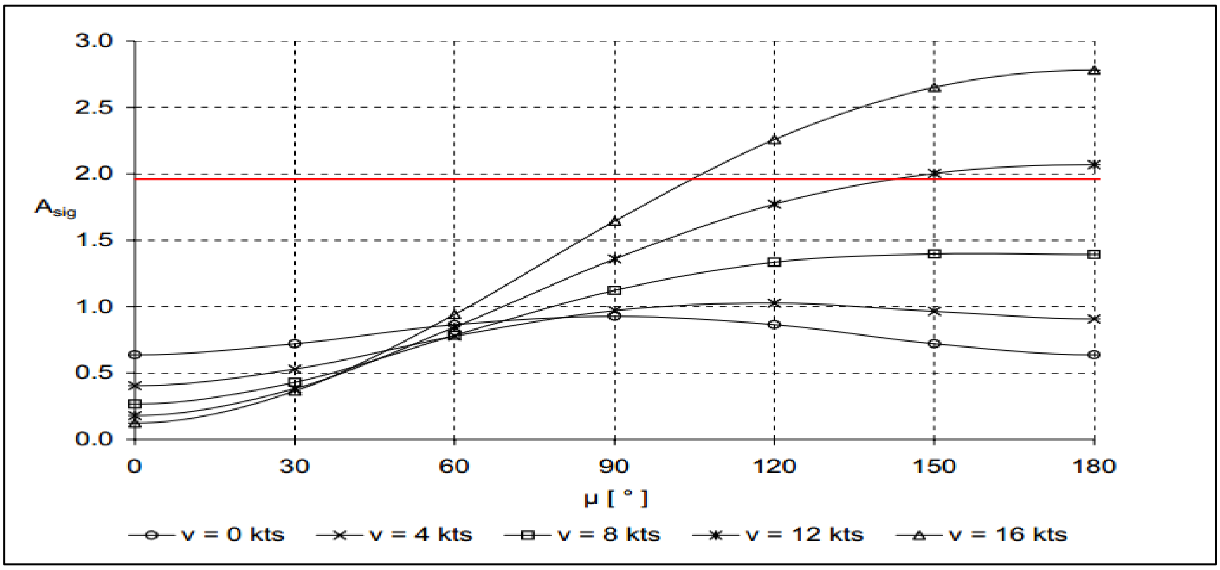


Figure 5-46 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in saloon is crossing the limits defined as performance criteria. The vertical acceleration amplification has a great impact on motion sickness.

5.6.6 Lateral acceleration at bridge (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.15g

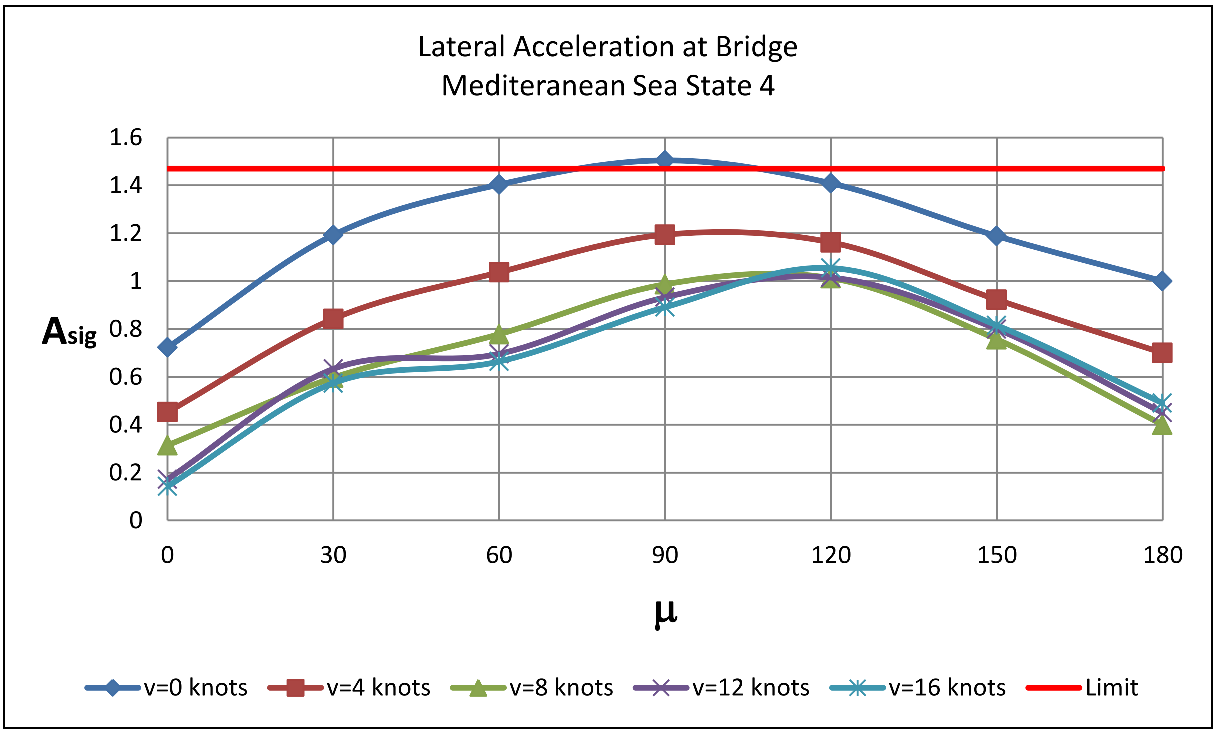


Figure 5-47 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

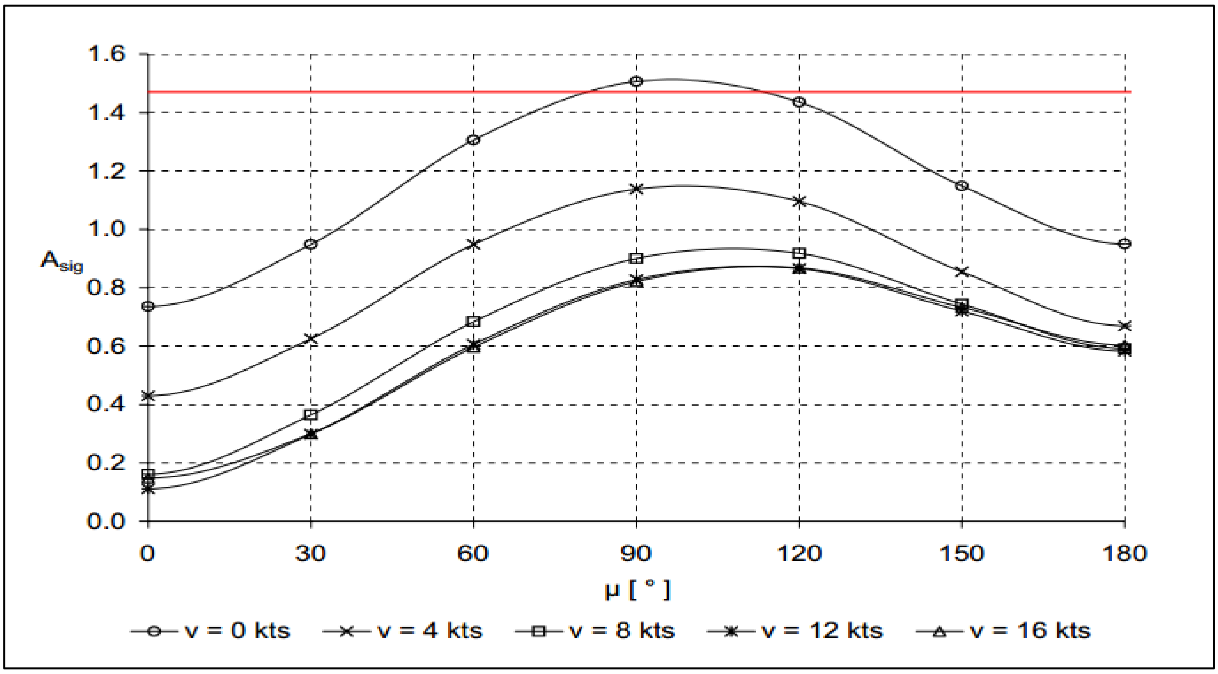


Figure 5-48 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.7 Aegean Sea State 5

5.7.1 Roll Motion (Aegean Sea State 5)

Performance Criteria — Significant roll motion amplitude <= 6 degree

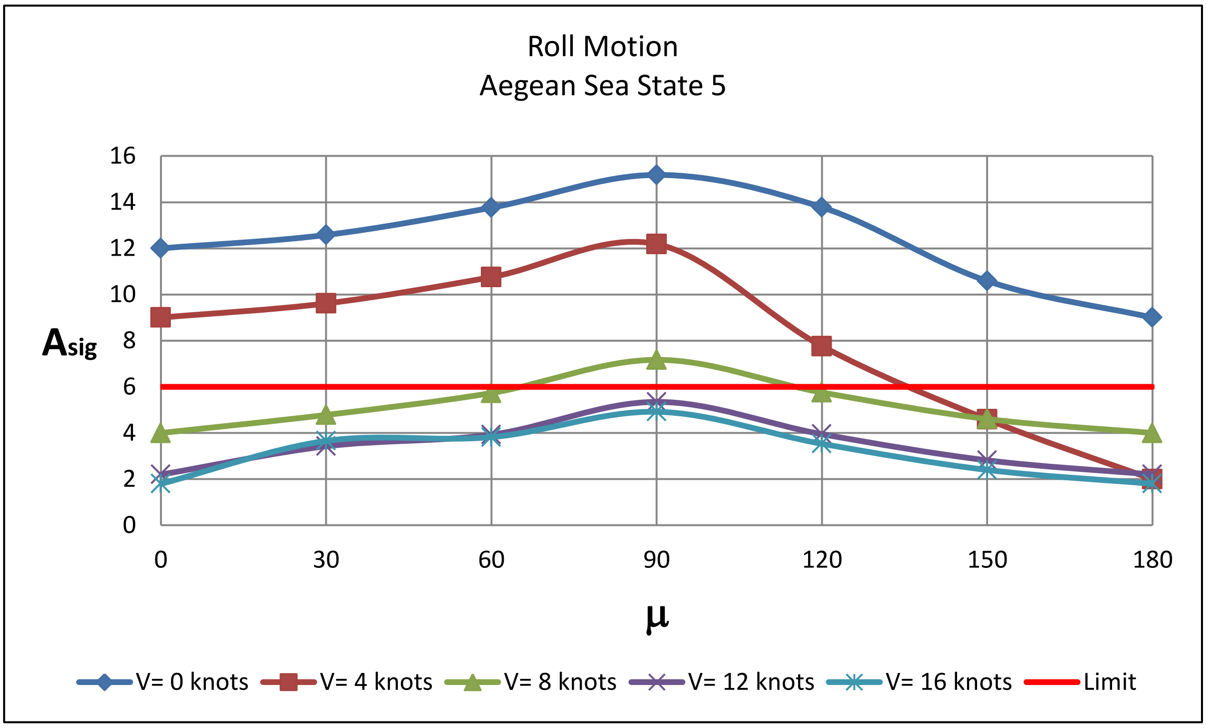


Figure 5-49 Significant roll motion amplitude

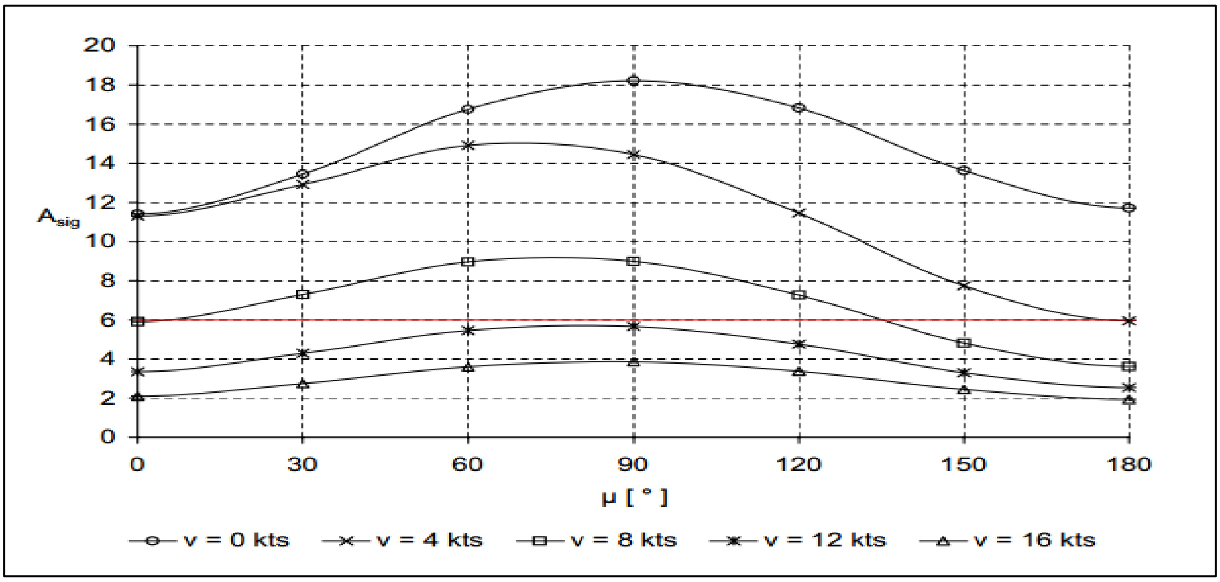


Figure 5-50 Significant roll motion amplitude

The computed significant amplitude for roll motion satisfies the performance criteria at a high speed while at slow speed the roll motion is overstepping the defined limits.

5.7.2 Pitch Motion (Aegean Sea State 5)

Performance Criteria Significant pitch motion amplitude <= 3 degree

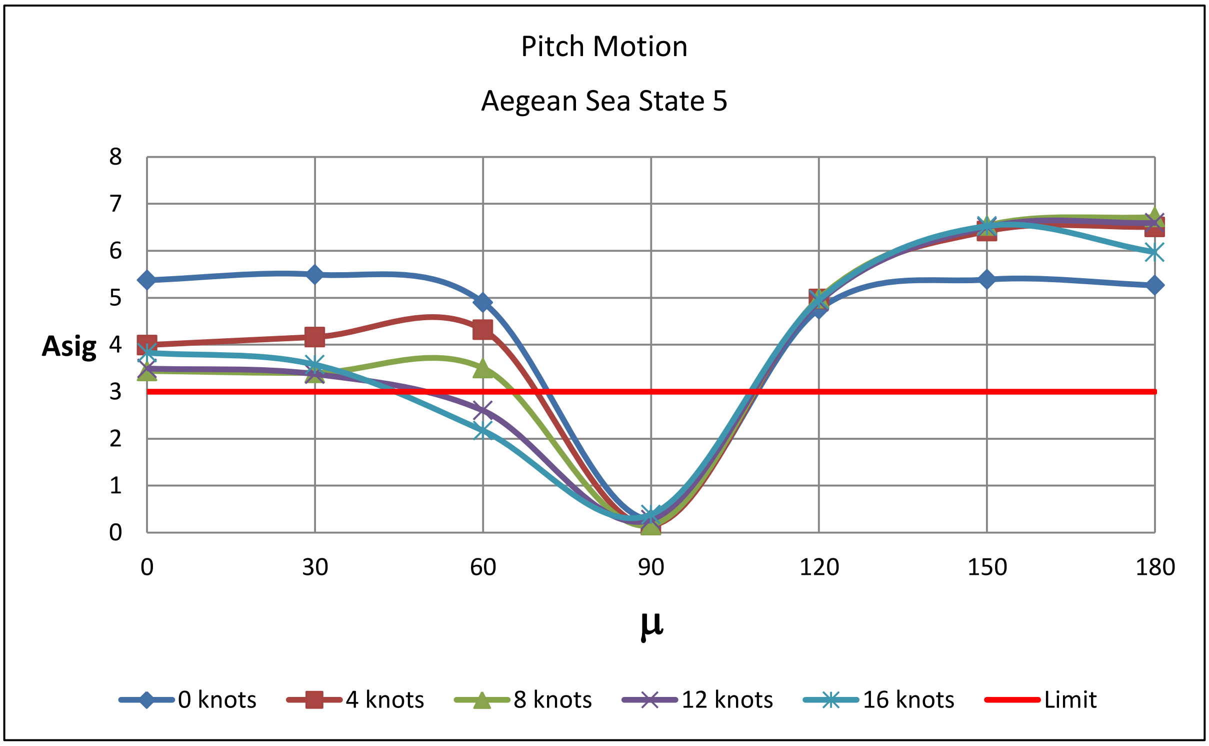


Figure 5-51 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

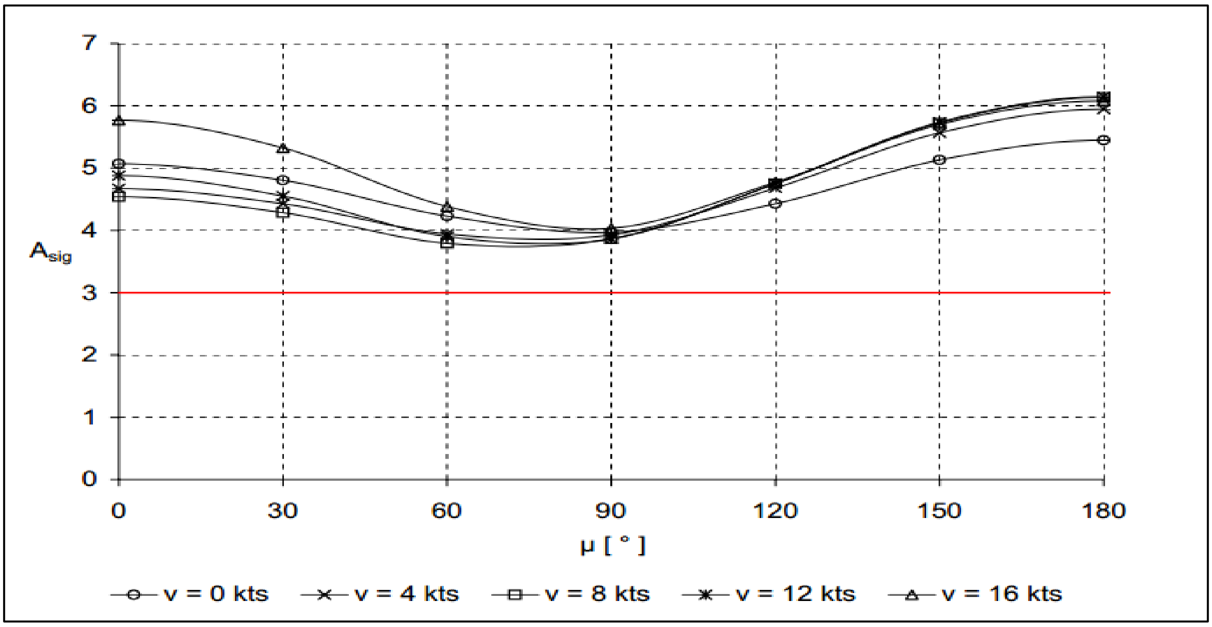


Figure 5-52 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

The computed significant amplitude for pitch motion does not satisfy the performance criteria at all speeds and headings.

5.7.3 Vertical acceleration at owner's cabin (Aegean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

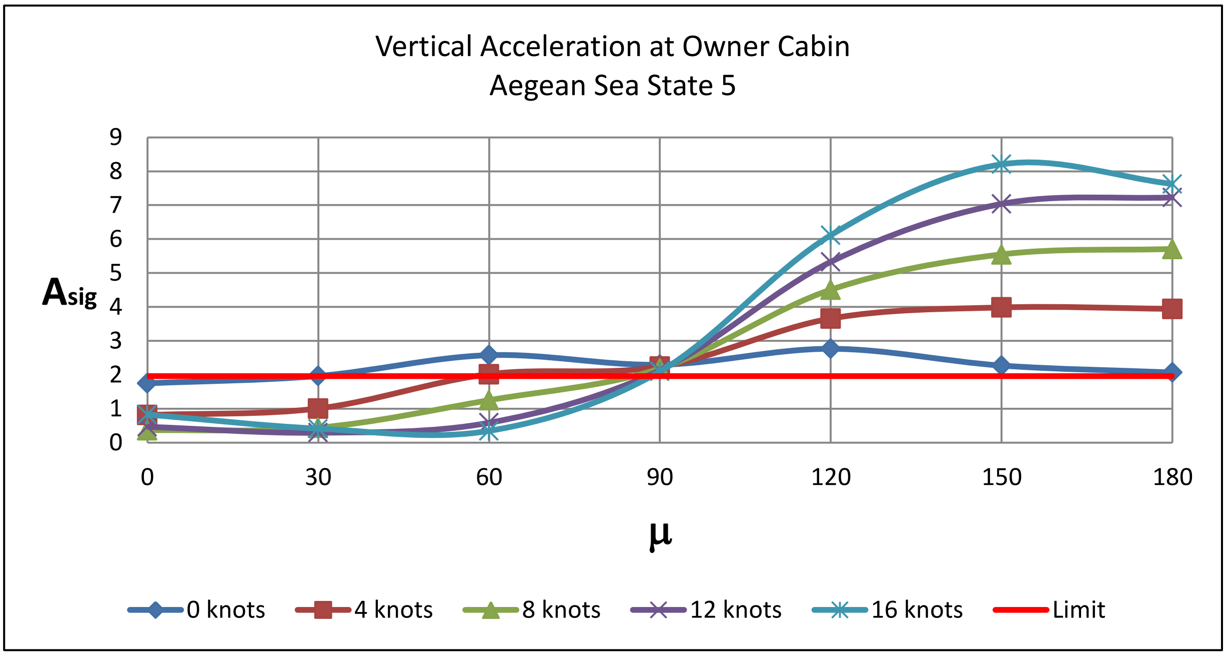


Figure 5-53 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

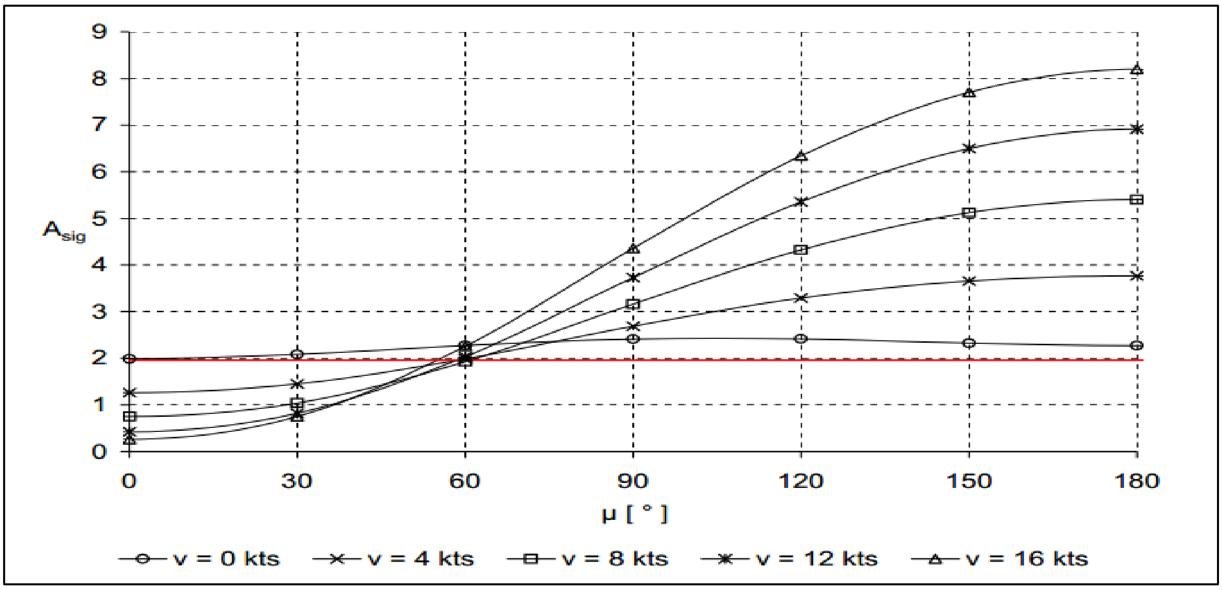


Figure 5-54 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in owner cabins shows the great amplification above 90 degree headings at all speeds. The vertical acceleration has a great impact on the human body and cause motion sickness. This amplification can disturb the comfort of the owner.

5.7.4 Vertical acceleration at bridge (Aegean Sea State 5)

Performance Criteria   Significant acceleration amplitude <= 0.2g

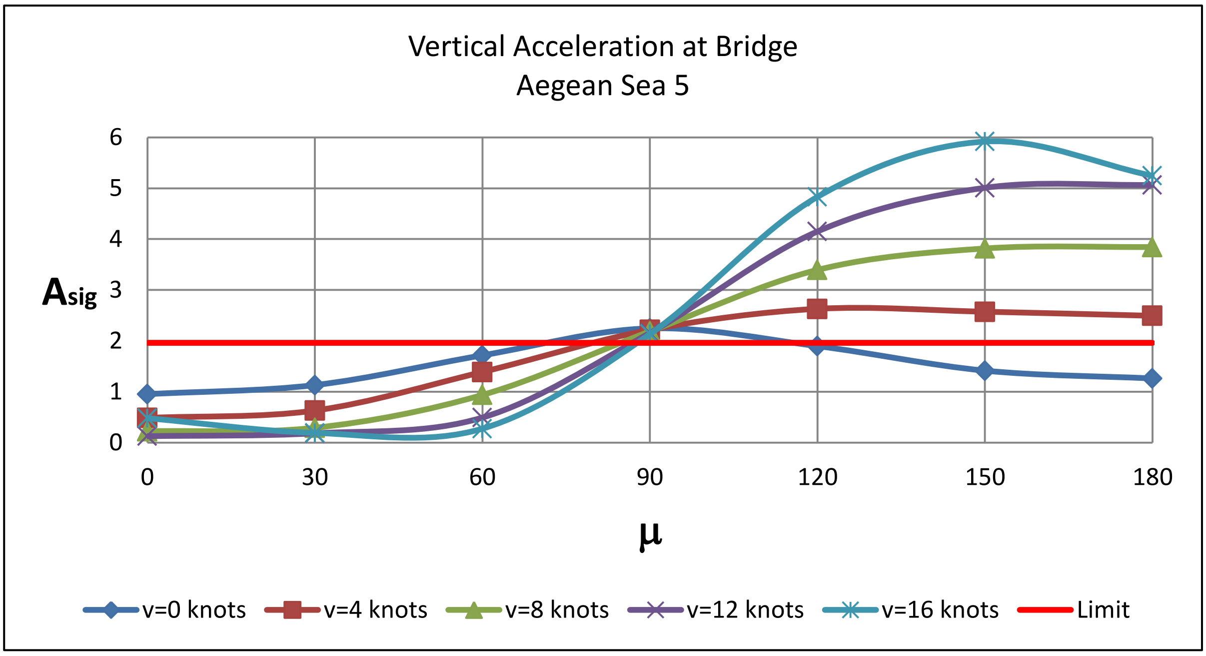


Figure 5-55 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

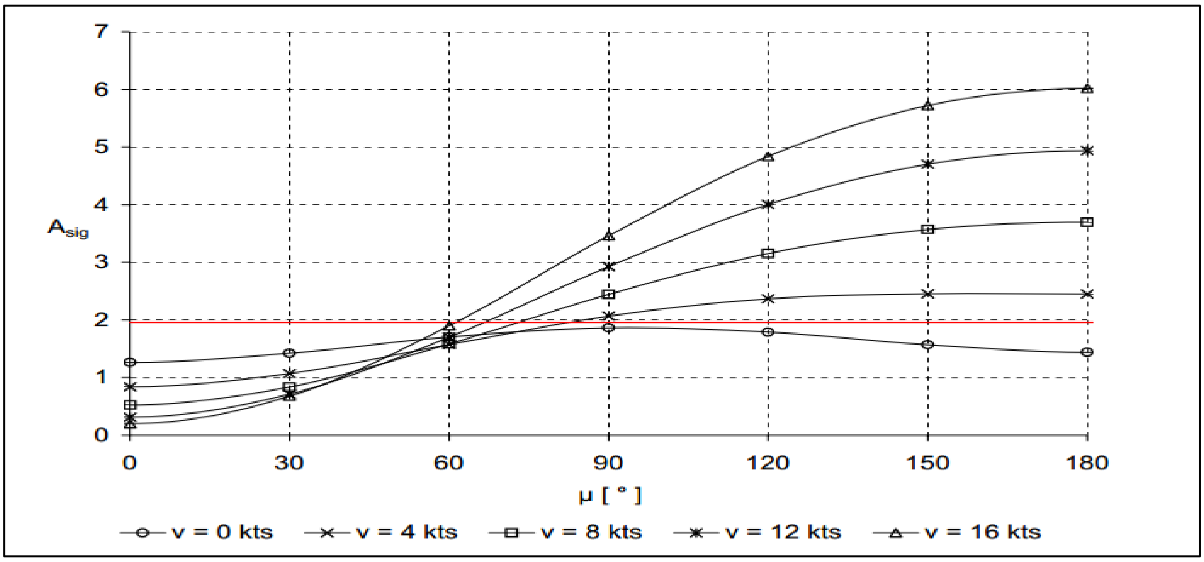


Figure 5-56 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in Bridge shows the great amplification above 90 degree headings. The amplification of vertical acceleration will reduce the comfort of the crew in bridge.

5.7.5 Vertical acceleration at saloon (Aegean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

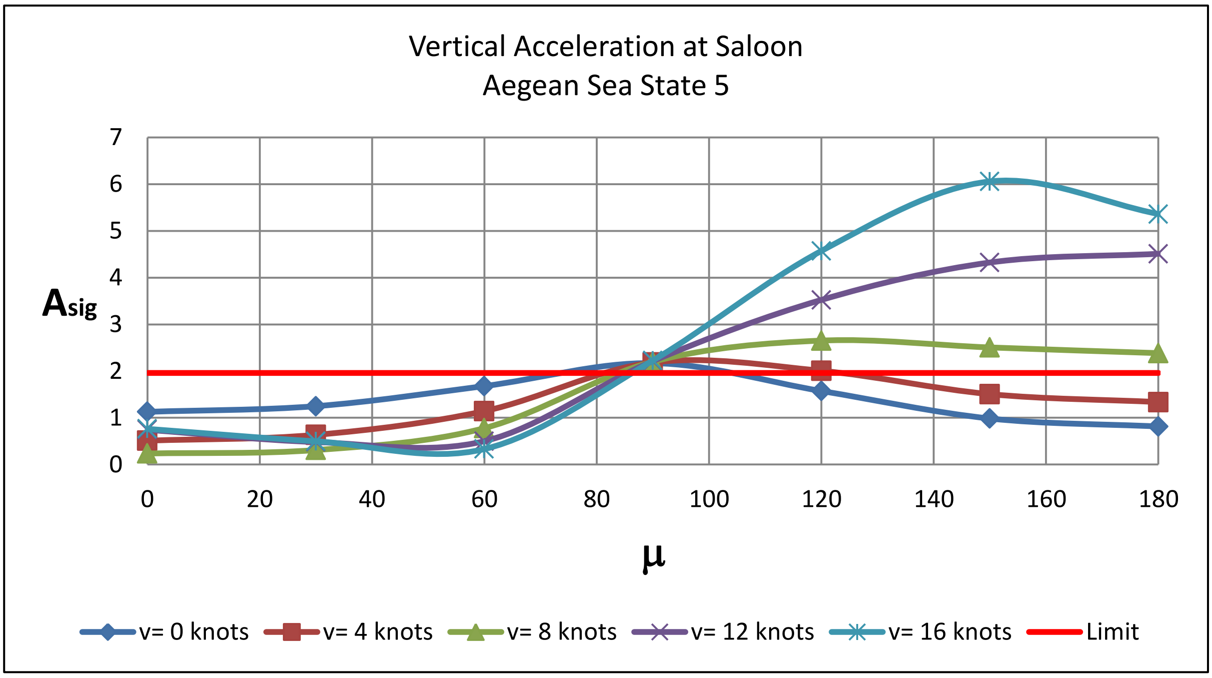


Figure 5-57 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

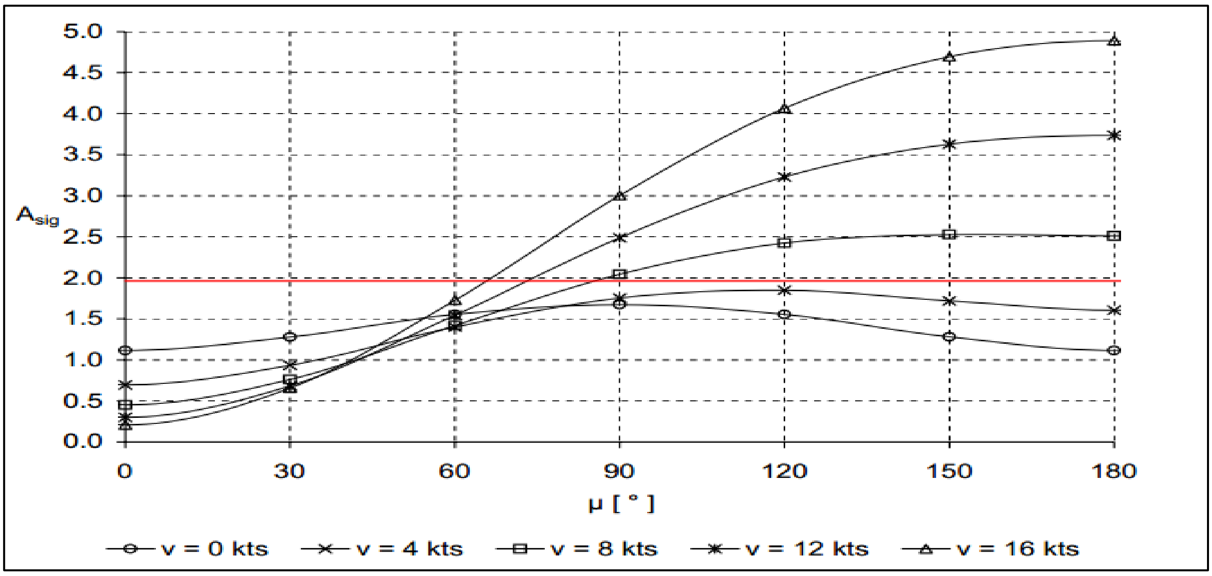


Figure 5-58 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

The significant amplitude of vertical acceleration obtained in saloon is crossing the limits defined as performance criteria. The vertical acceleration amplification has a great impact on motion sickness of owner, crew and guest.

5.7.6 Lateral acceleration at bridge (Aegean Sea State 5)

Performance Criteria | Significant acceleration amplitude <= 0.15g

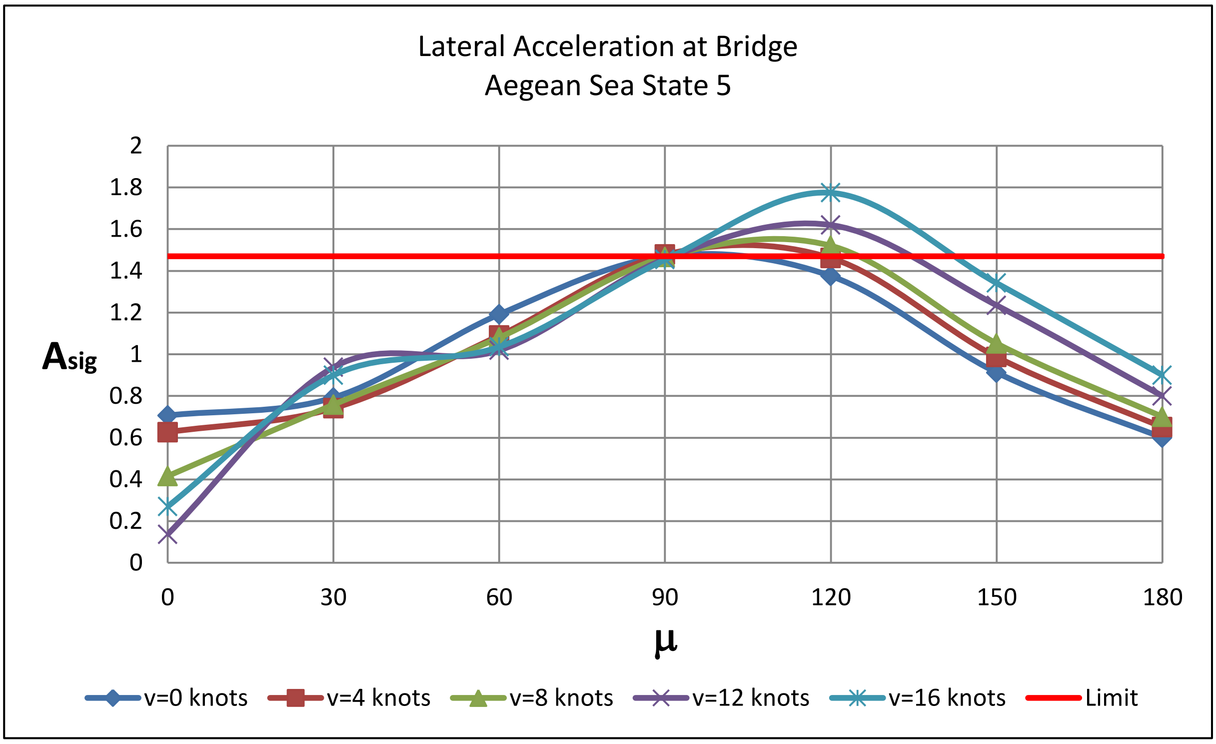


Figure 5-59 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

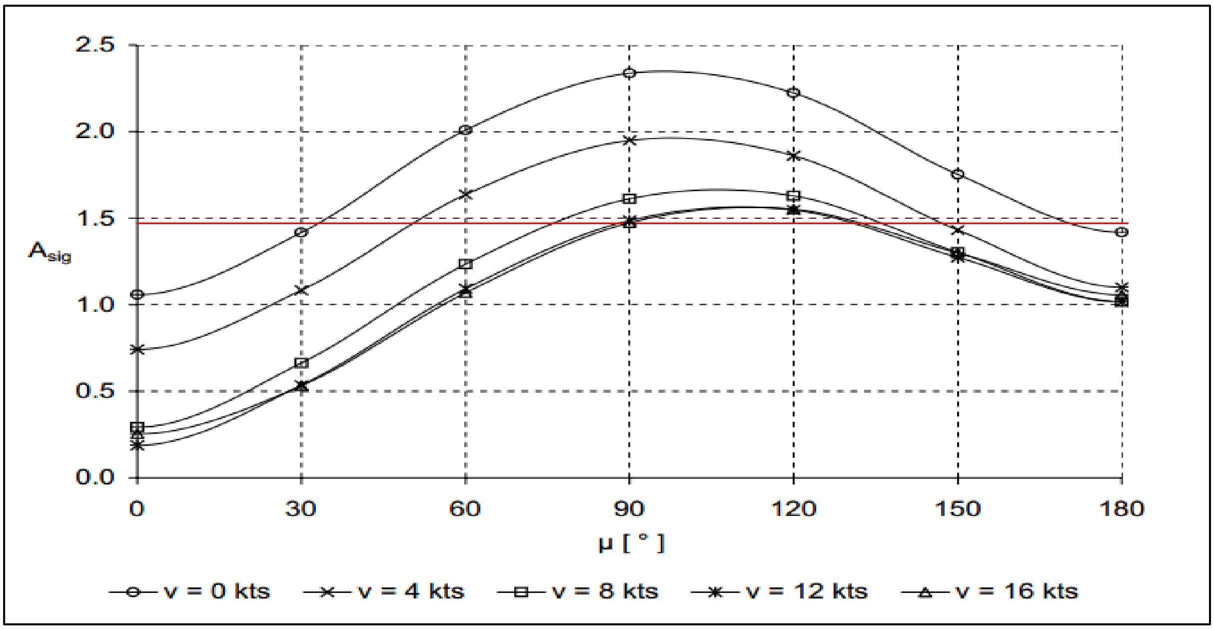


Figure 5-60 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.8 Mediterranean Sea State 5

5.8.1.1 Roll Motion (Mediterranean Sea State 5)

Performance Criteria Significant roll motion amplitude <= 6 degree

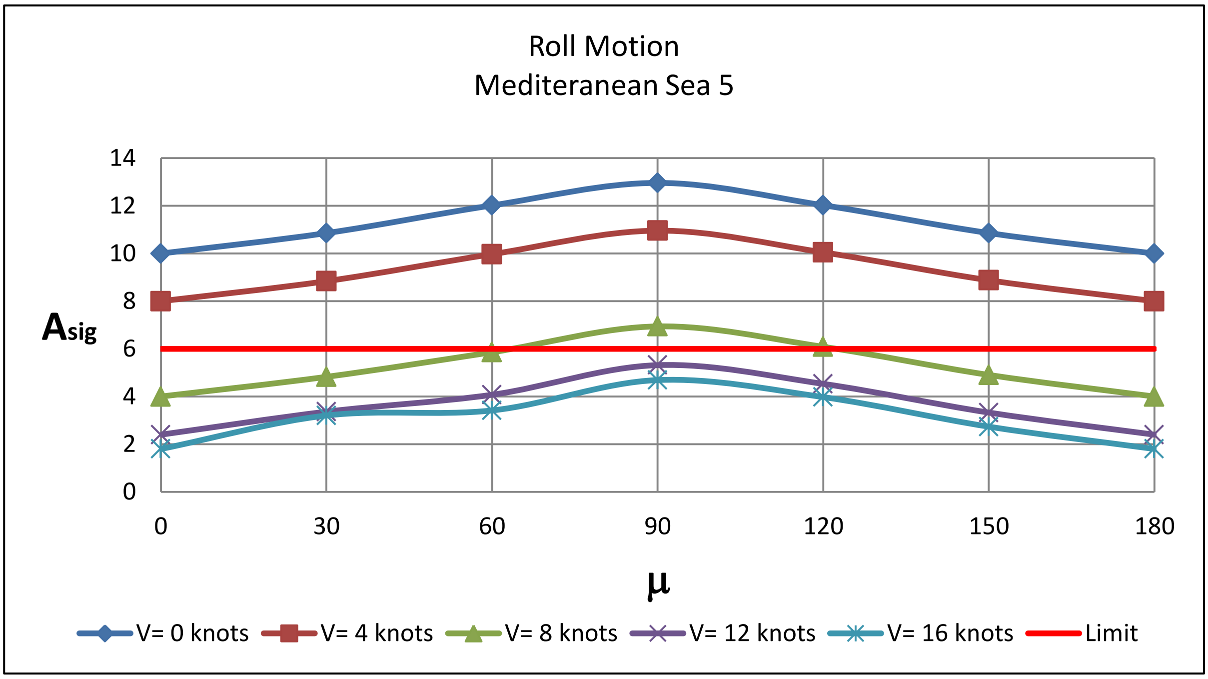


Figure 5-61 Significant roll motion amplitude

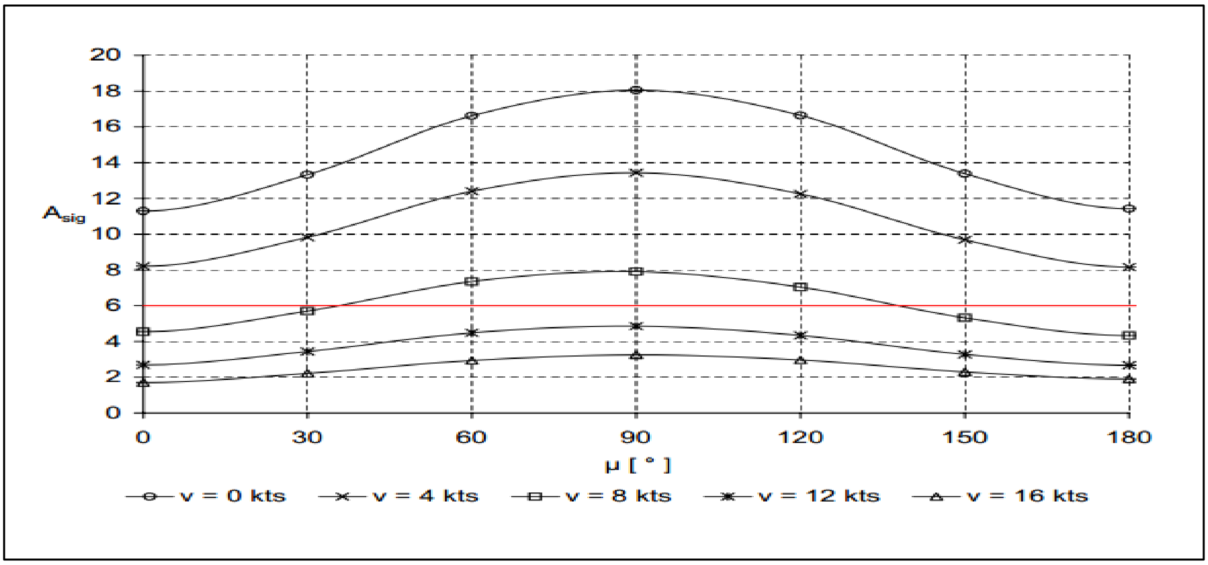


Figure 5-62 HSVA Significant roll motion amplitude

The computed significant amplitude for roll motion satisfies the performance criteria at a speed greater than 8 knots and has maximum values from 60 to 90 degree headings.

5.8.2 Pitch Motion (Mediterranean Sea State 5)

Performance Criteria Significant pitch motion amplitude <= 3 degree

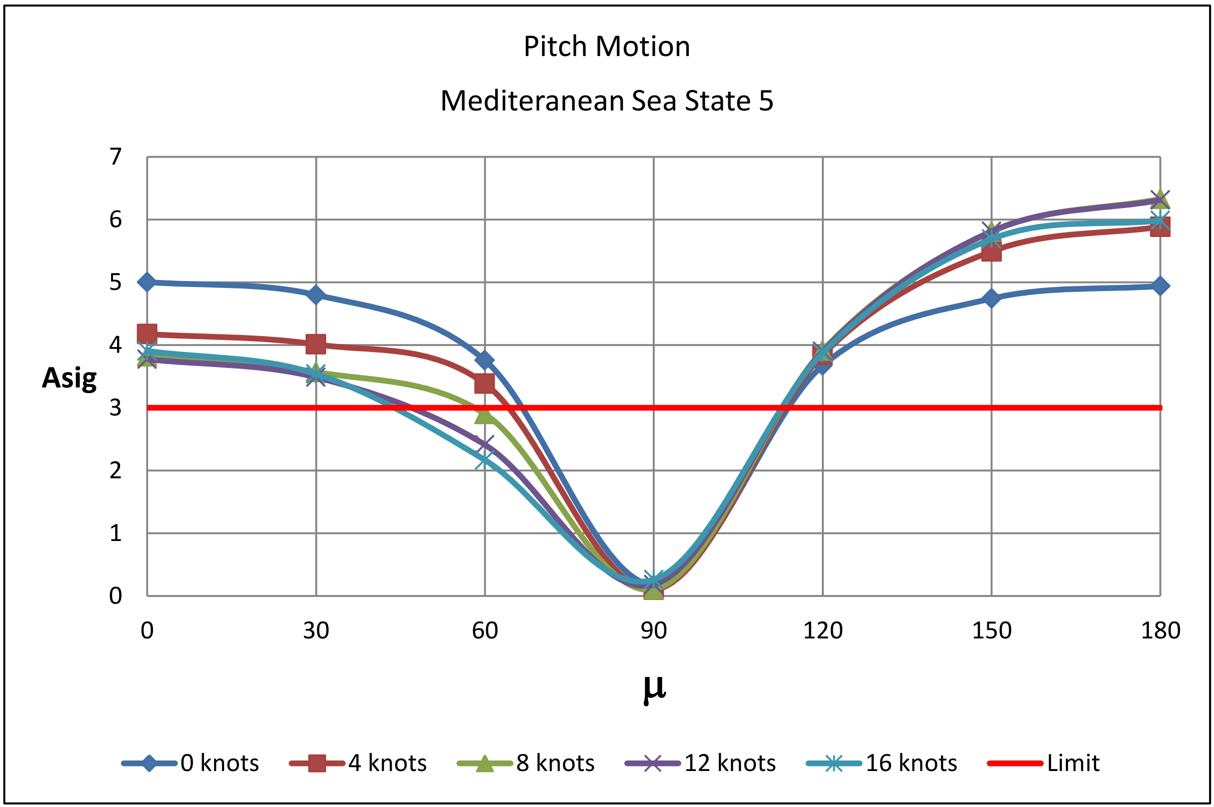


Figure 5-63 Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

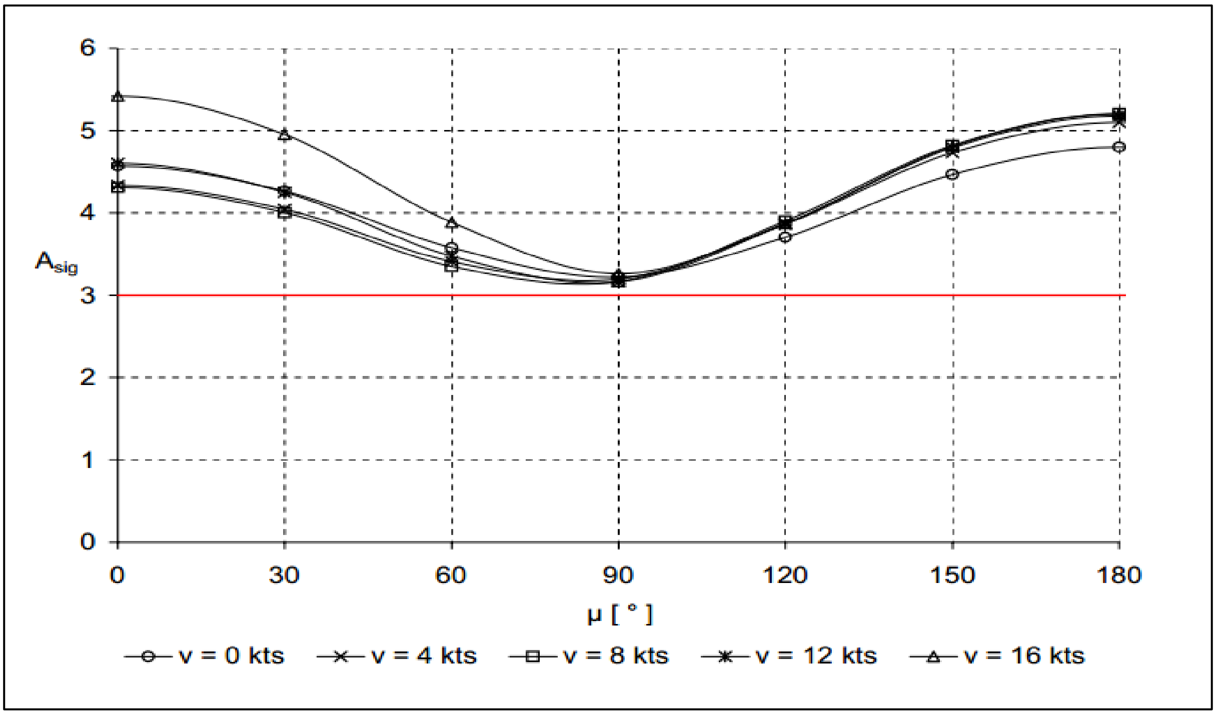


Figure 5-64 HSVA Significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.8.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

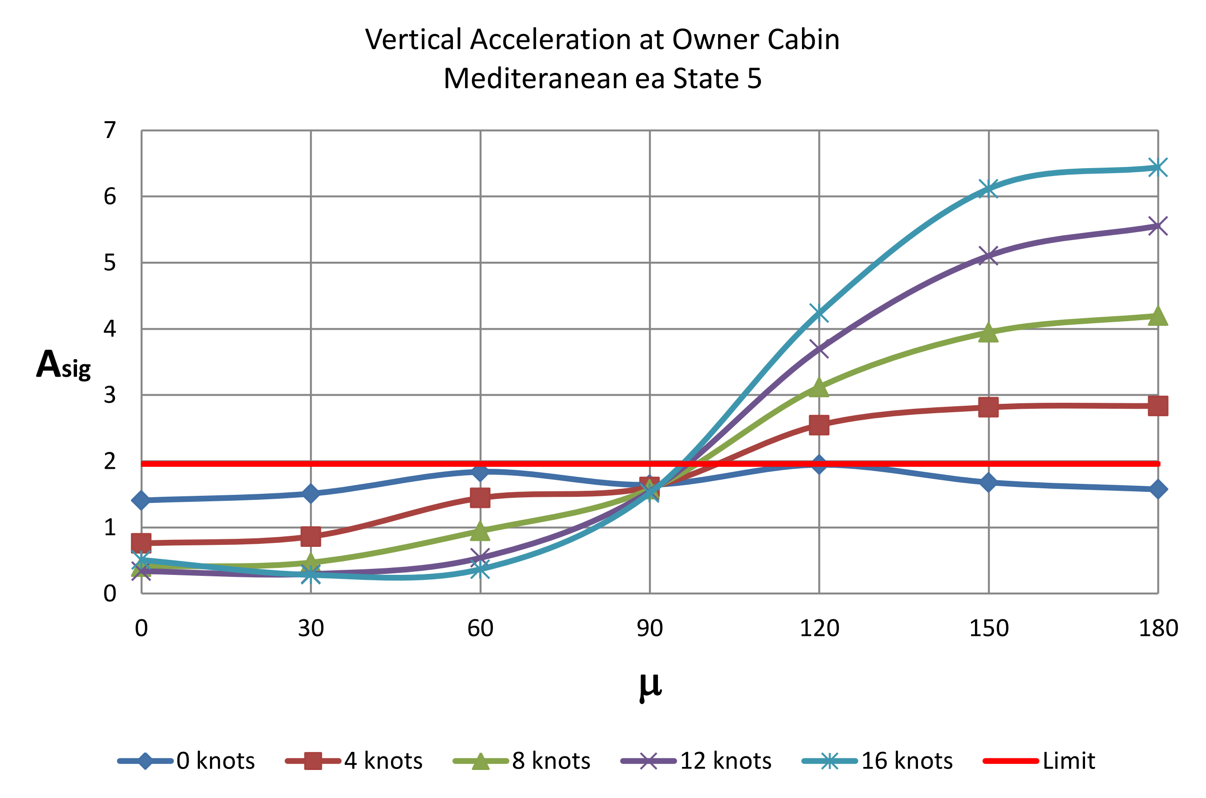


Figure 5-65 Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

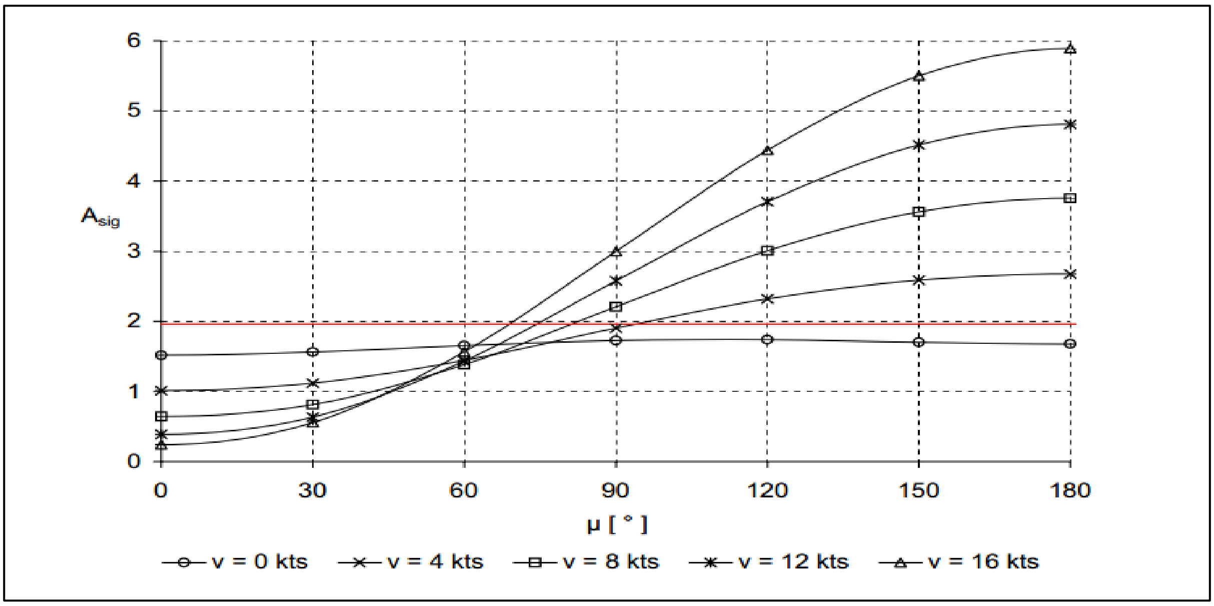


Figure 5-66 HSVA Significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.8.4 Vertical acceleration at bridge (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

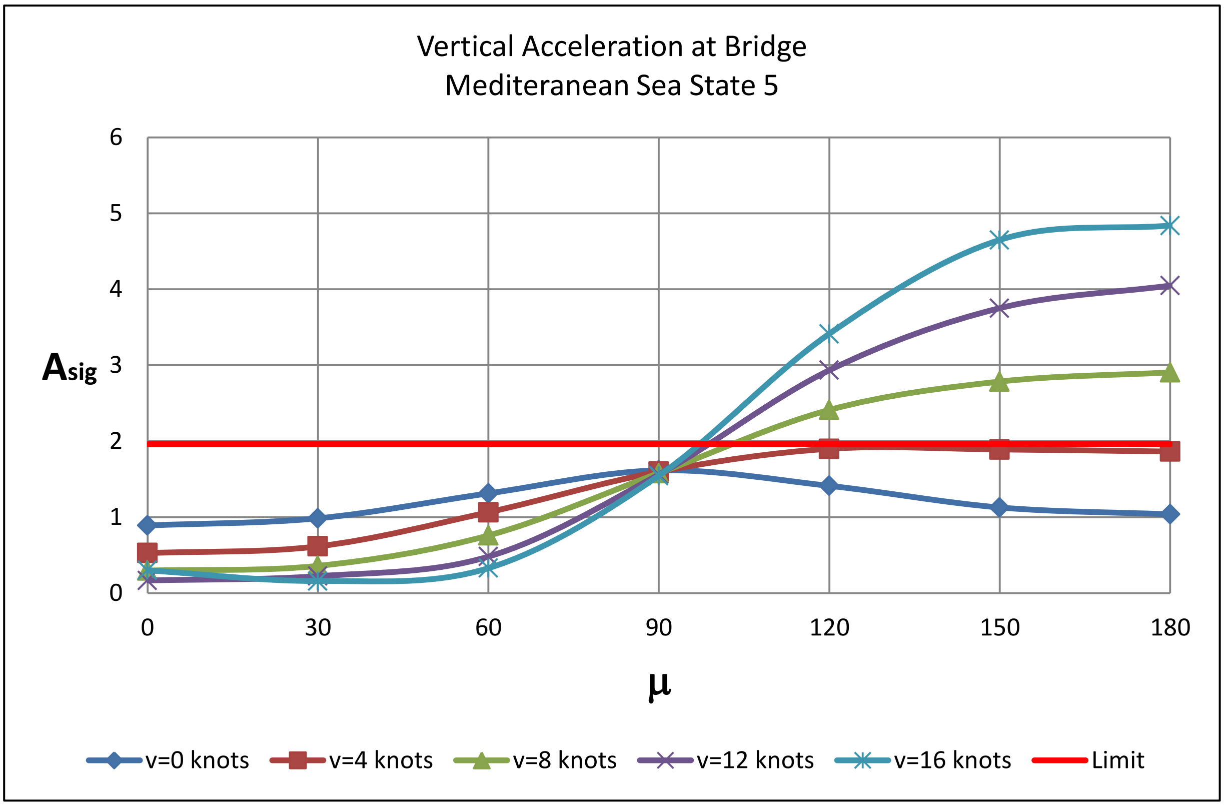


Figure 5-67 Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

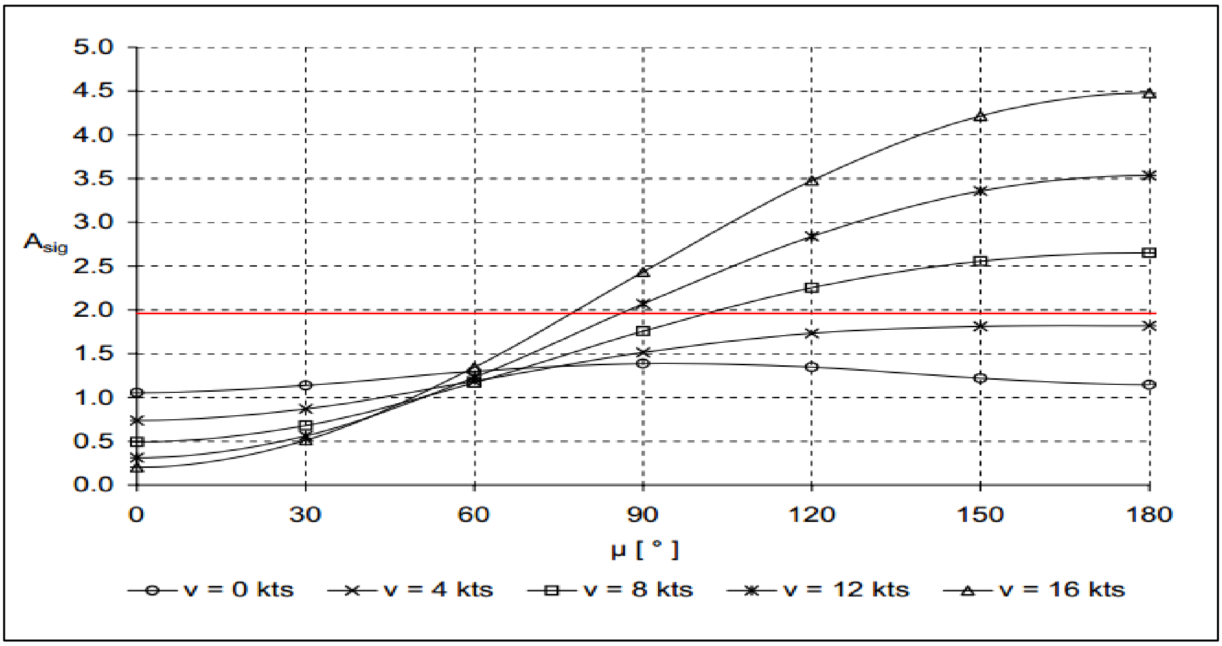


Figure 5-68 HSVA Significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.8.5 Vertical acceleration at saloon (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

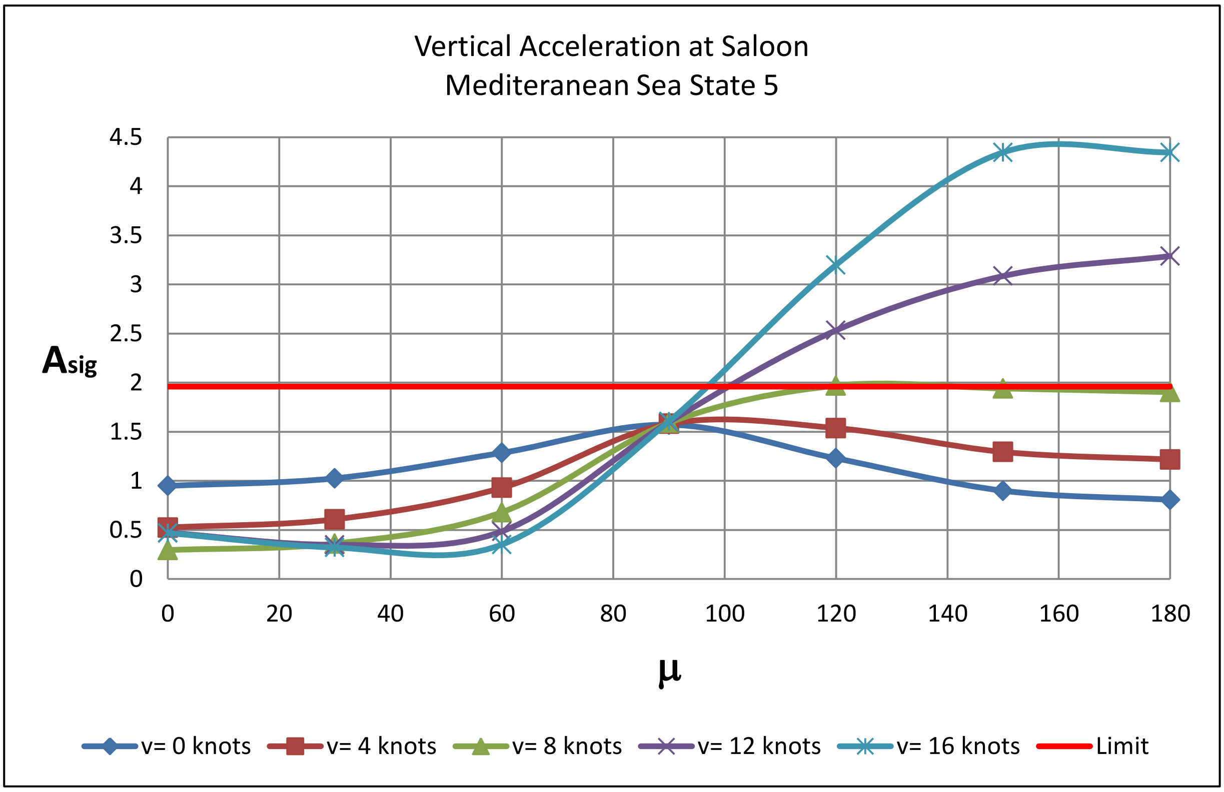


Figure 5-69 Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

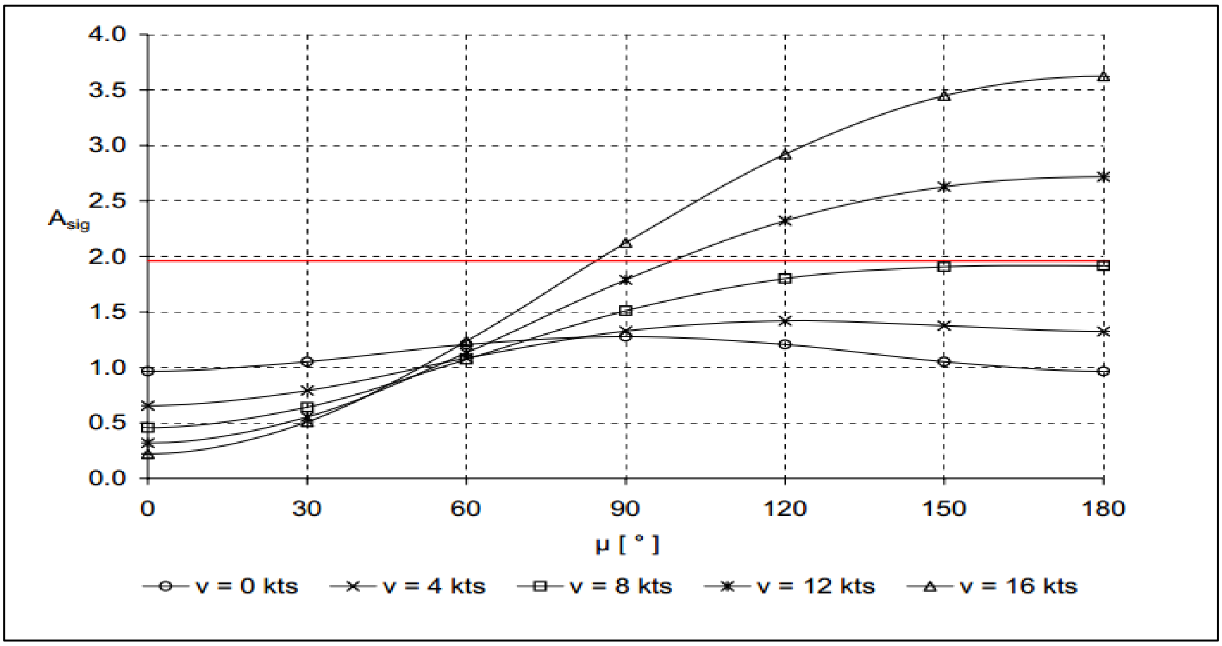


Figure 5-70 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.8.6 Lateral acceleration at bridge (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.15g

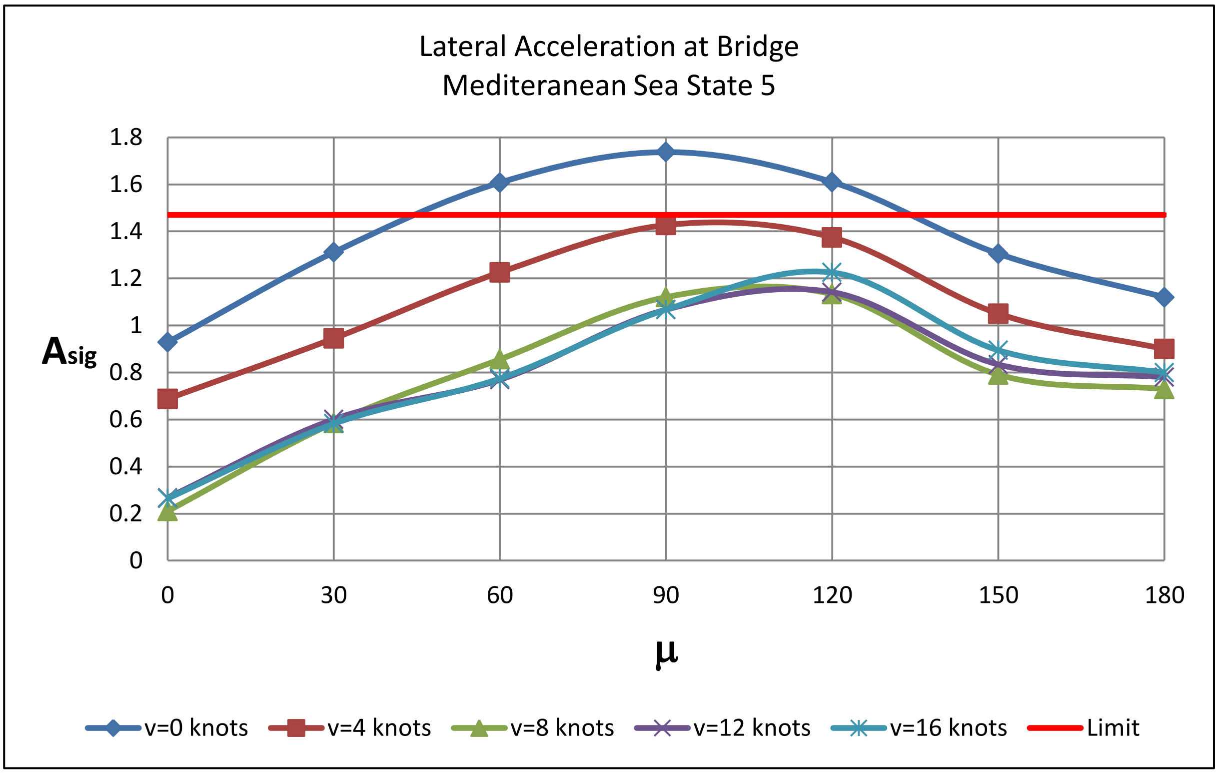


Figure 5-71 Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

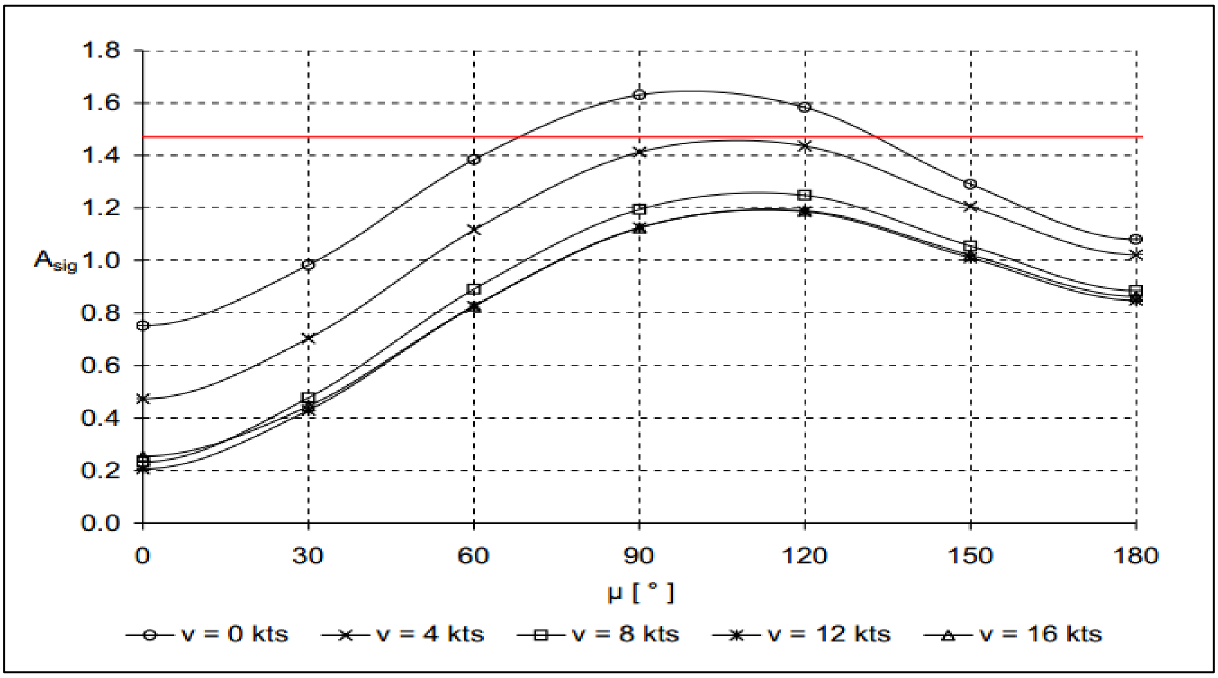


Figure 5-72 HSVA Significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.9 53 m and 46 m motor yacht Responses to Irregular Waves

5.10 Aegean Sea State 3

5.10.1 Roll Motion (Aegean Sea State 3)

Performance Criteria Significant roll motion amplitude <= 6 degree

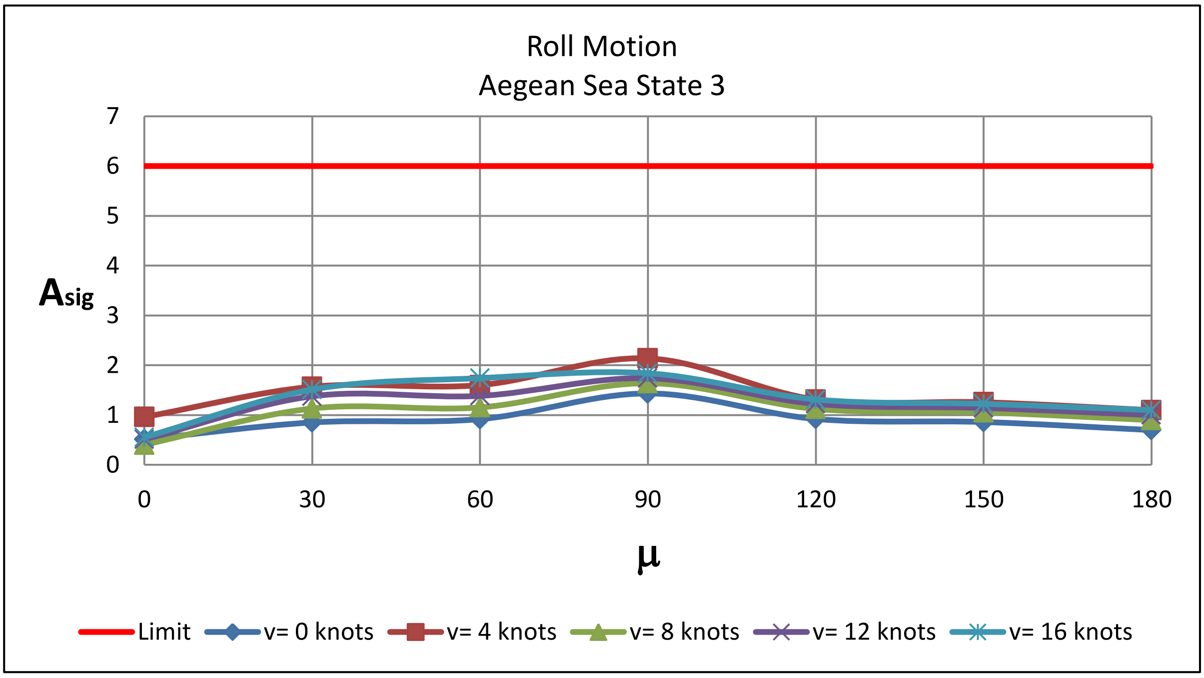


Figure 5-73 53 m motor yacht significant roll motion amplitude

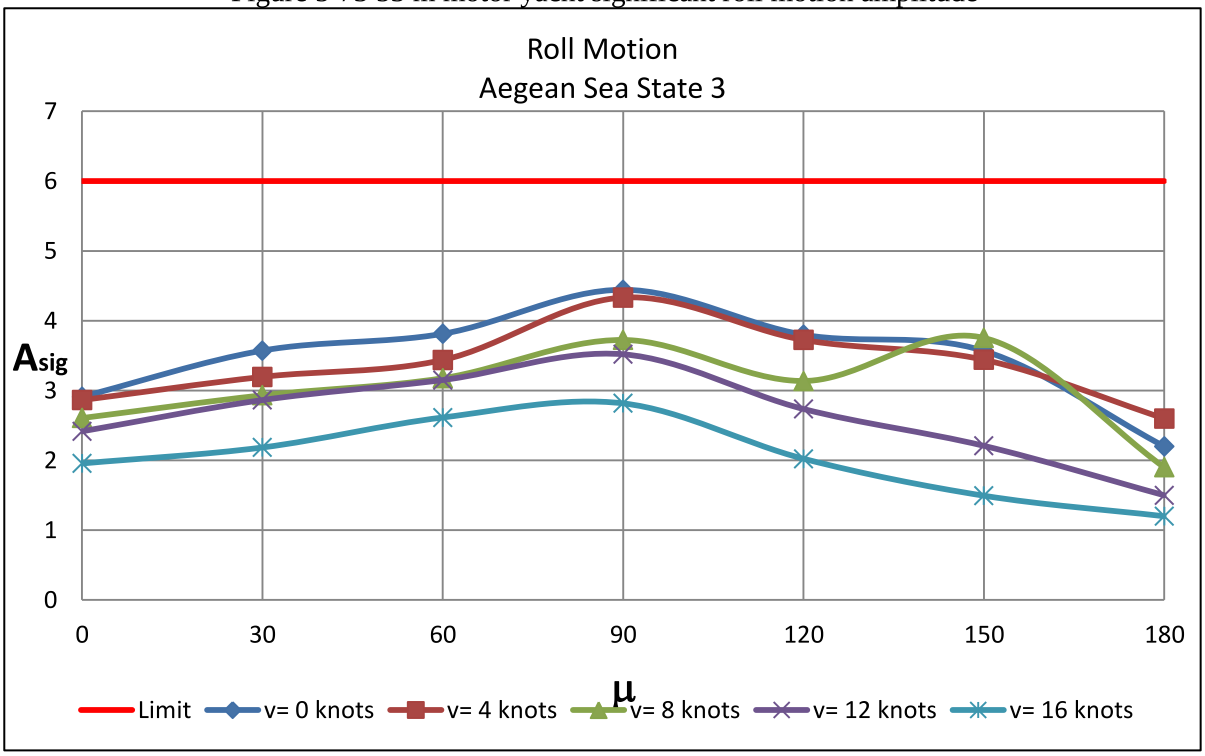


Figure 5-74 46 m motor yacht significant roll motion amplitude

5.10.2 Pitch Motion (Aegean Sea State 3)

Performance Criteria | Significant pitch motion amplitude <= 3 degree

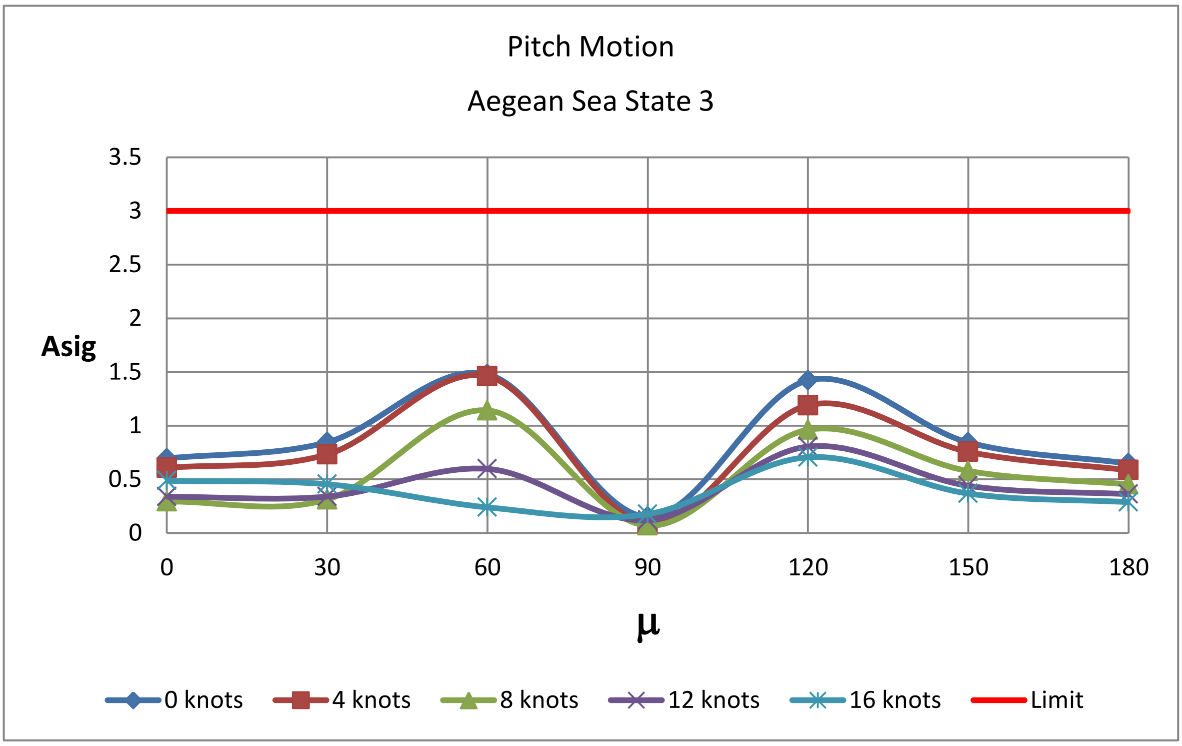


Figure 5-75 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

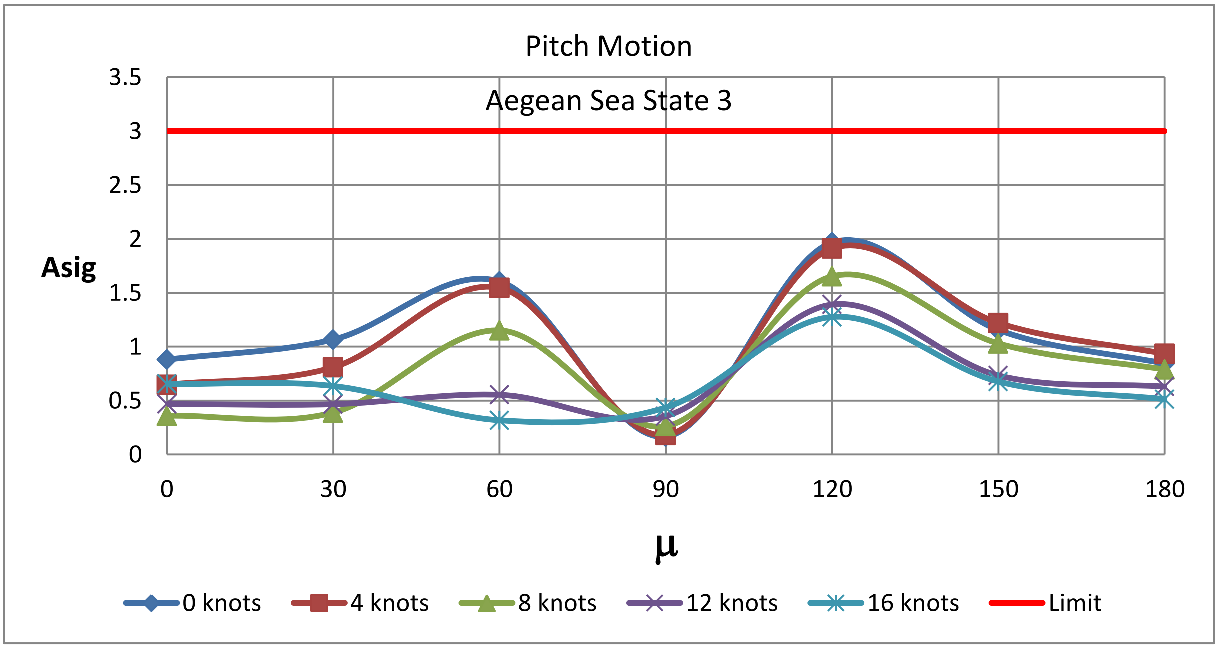


Figure 5-76 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.10.3 Vertical acceleration at owner's cabin (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

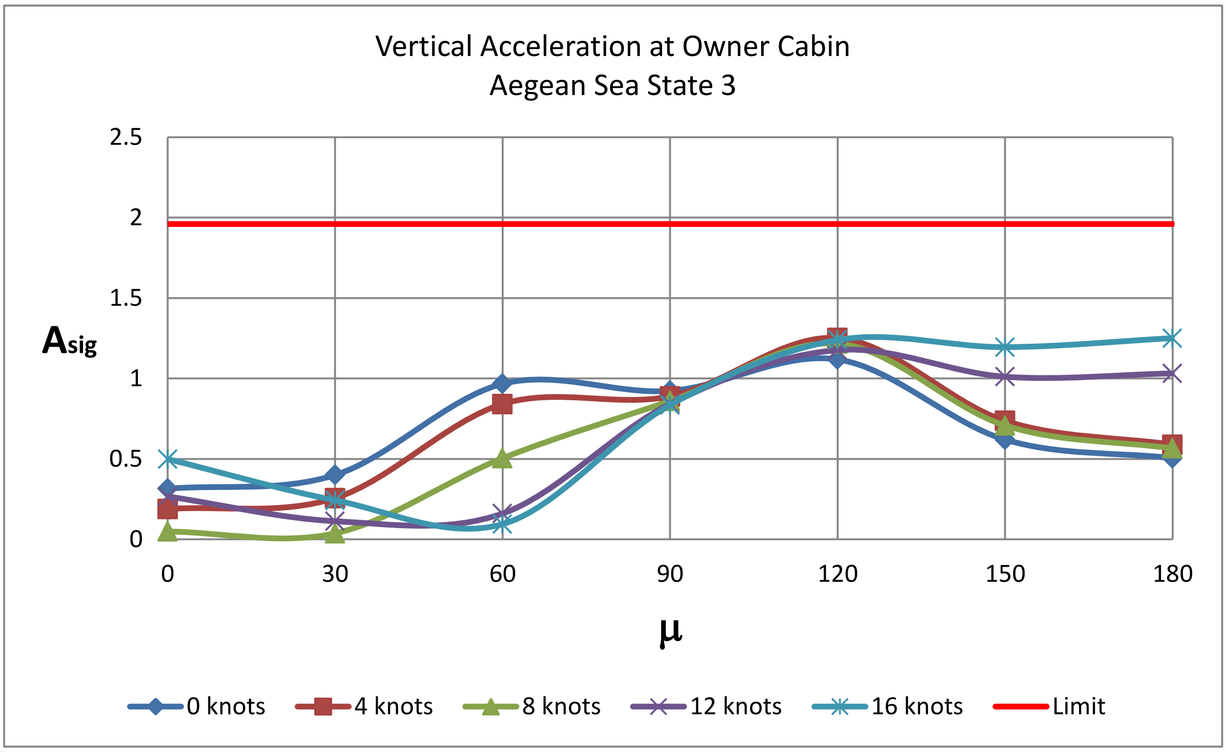


Figure 5-77 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

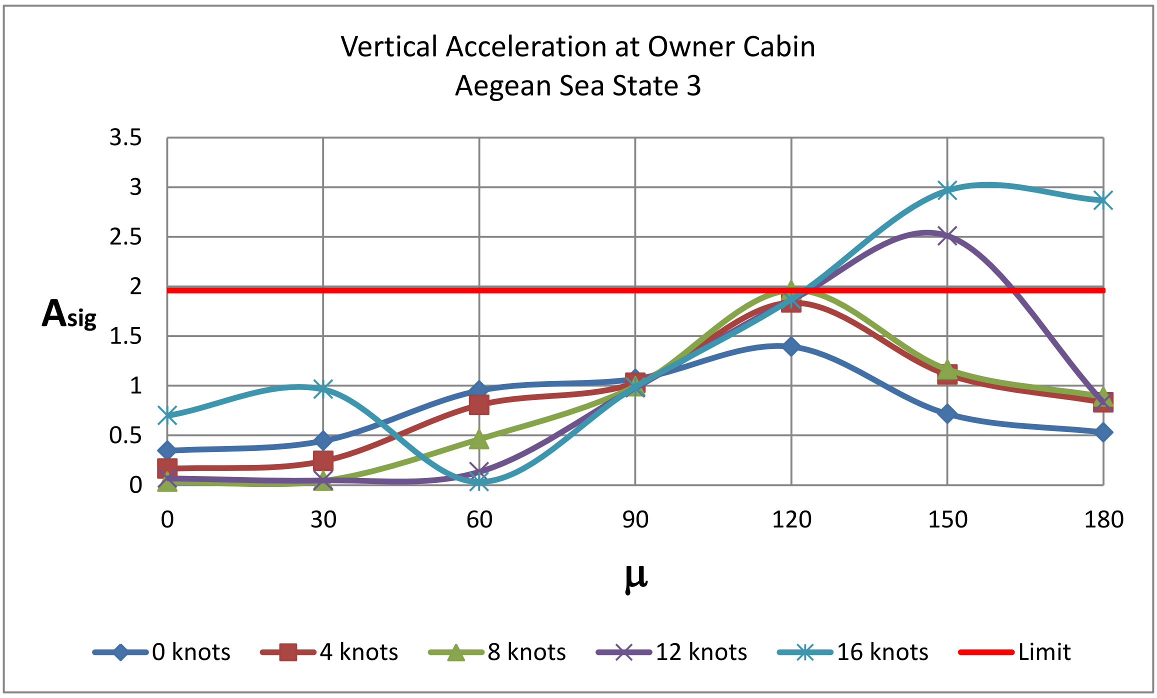


Figure 5-78 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.10.4 Vertical acceleration at bridge (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

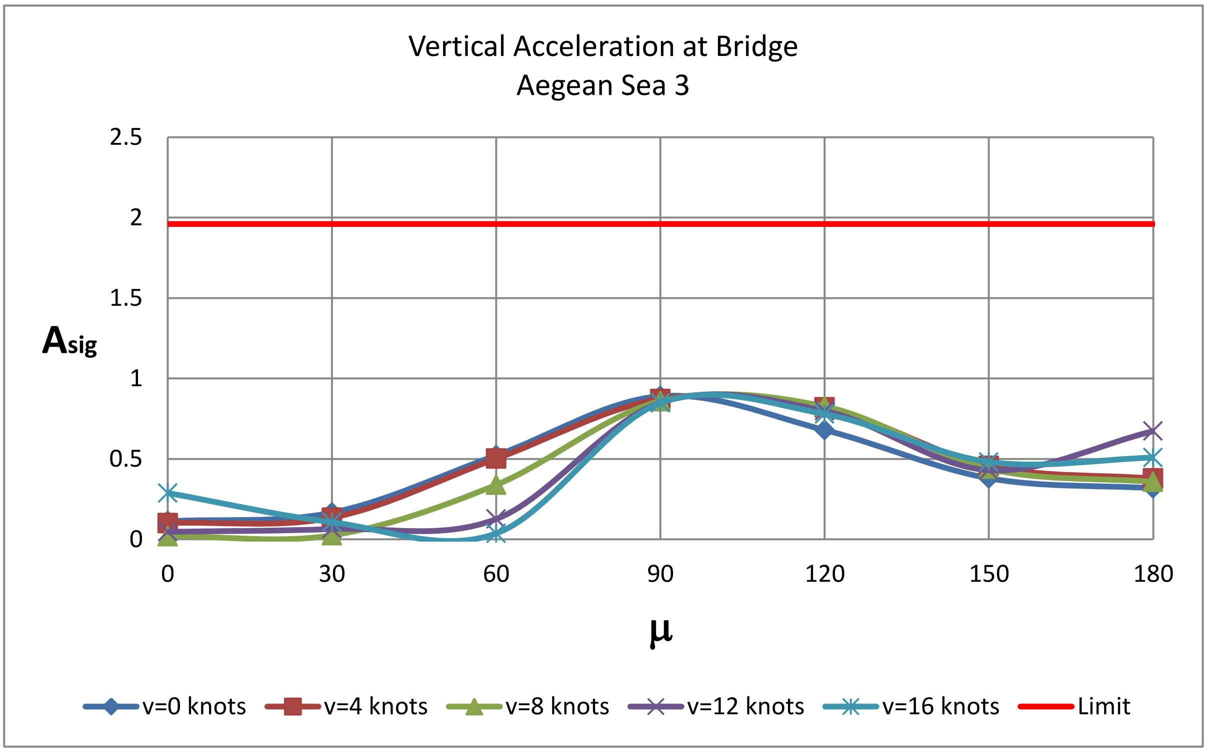


Figure 5-79 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

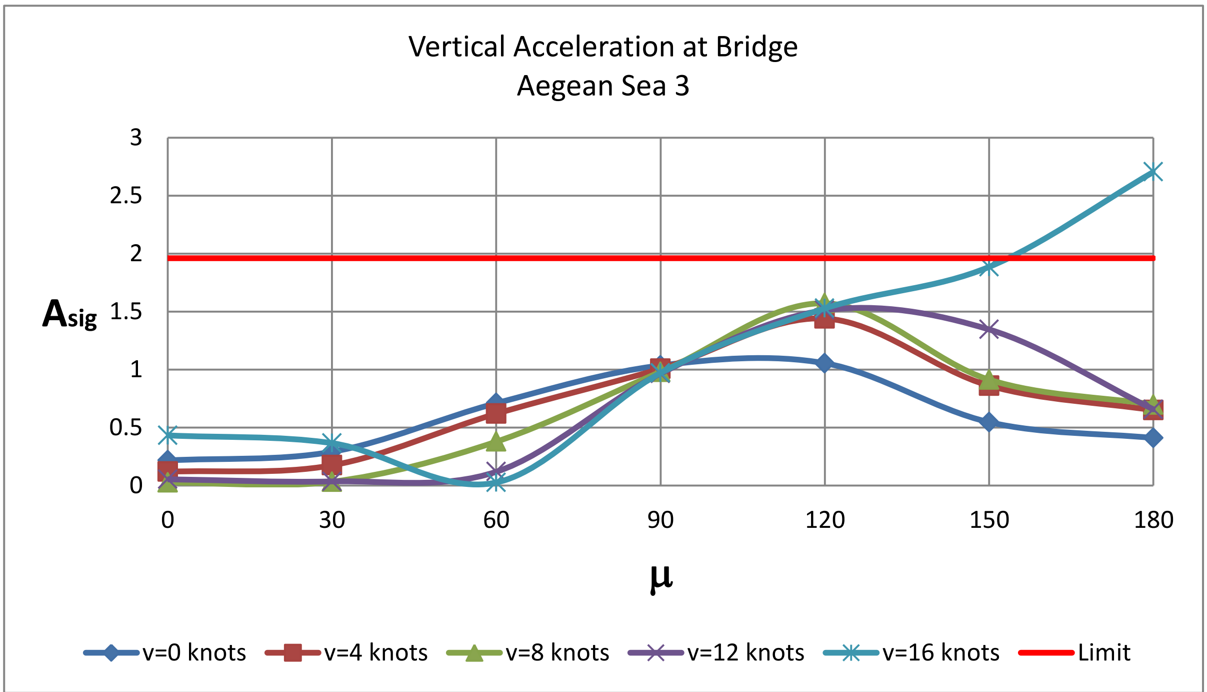


Figure 5-80 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.10.5 Vertical acceleration at saloon (Aegean Sea State 3)

Performance Criteria — Significant acceleration amplitude <= 0.2g

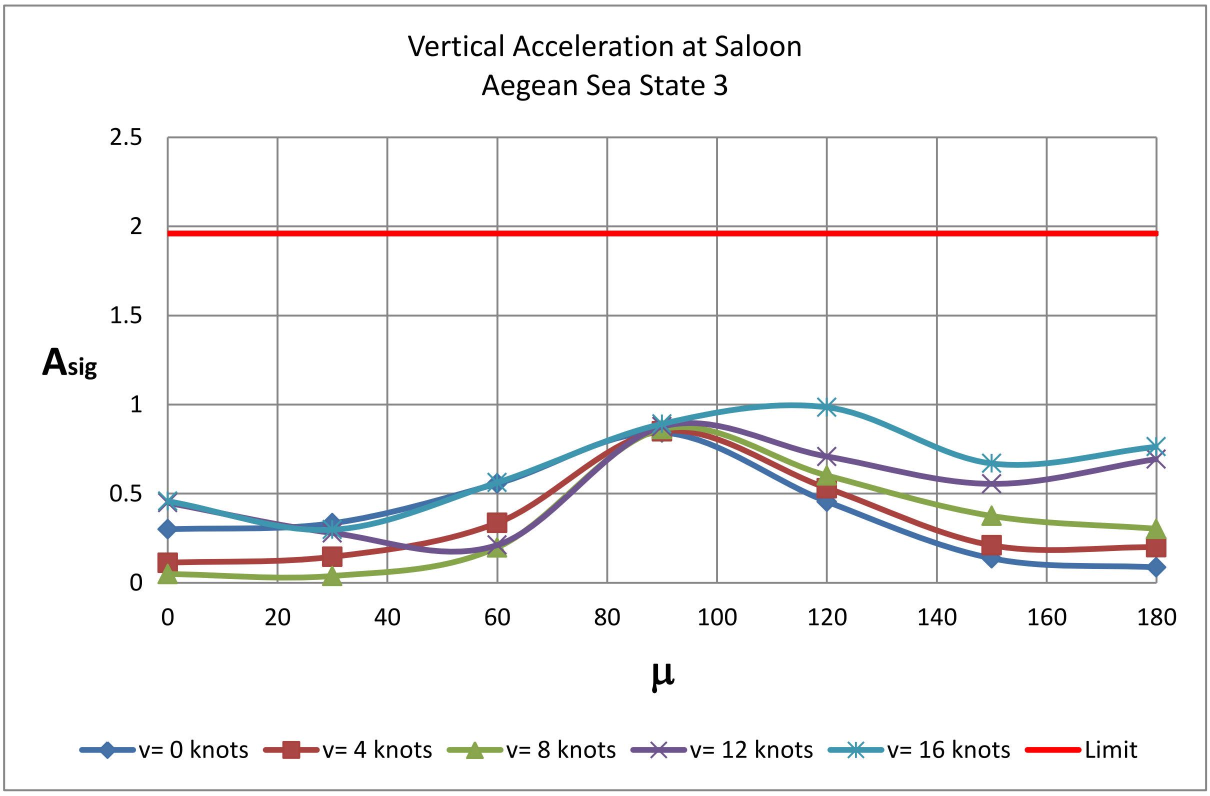


Figure 5-81 53 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

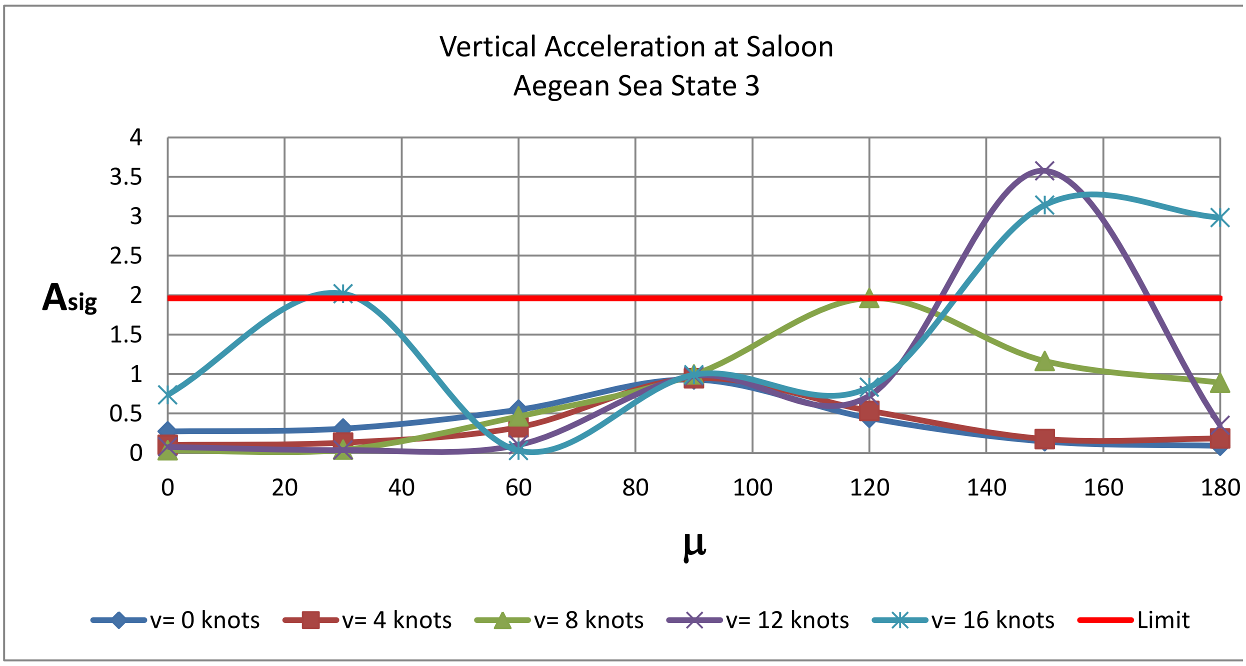


Figure 5-82 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.10.6 Lateral acceleration at bridge (Aegean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.15g

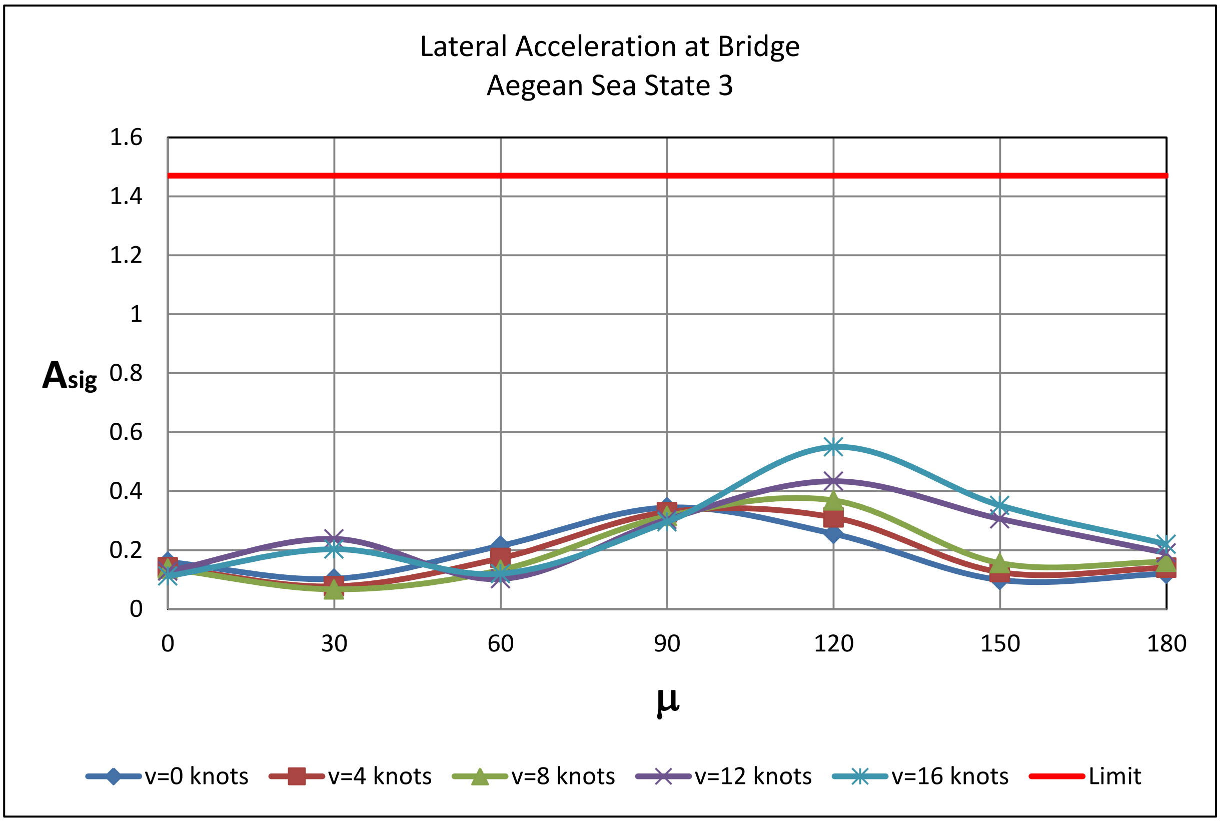


Figure 5-83 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

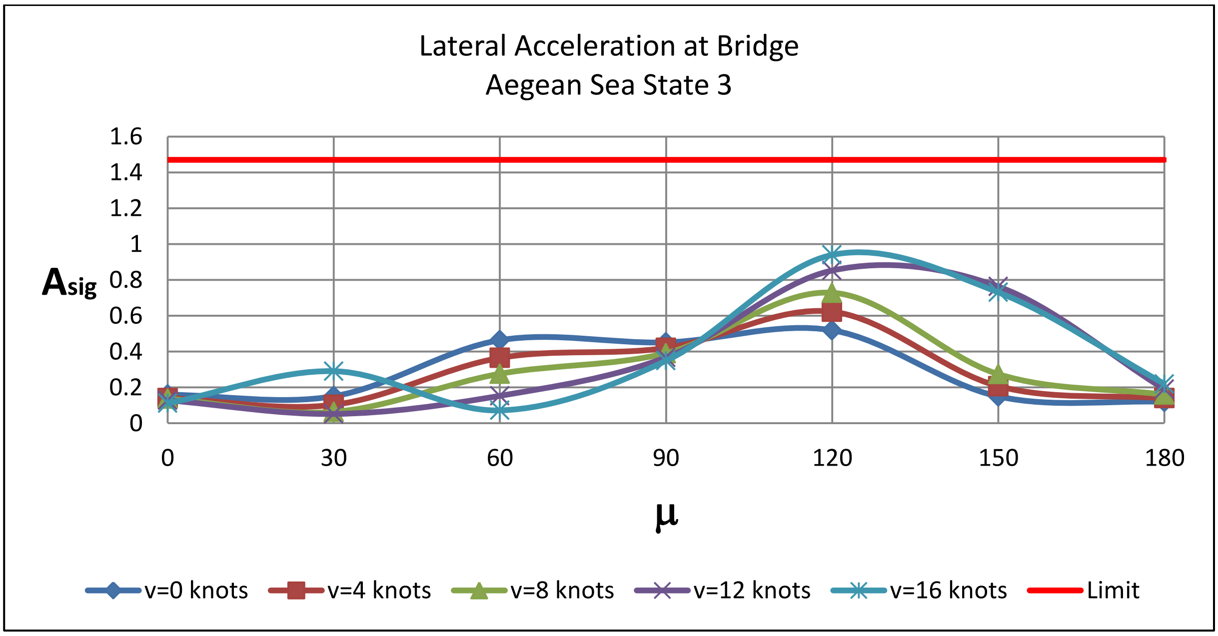


Figure 5-84 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s

5.11 Mediterranean Sea State 3

5.11.1 Roll Motion (Mediterranean Sea State 3)

Performance Criteria Significant roll motion amplitude <= 6 degree

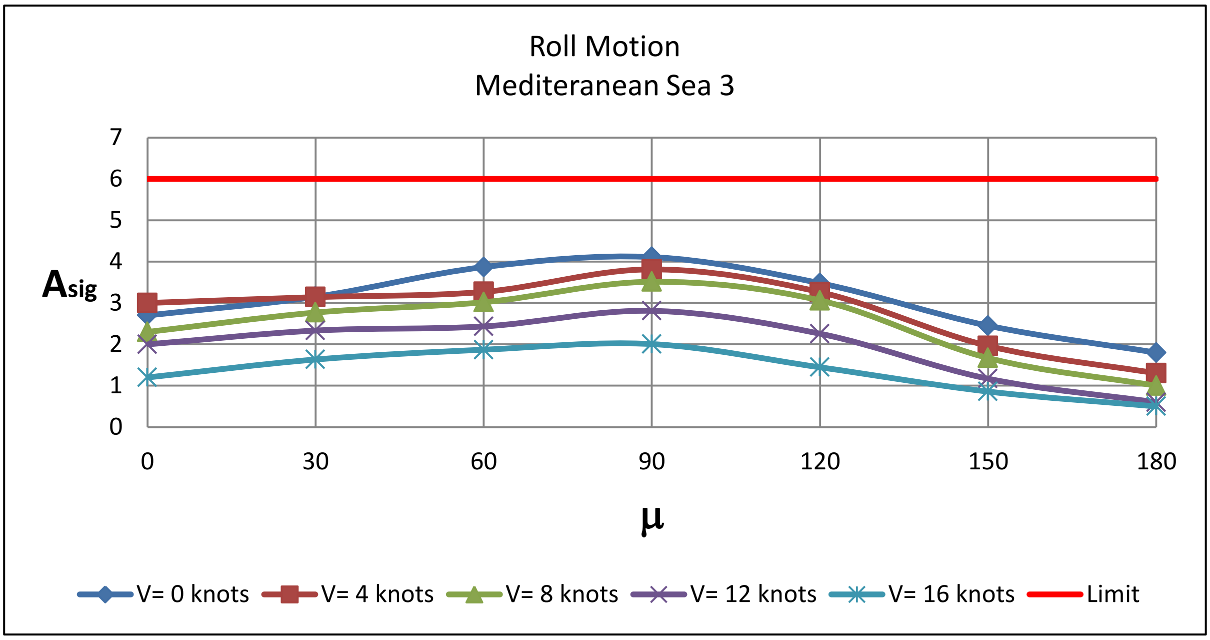


Figure 5-85 53 m motor yacht significant roll motion amplitude

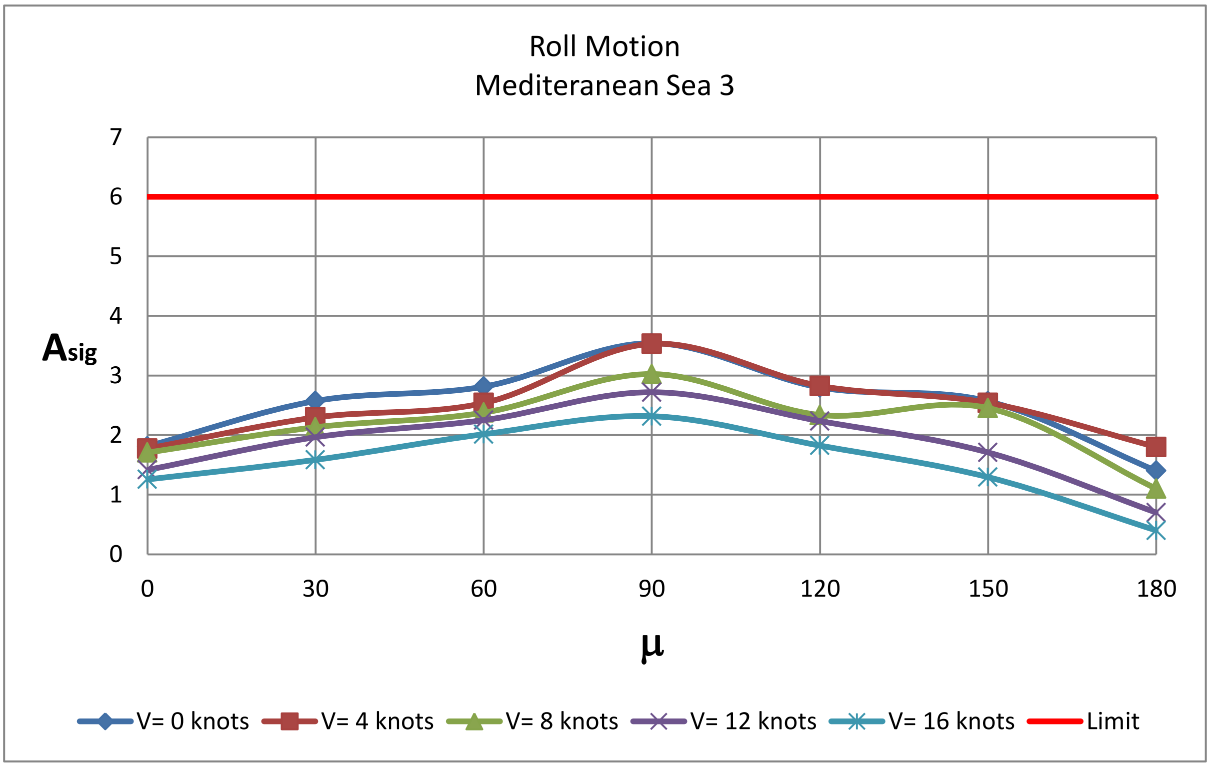


Figure 5-86 46 m motor yacht significant roll motion amplitude

5.11.2 Pitch Motion (Mediterranean Sea State 3)

Performance Criteria Significant pitch motion amplitude <= 3 degree

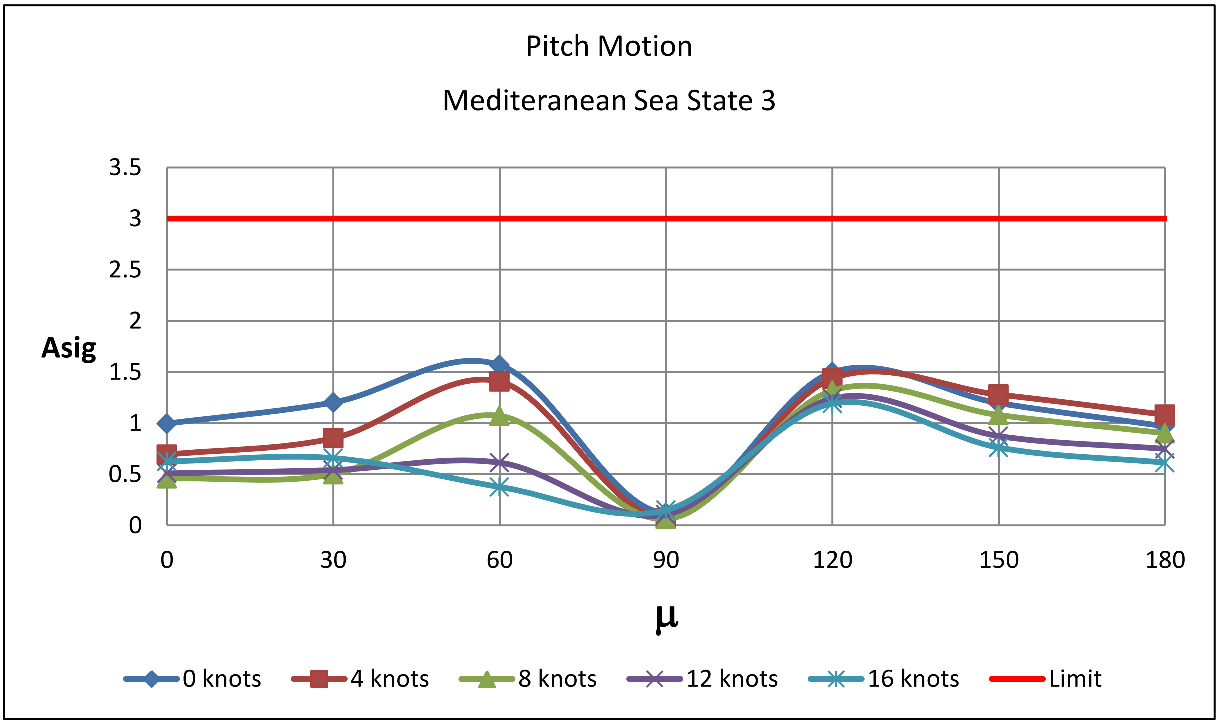


Figure 5-87 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

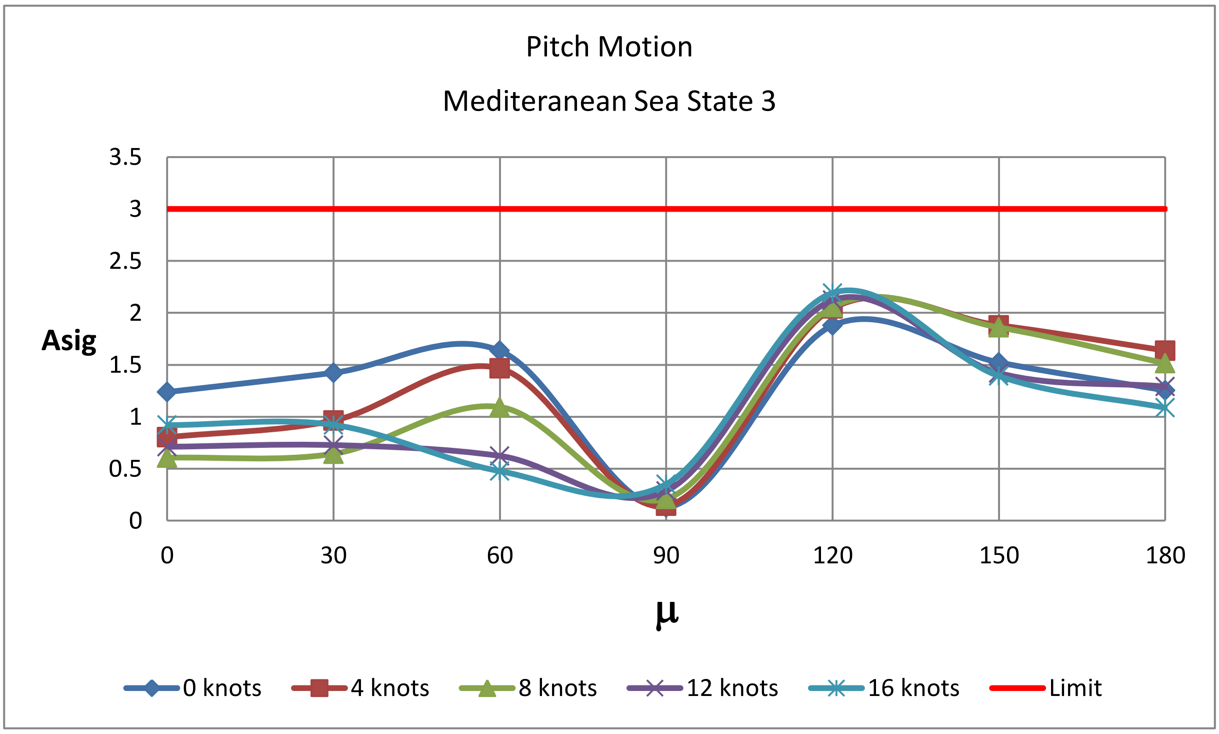


Figure 5-88 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.11.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 3)

Performance Criteria   Significant acceleration amplitude <= 0.2g

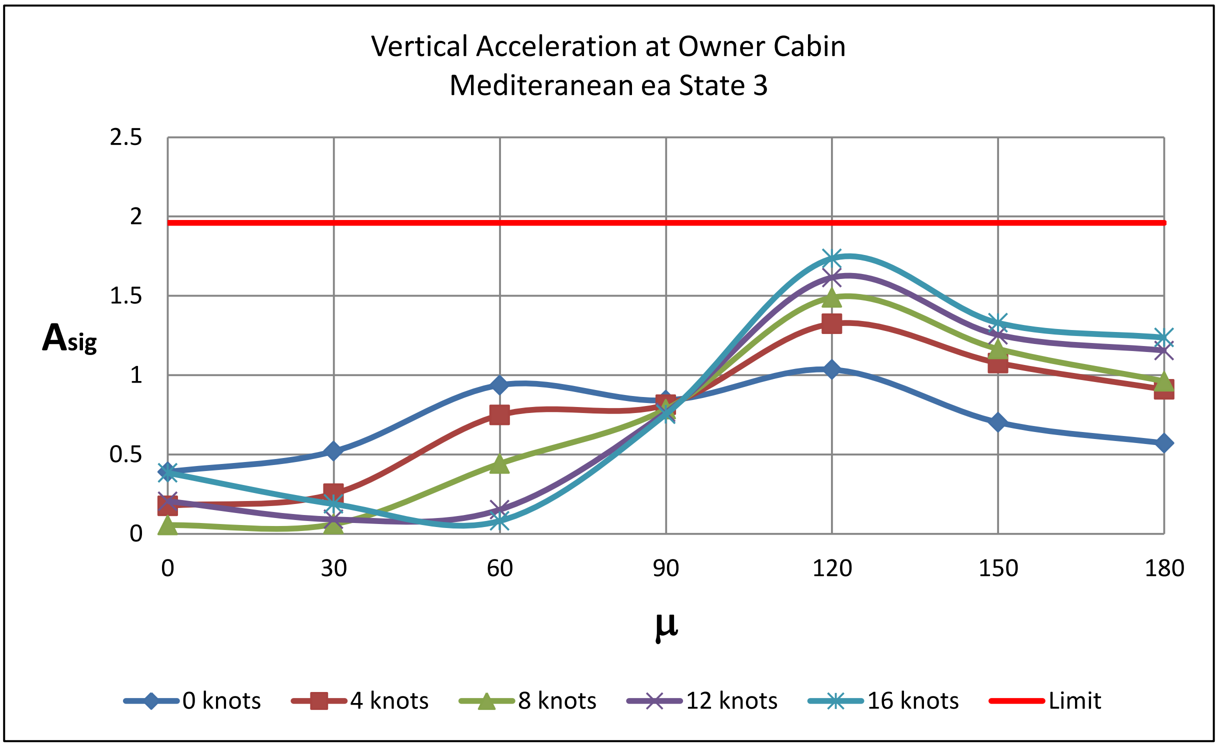


Figure 5-89 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

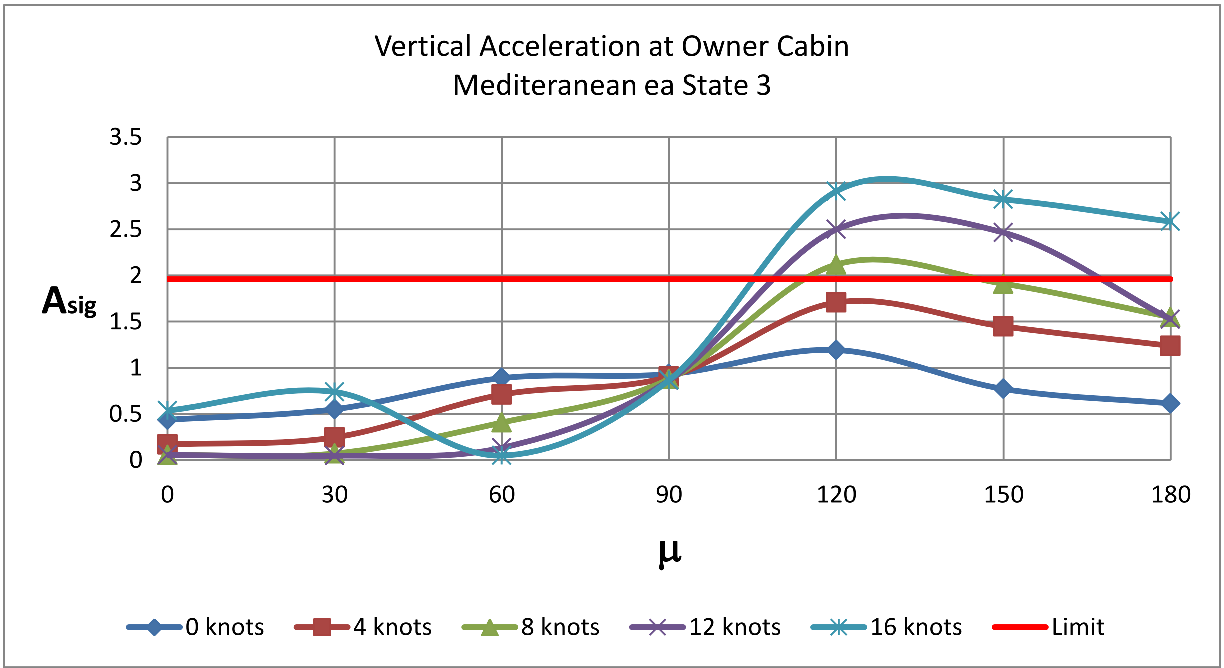


Figure 5-90 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.11.4 Vertical acceleration at bridge (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

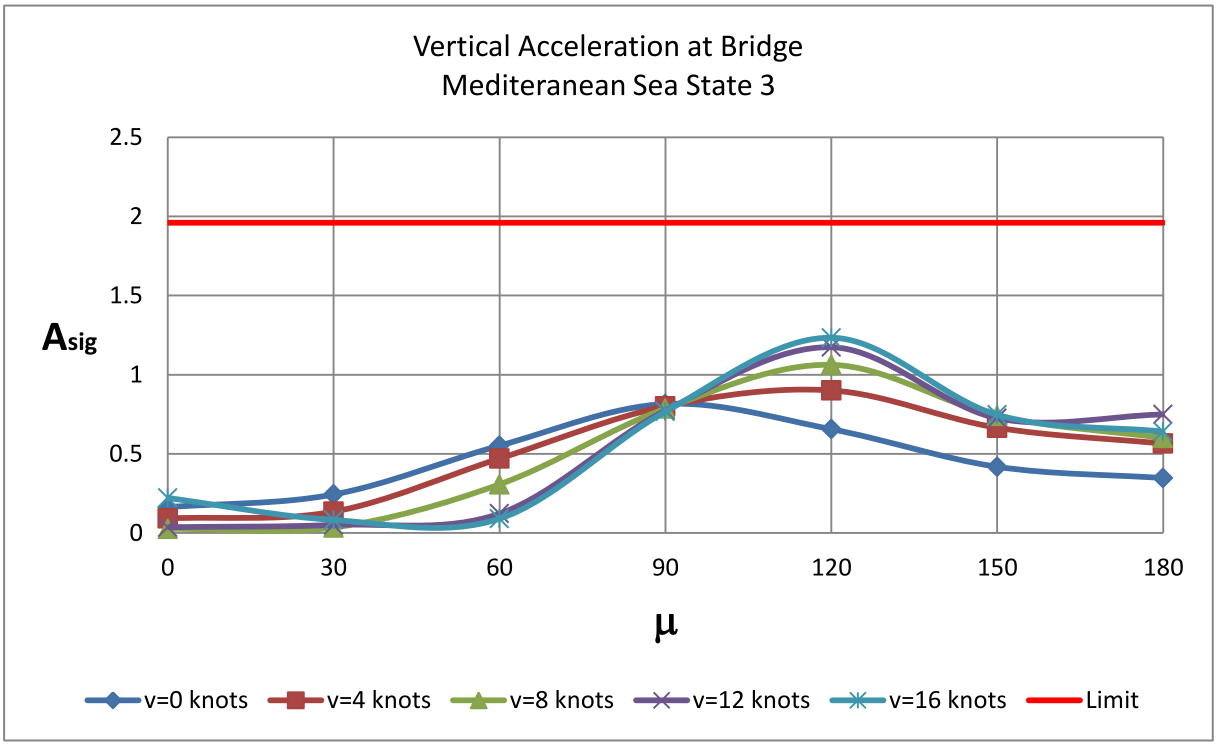


Figure 5-91 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

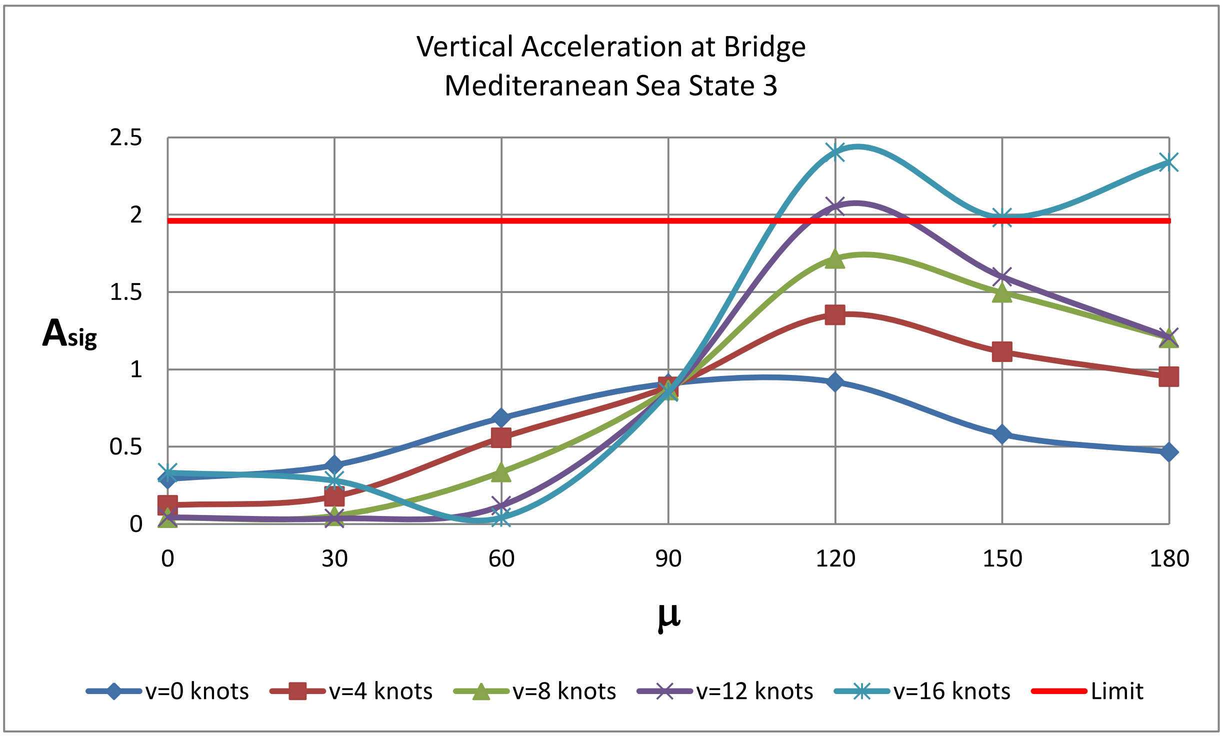


Figure 5-92 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.11.5 Vertical acceleration at saloon (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.2g

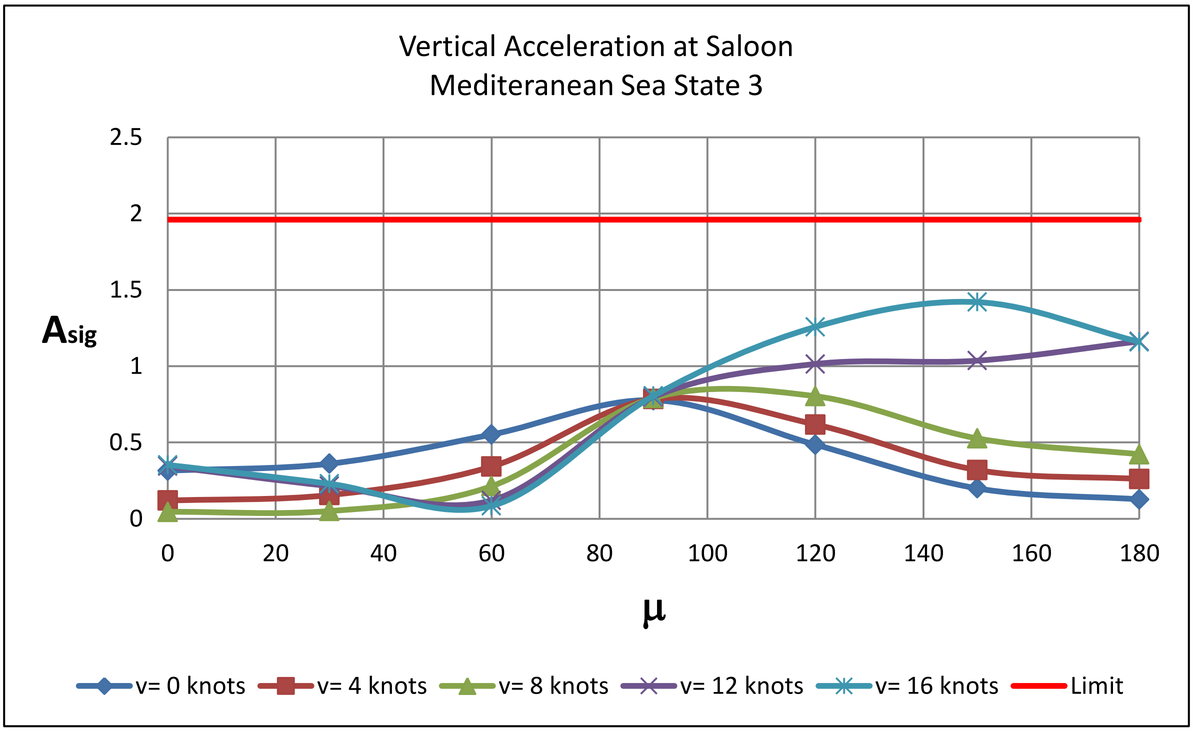


Figure 5-93 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

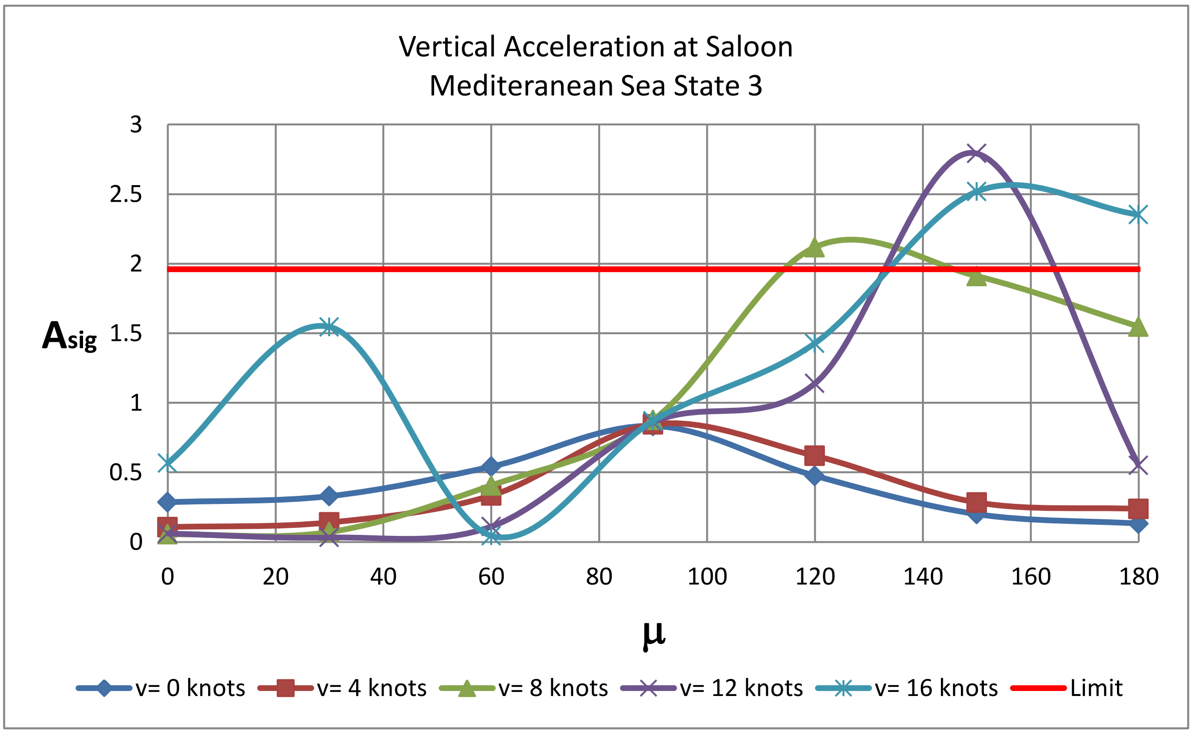


Figure 5-94 HSVA Significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.11.6 Lateral acceleration at bridge (Mediterranean Sea State 3)

Performance Criteria Significant acceleration amplitude <= 0.15g

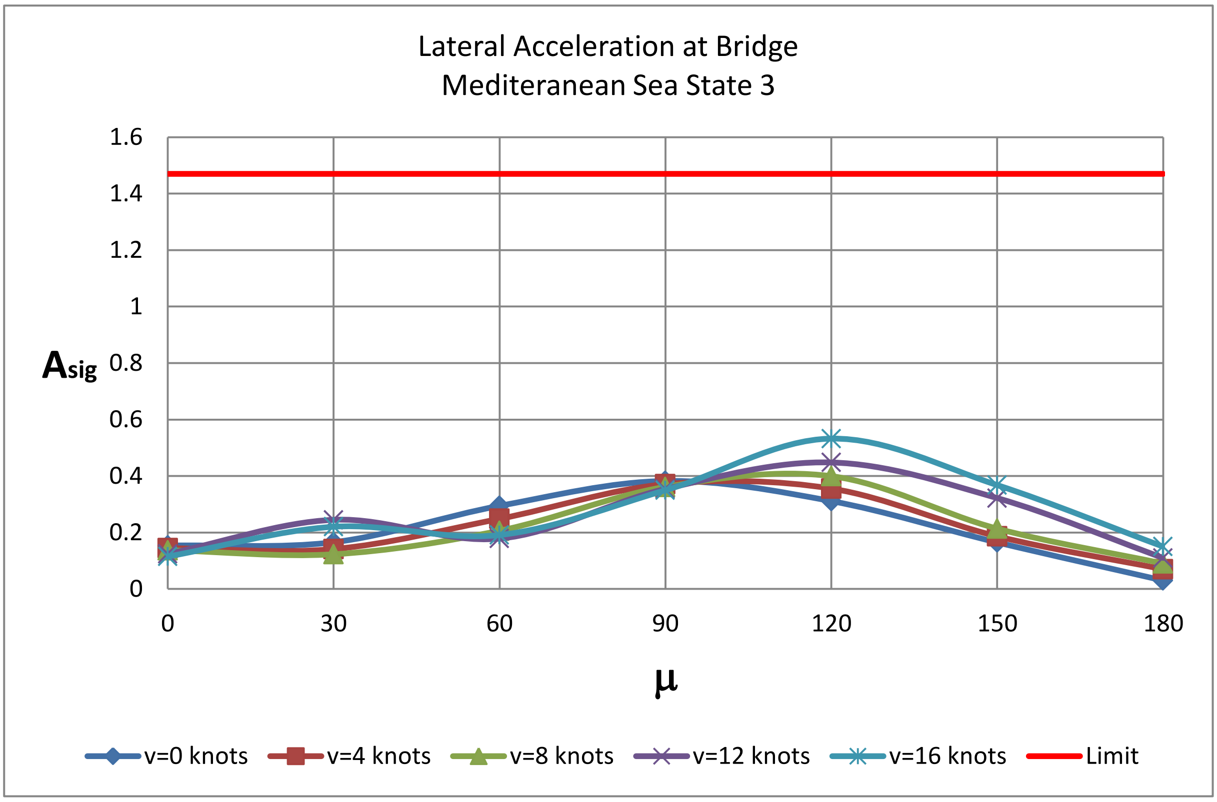


Figure 5-95 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

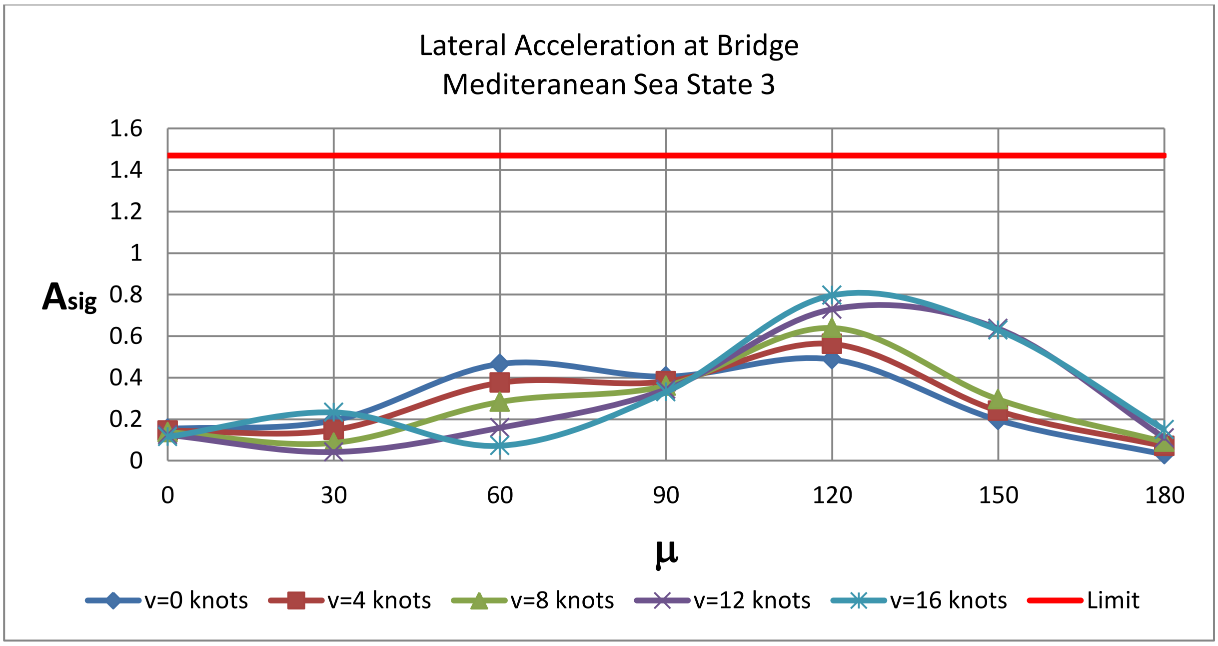


Figure 5-96 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.12 Aegean Sea State 4

5.12.1 Roll Motion (Aegean Sea State 4)

Performance Criteria Significant roll motion amplitude <= 6 degree

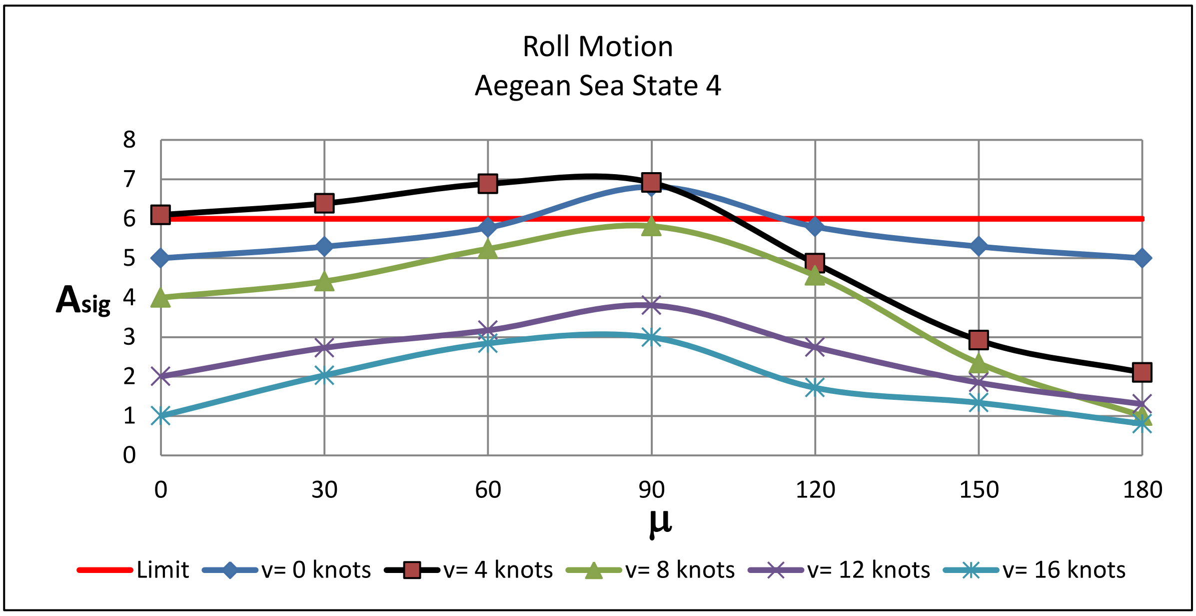


Figure 5-97 53 m motor yacht significant roll motion amplitude

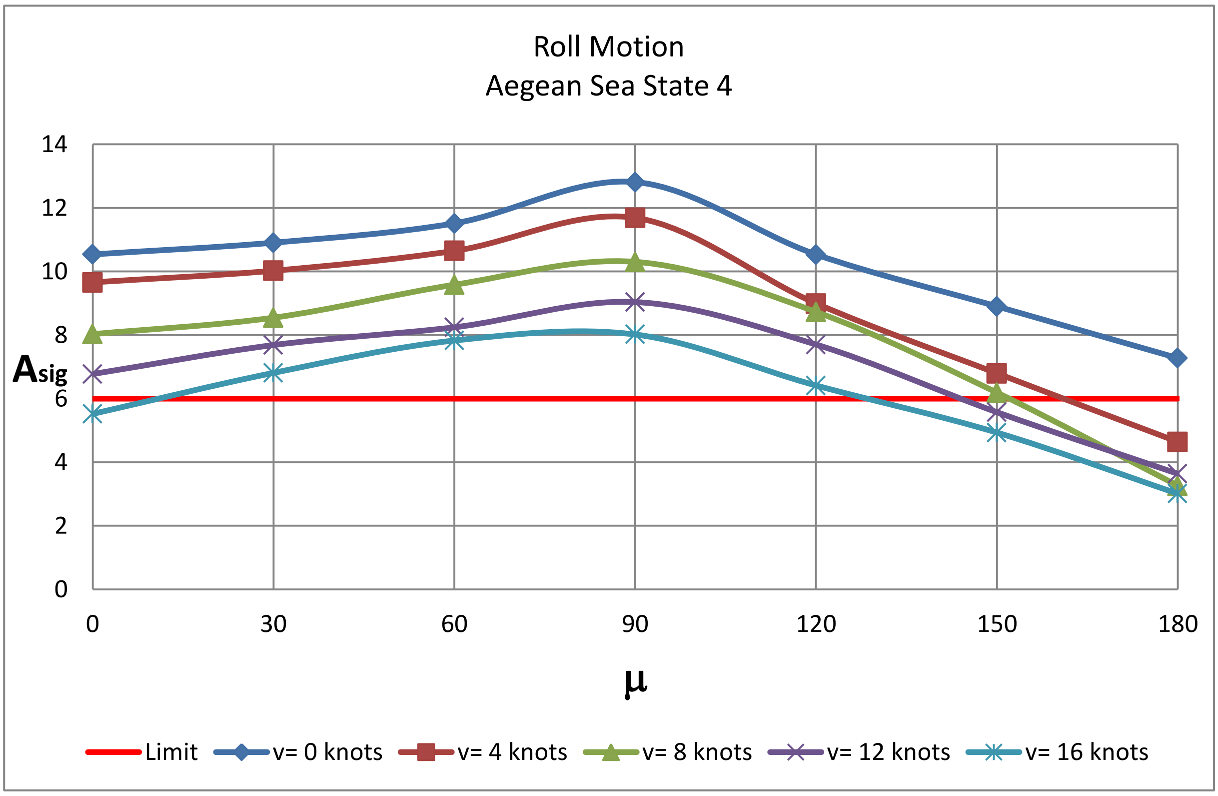


Figure 5-98 46 m motor yacht significant roll motion amplitude

5.12.2 Pitch Motion (Aegean Sea State 4)

Performance Criteria	Significant pitch motion amplitude <= 3 degree

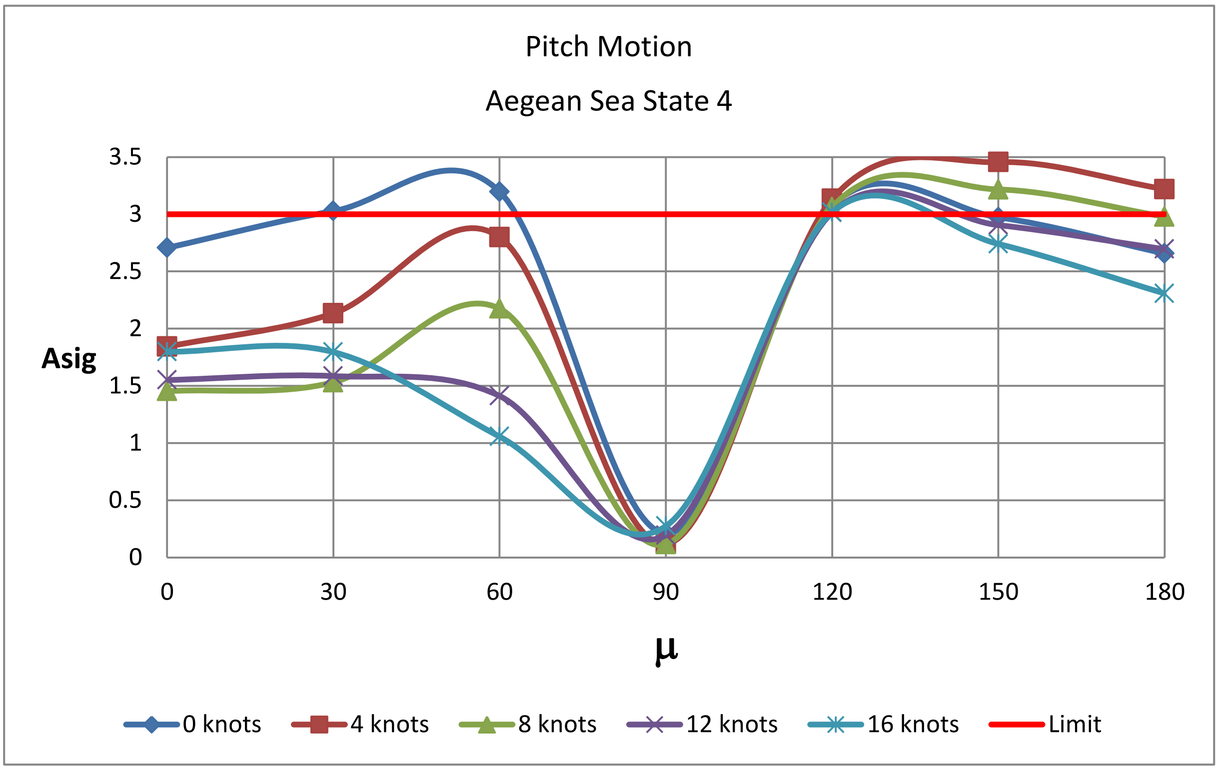


Figure 5-99 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

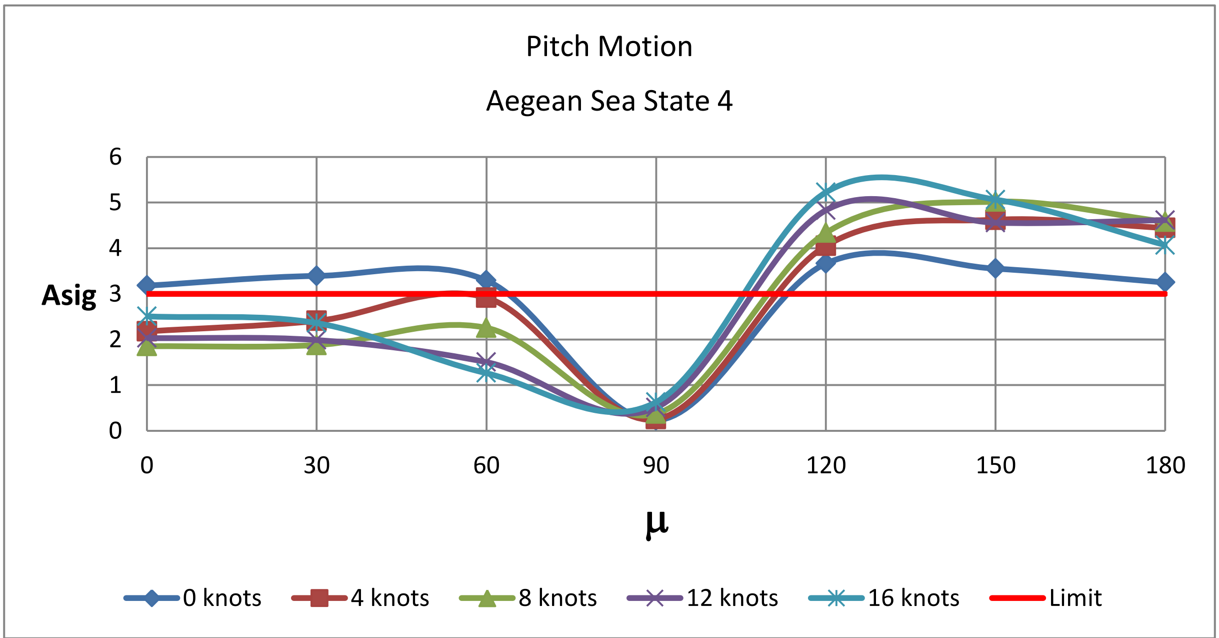


Figure 5-100 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.12.3 Vertical acceleration at owner's cabin (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

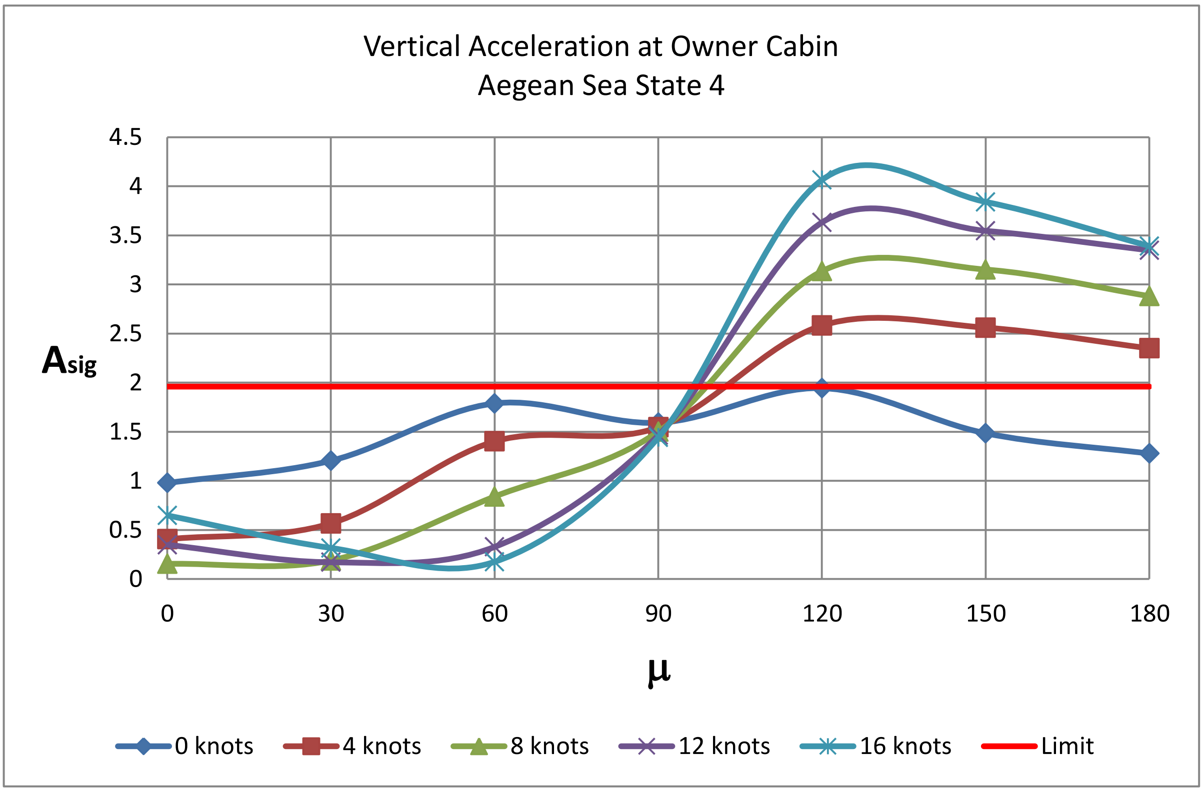


Figure 5-101 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

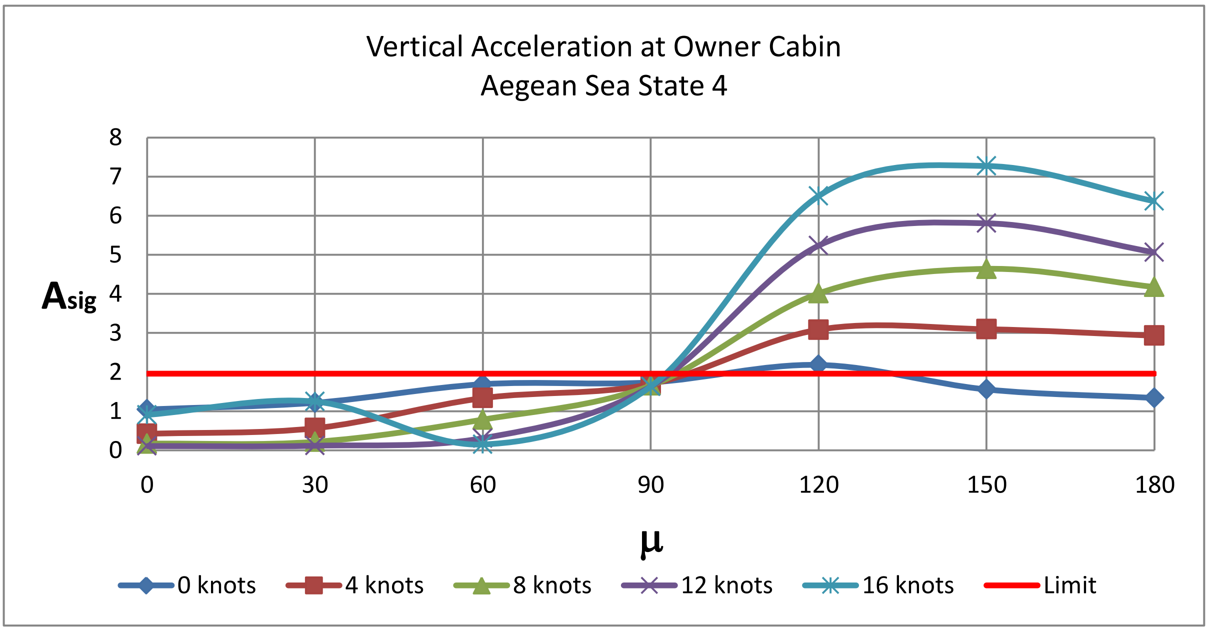


Figure 5-102 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.12.4 Vertical acceleration at bridge (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

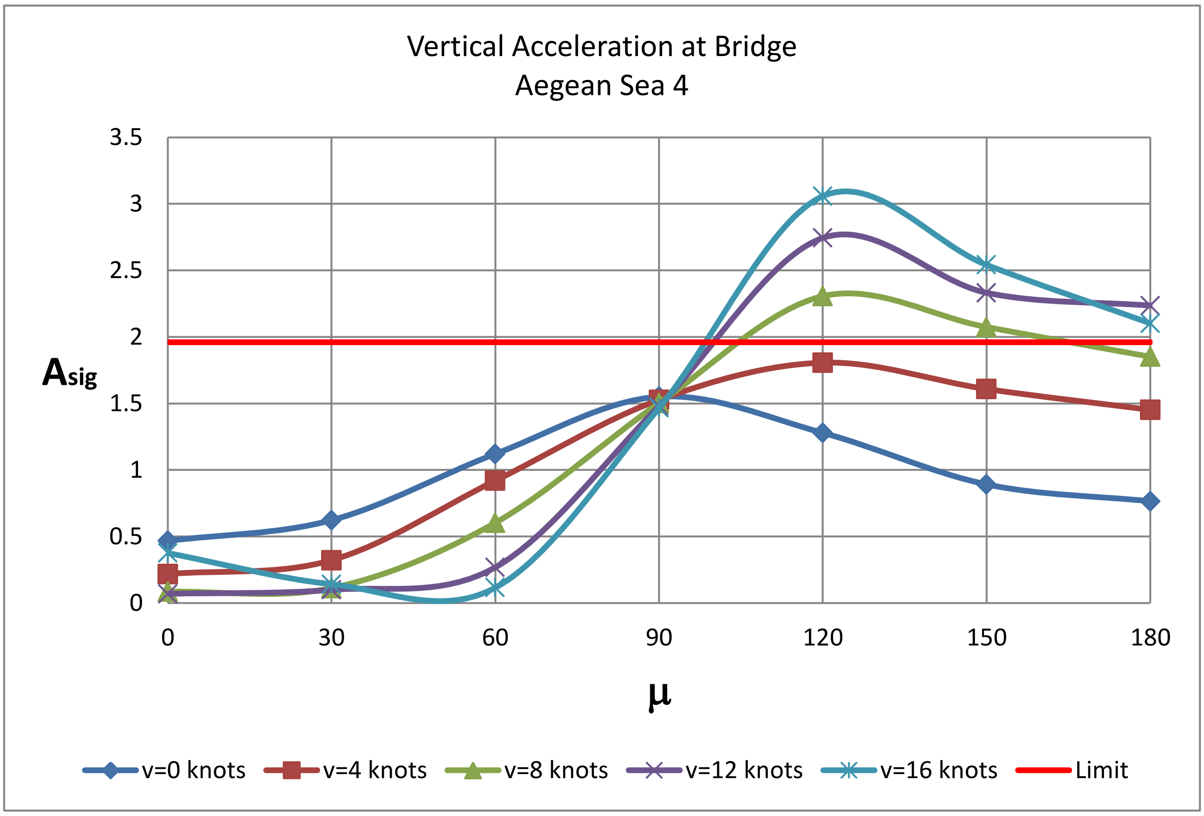


Figure 5-103 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

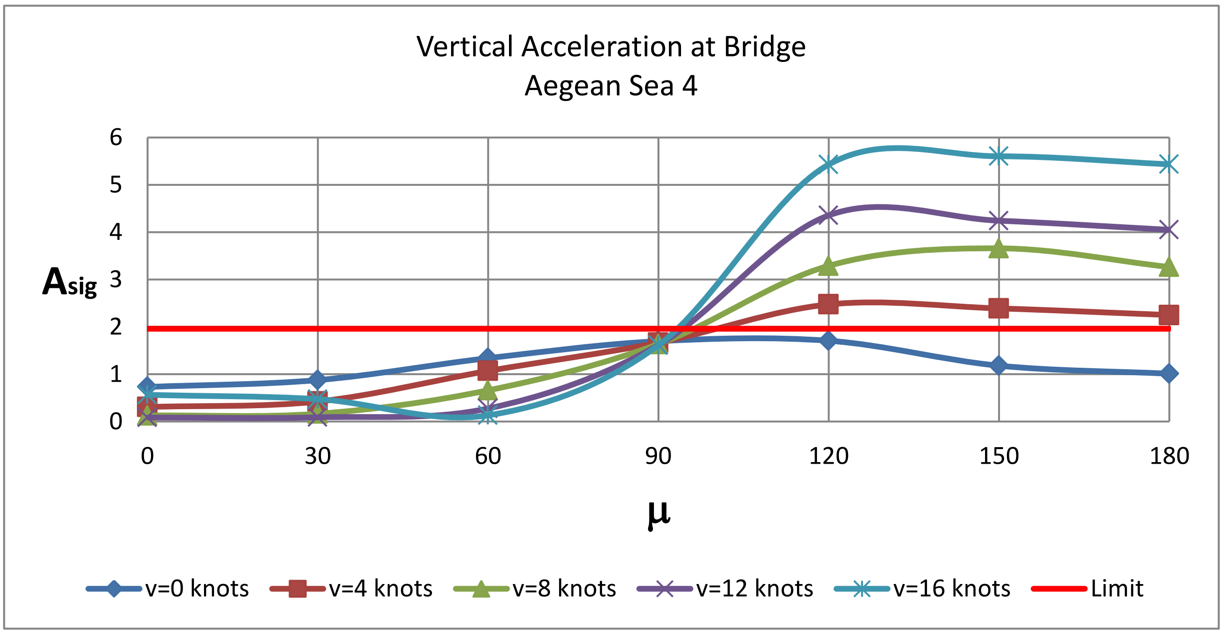


Figure 5-104 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.12.5 Vertical acceleration at saloon (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

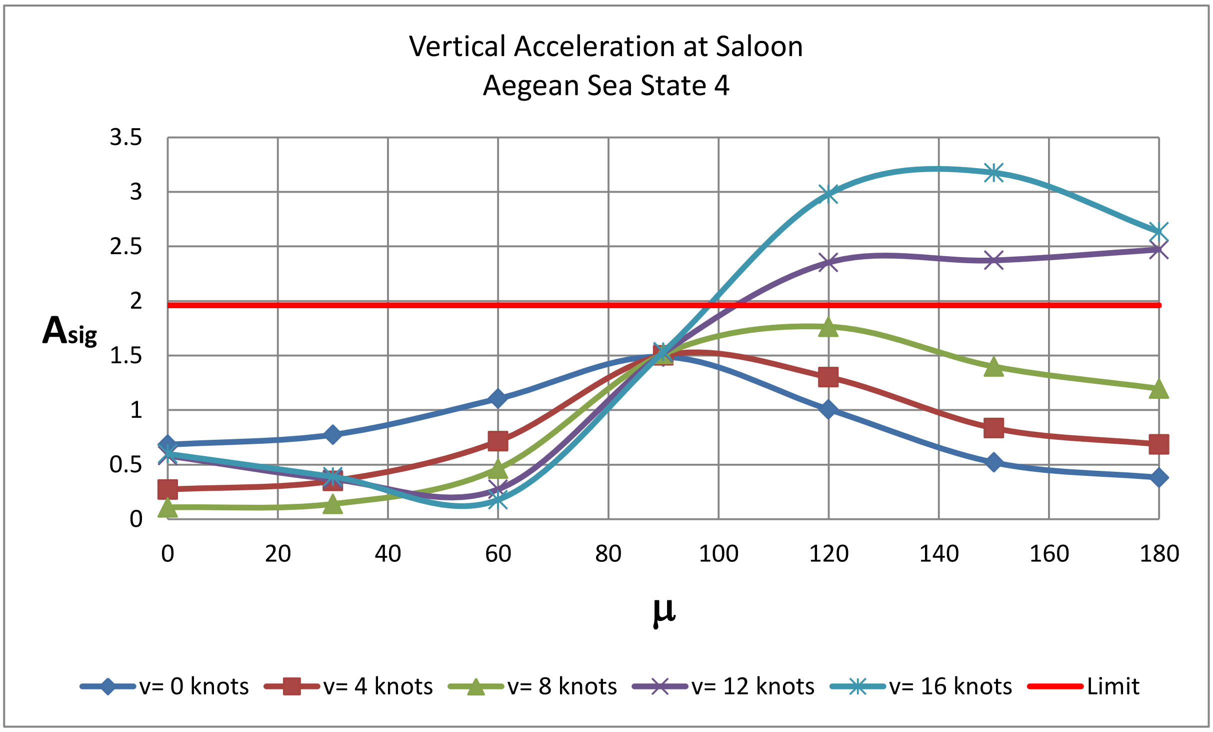


Figure 5-105 53 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

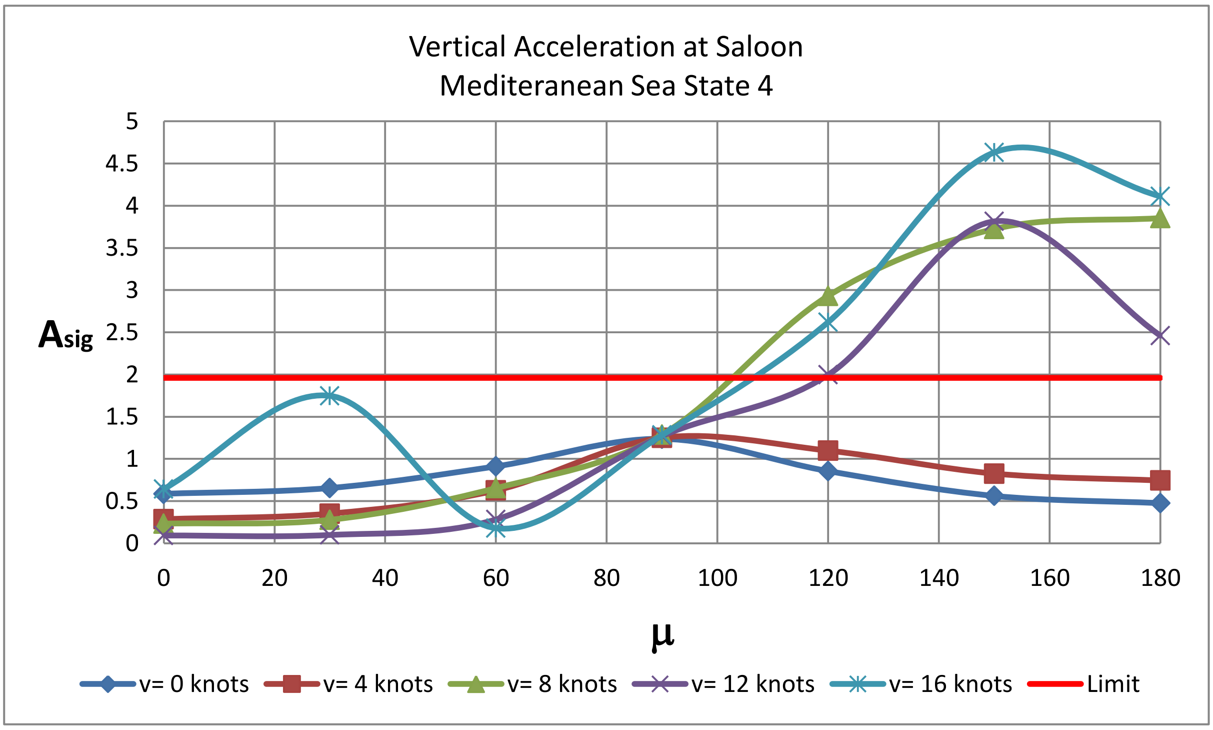


Figure 5-106 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.12.6 Lateral acceleration at bridge (Aegean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.15g

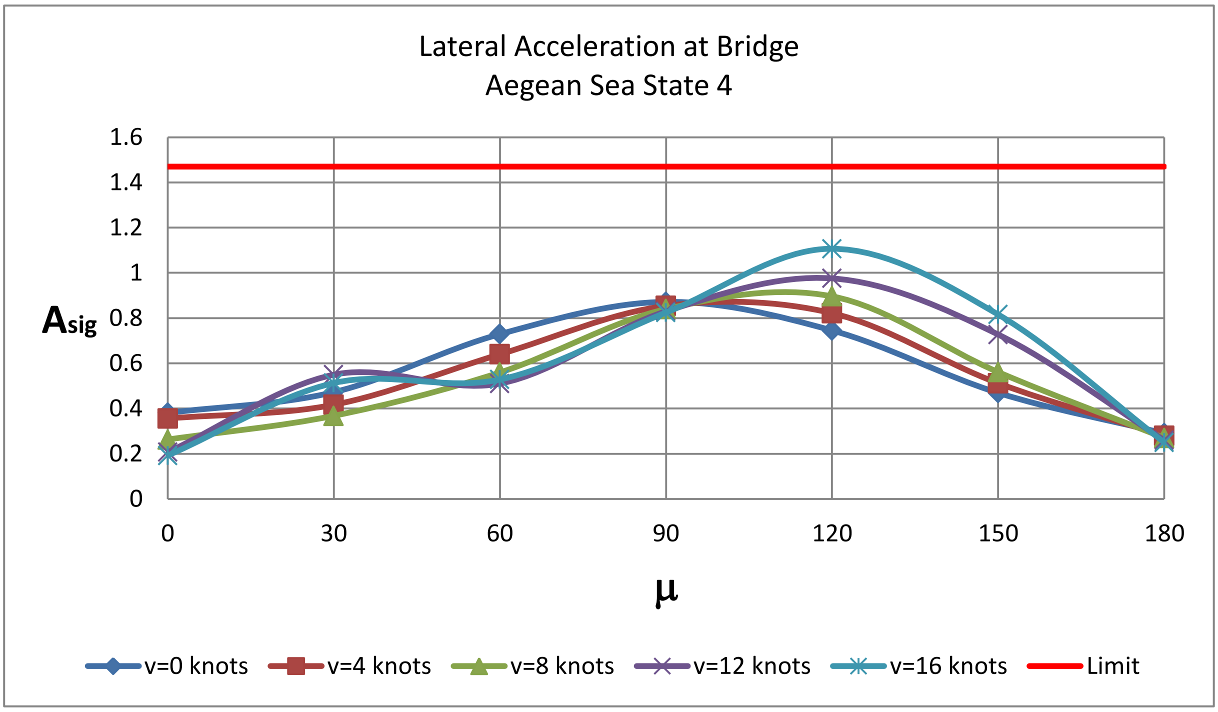


Figure 5-107 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

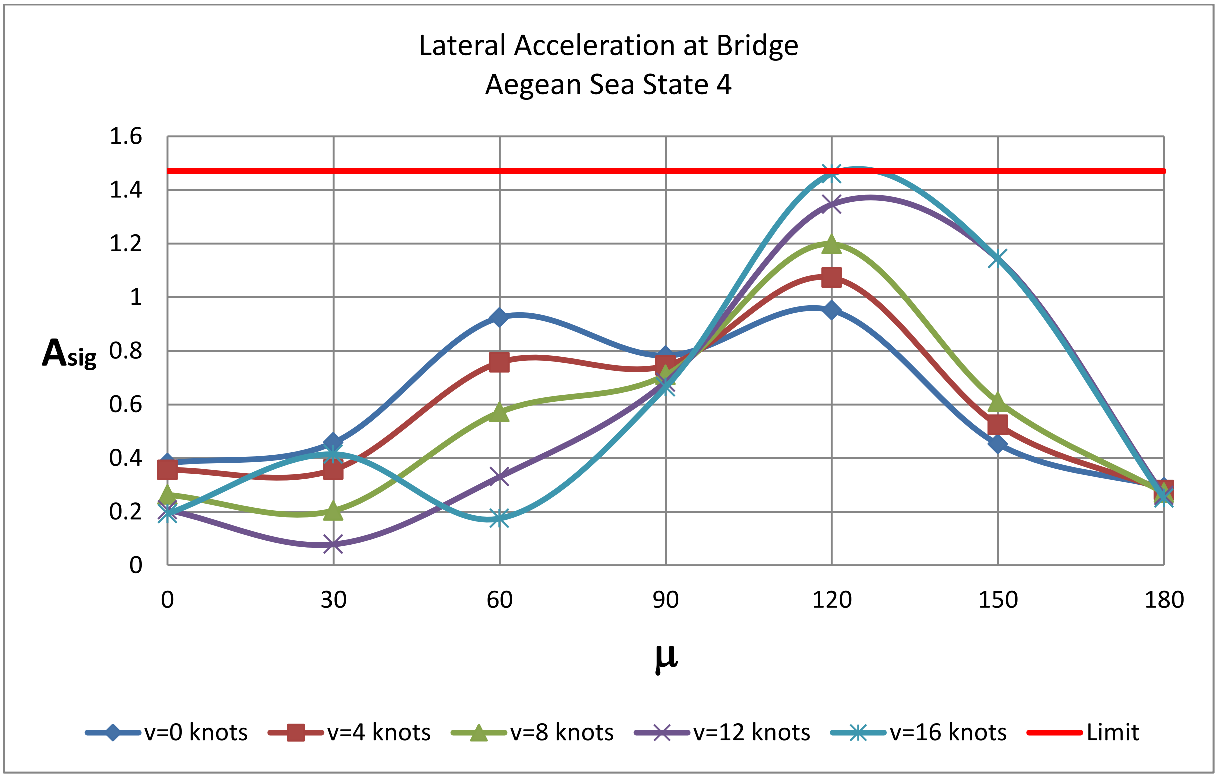


Figure 5-108 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.13 Mediterranean Sea State 4

5.13.1 Roll Motion (Mediterranean Sea State 4)

Performance Criteria Significant roll motion amplitude <= 6 degree

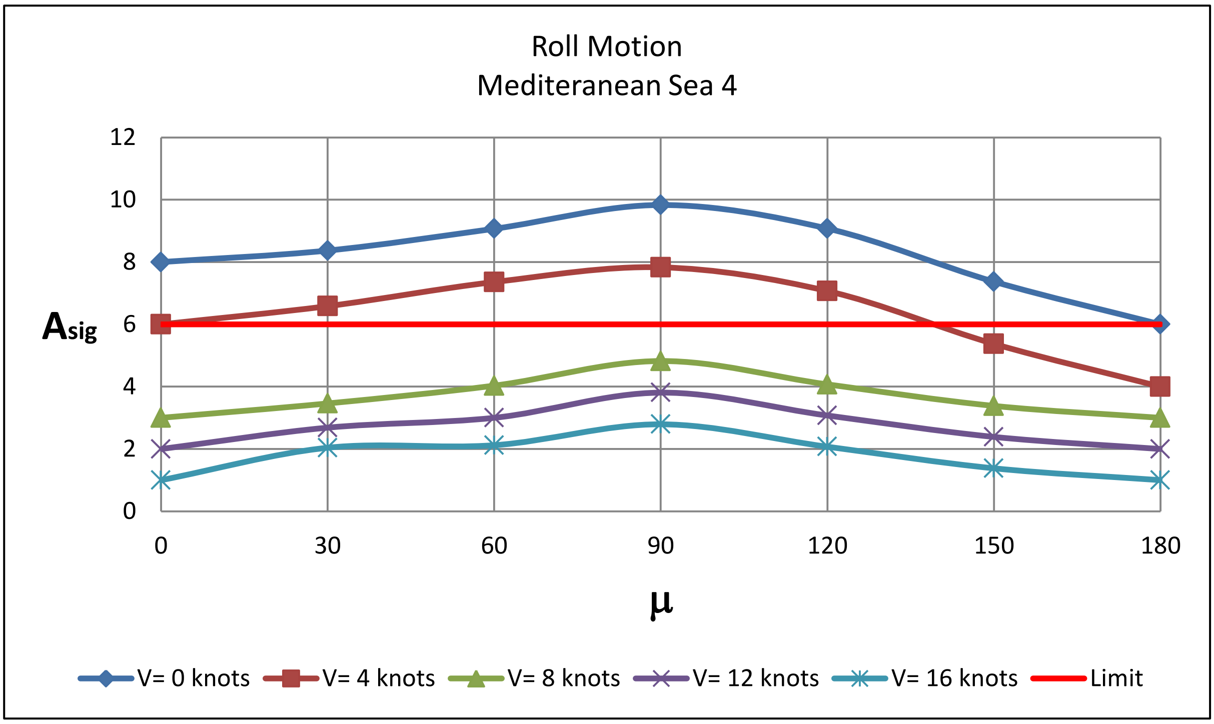


Figure 5-109 53 m motor yacht significant roll motion amplitude

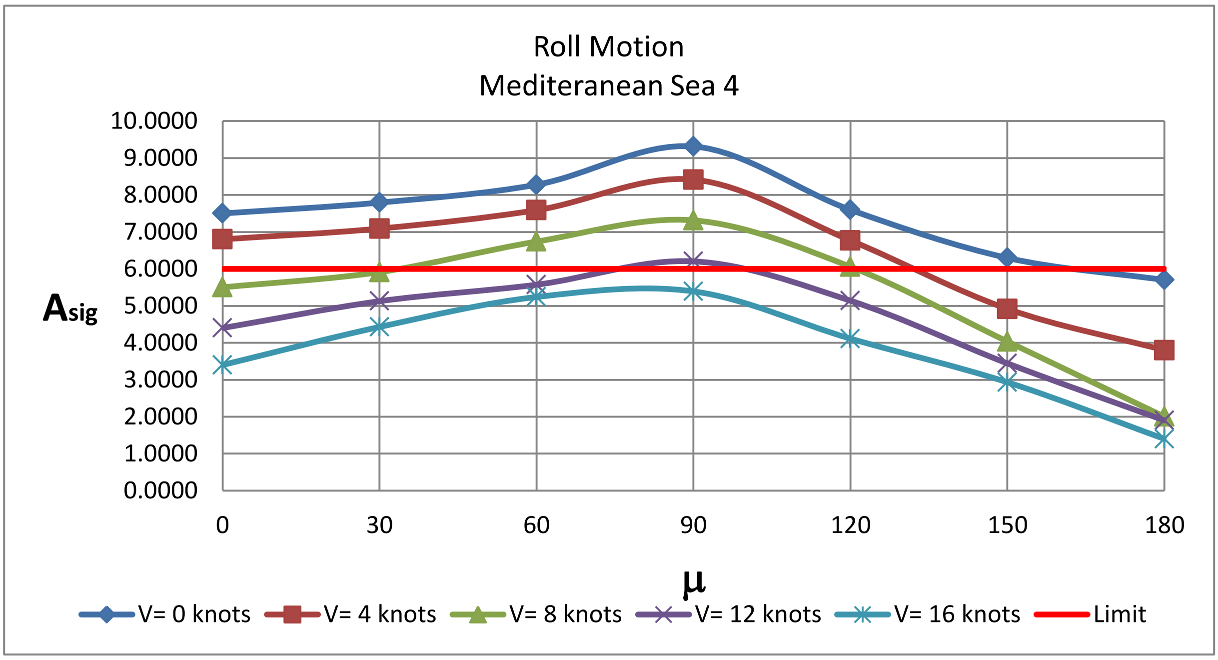


Figure 5-110 46 m motor yacht significant roll motion amplitude

5.13.2 Pitch Motion (Mediterranean Sea State 4)

Performance Criteria   Significant pitch motion amplitude <= 3 degree

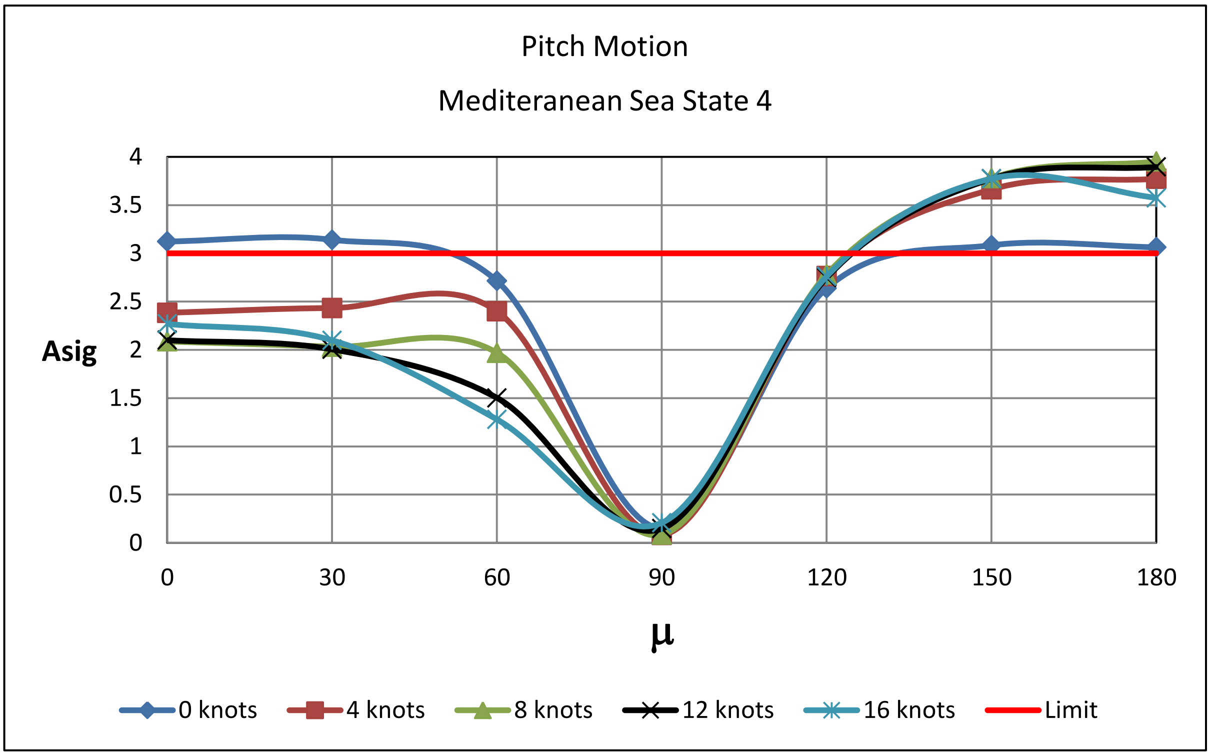


Figure 5-111 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

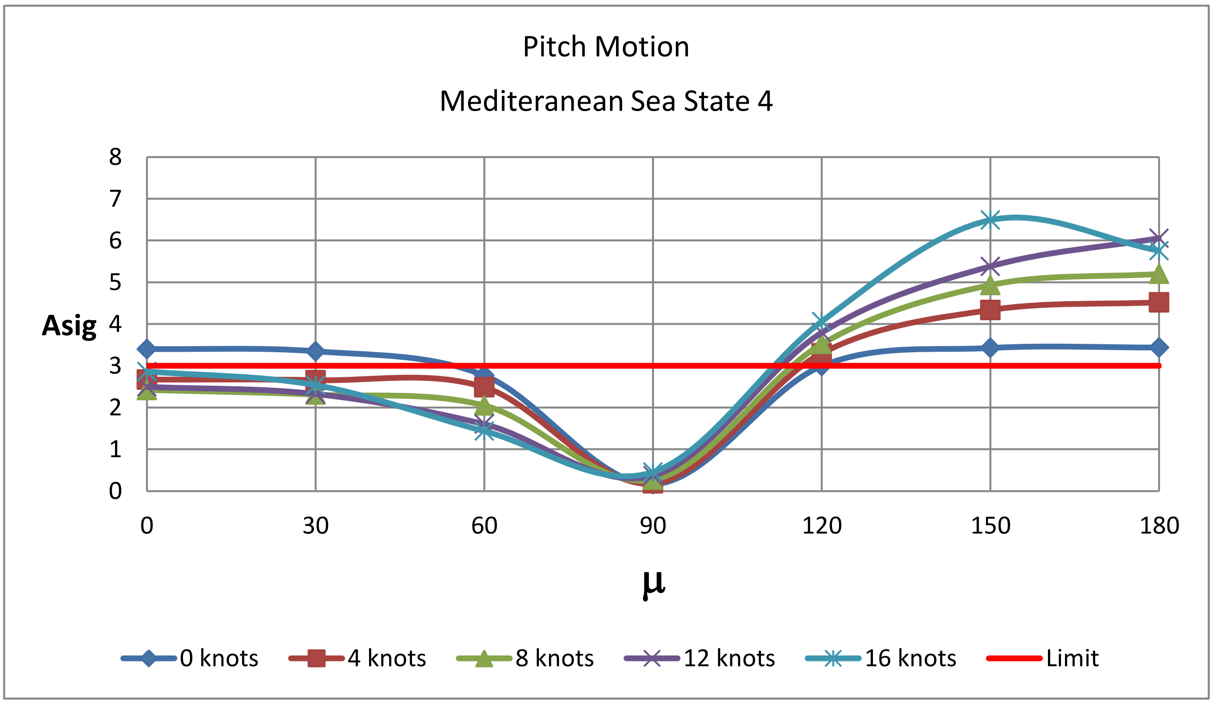


Figure 5-112 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.13.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

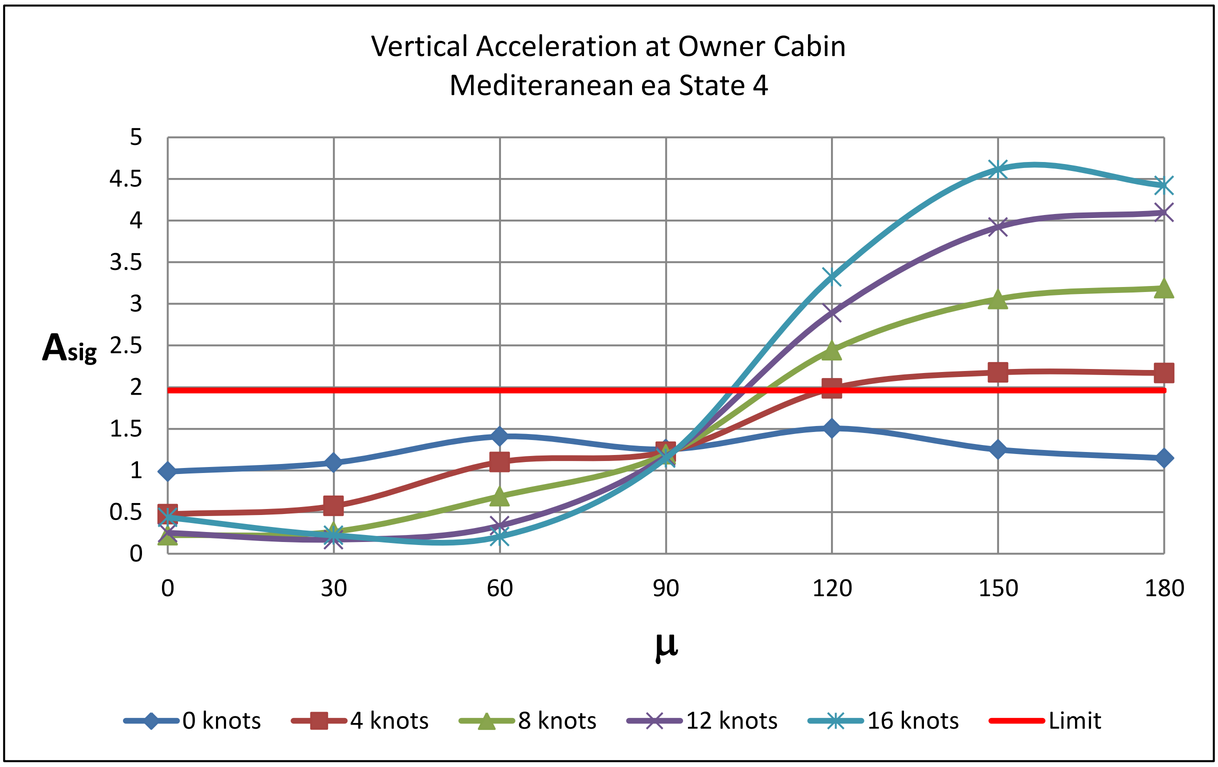


Figure 5-113 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

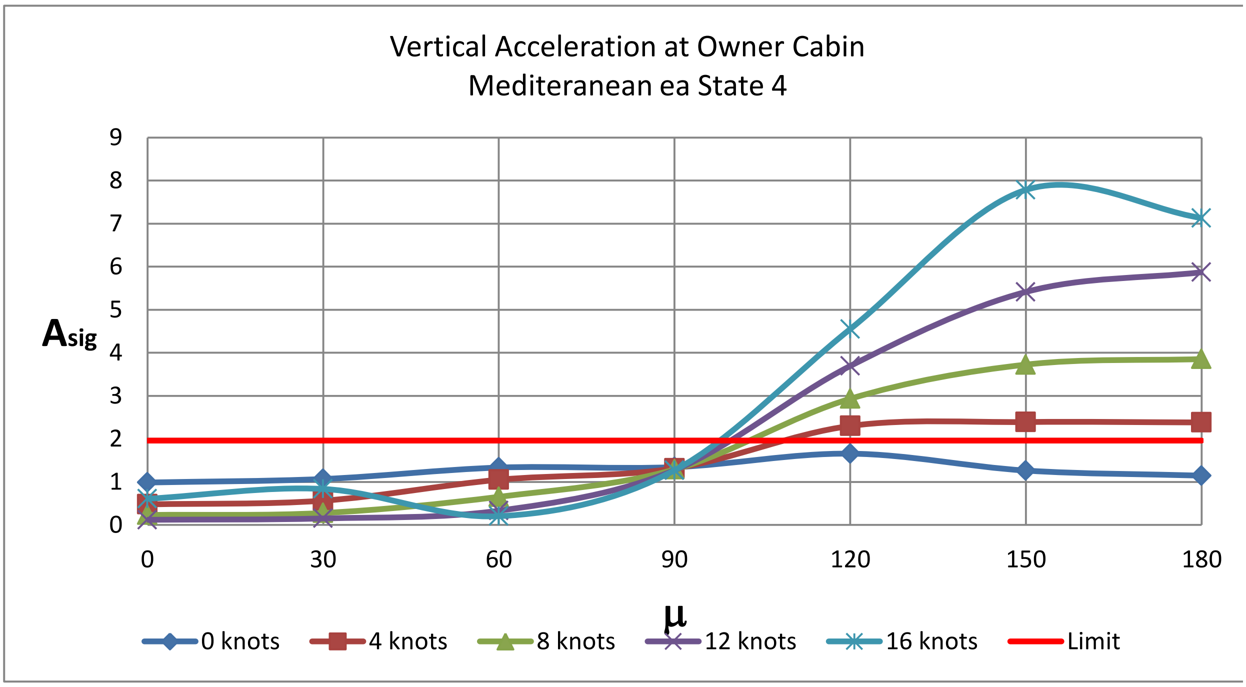


Figure 5-114 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.13.4 Vertical acceleration at bridge (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

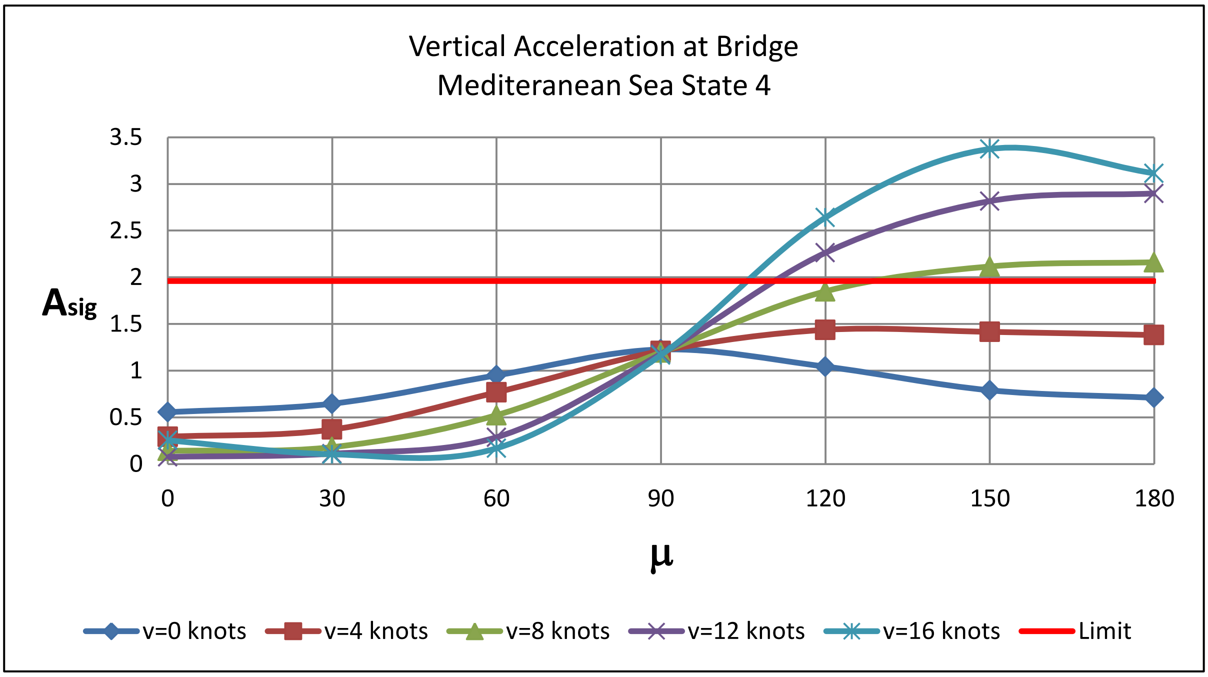


Figure 5-115 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

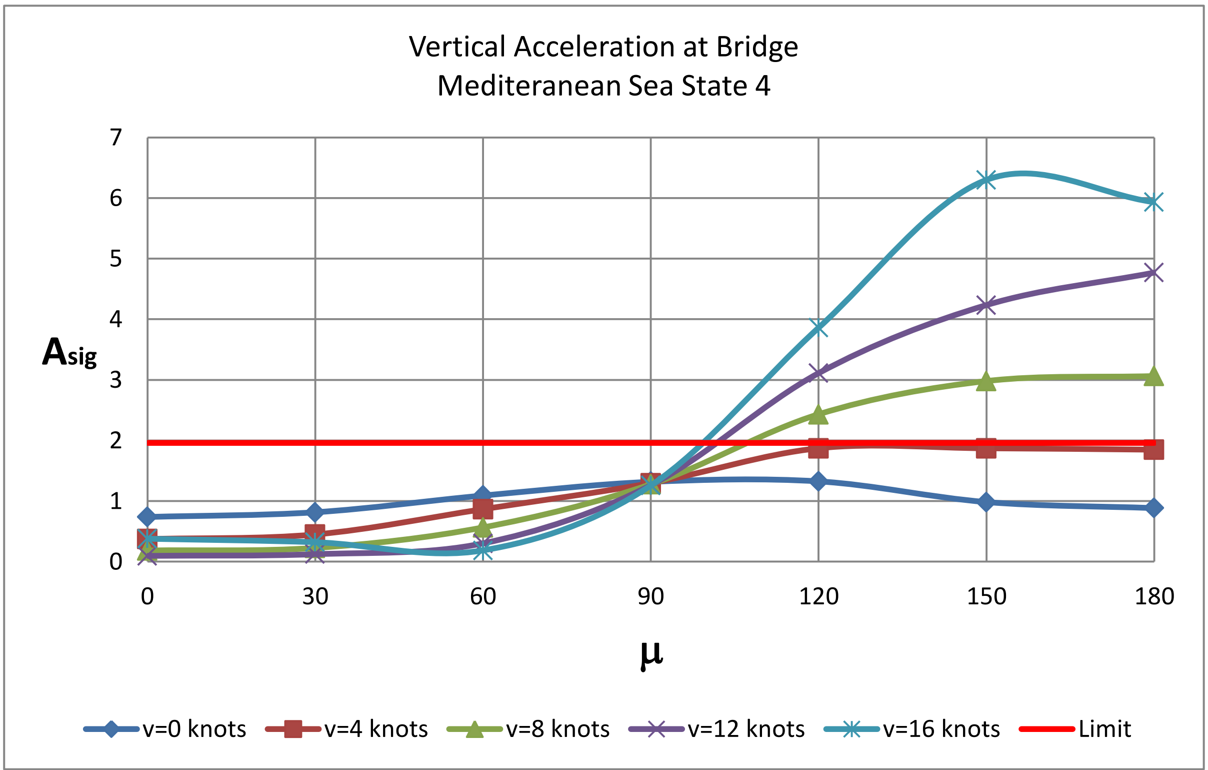


Figure 5-116 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.13.5 Vertical acceleration at saloon (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.2g

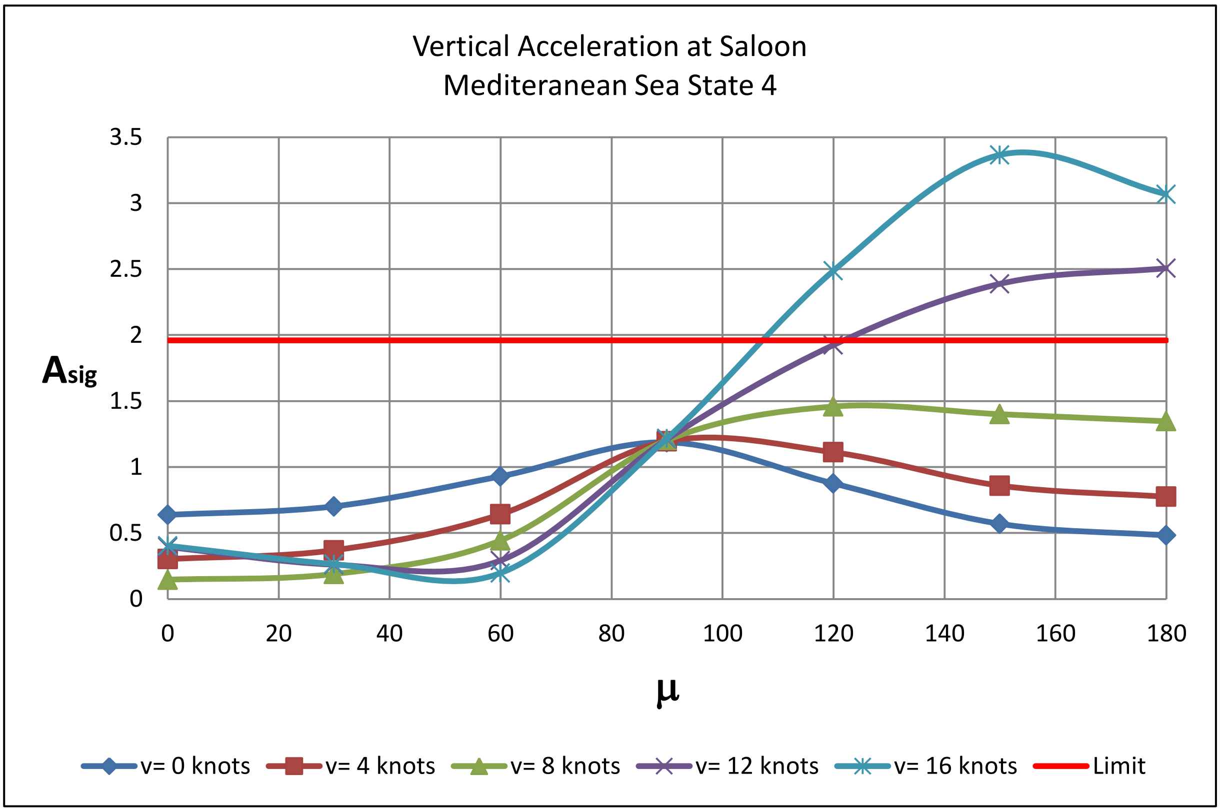


Figure 5-117 53 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

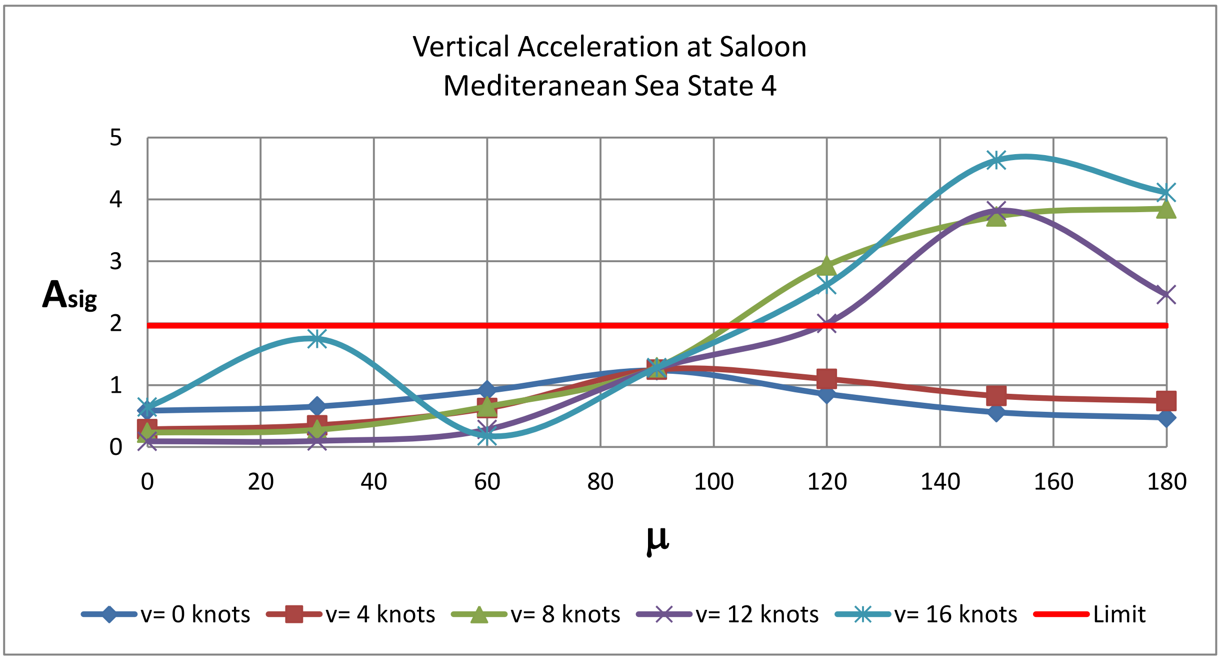


Figure 5-118 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.13.6 Lateral acceleration at bridge (Mediterranean Sea State 4)

Performance Criteria Significant acceleration amplitude <= 0.15g

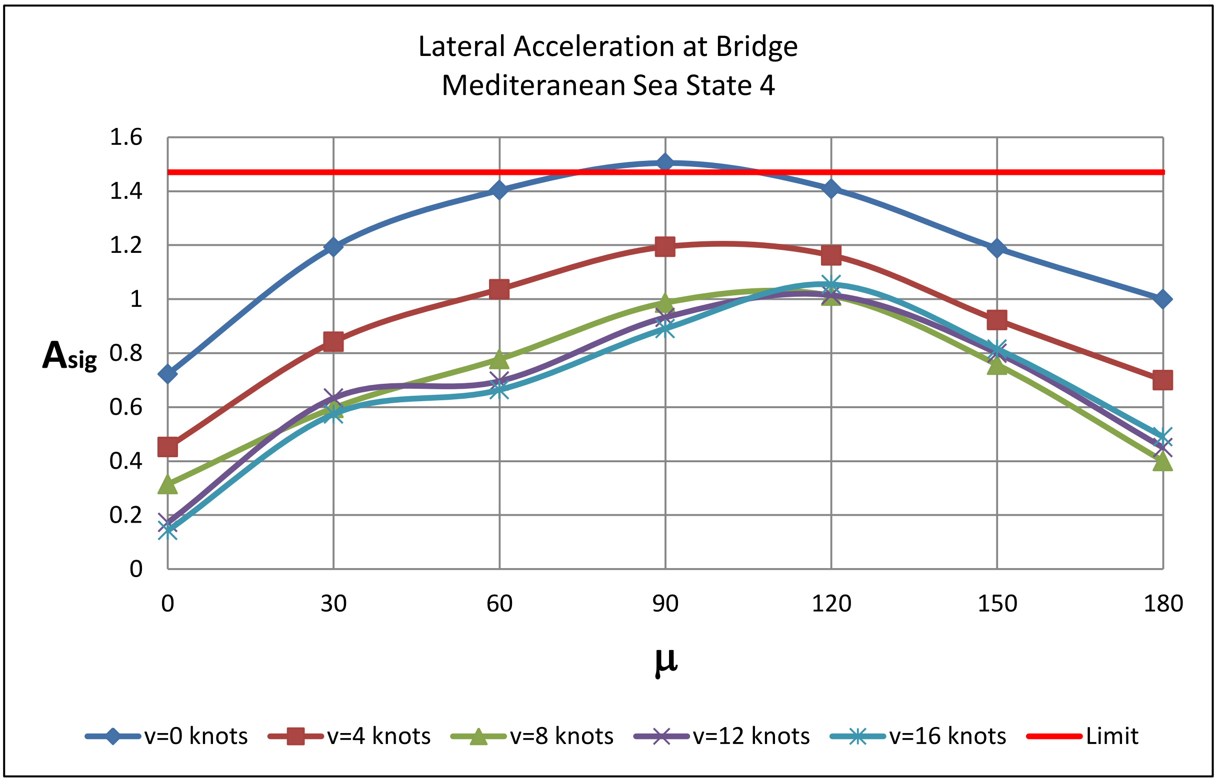


Figure 5-119 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

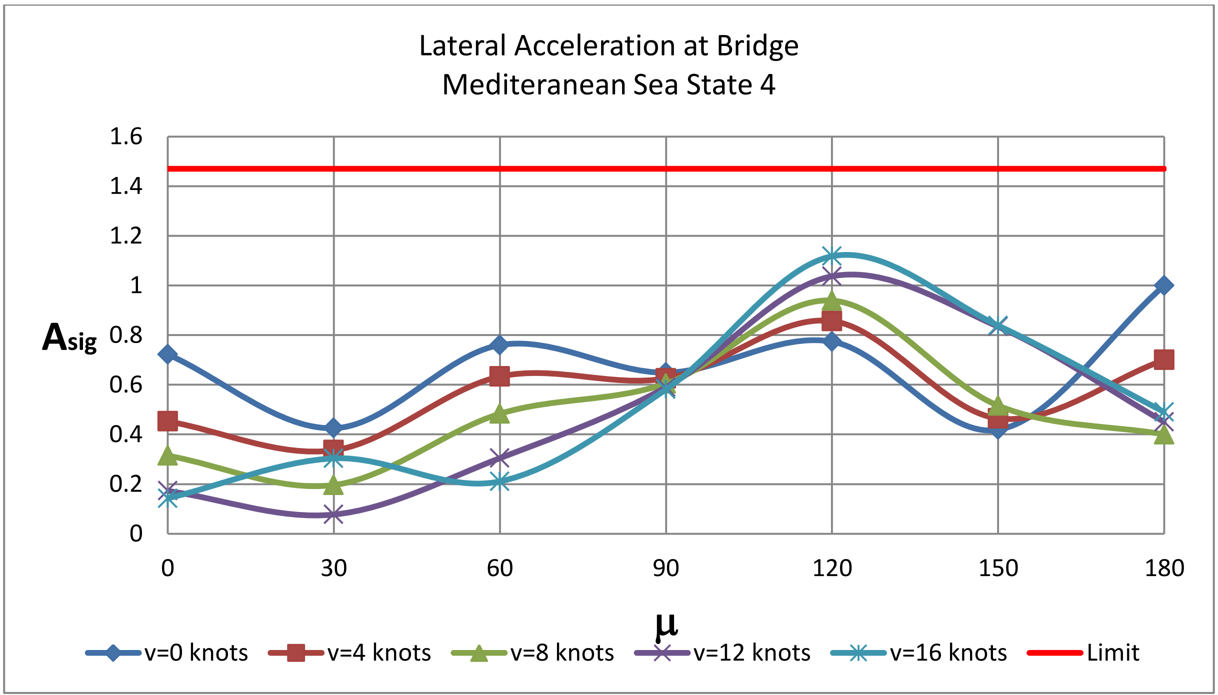


Figure 5-120 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.14 Aegean Sea State 5

5.14.1 Roll Motion (Aegean Sea State 5)

Performance Criteria Significant roll motion amplitude <= 6 degree

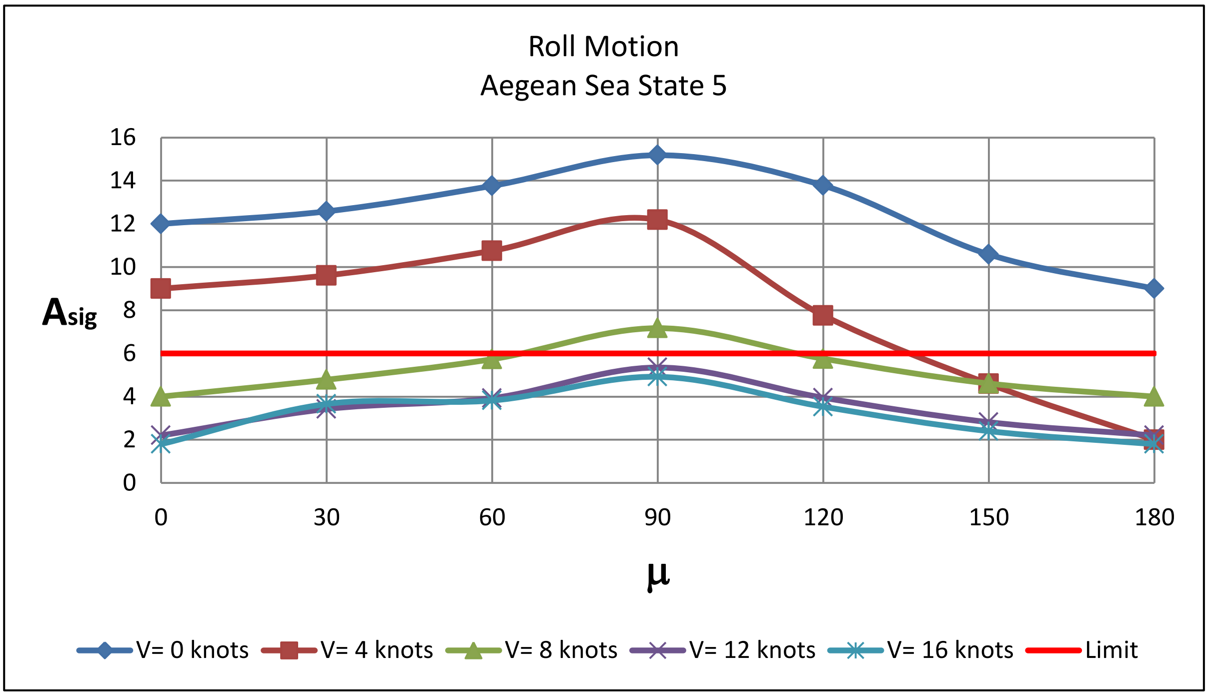


Figure 5-121 53 m motor yacht significant roll motion amplitude

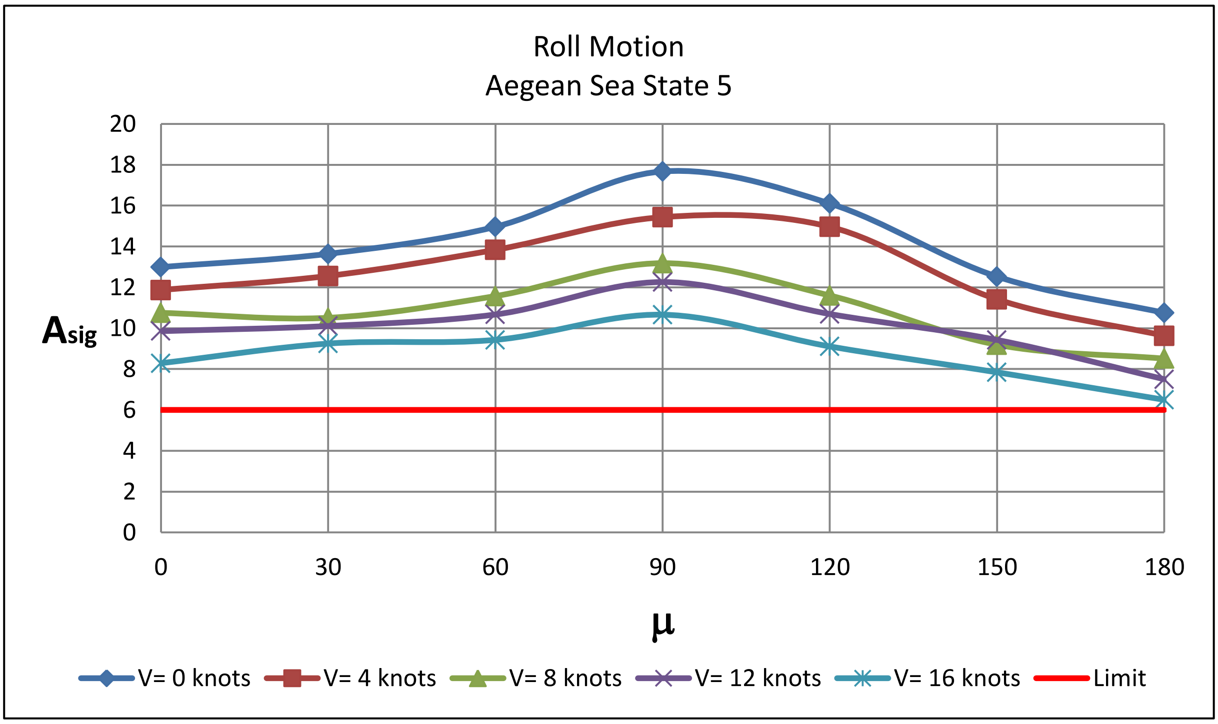


Figure 5-122 46 m motor yacht Significant roll motion amplitude

5.14.2 Pitch Motion (Aegean Sea State 5)

Performance Criteria Significant pitch motion amplitude <= 3 degree

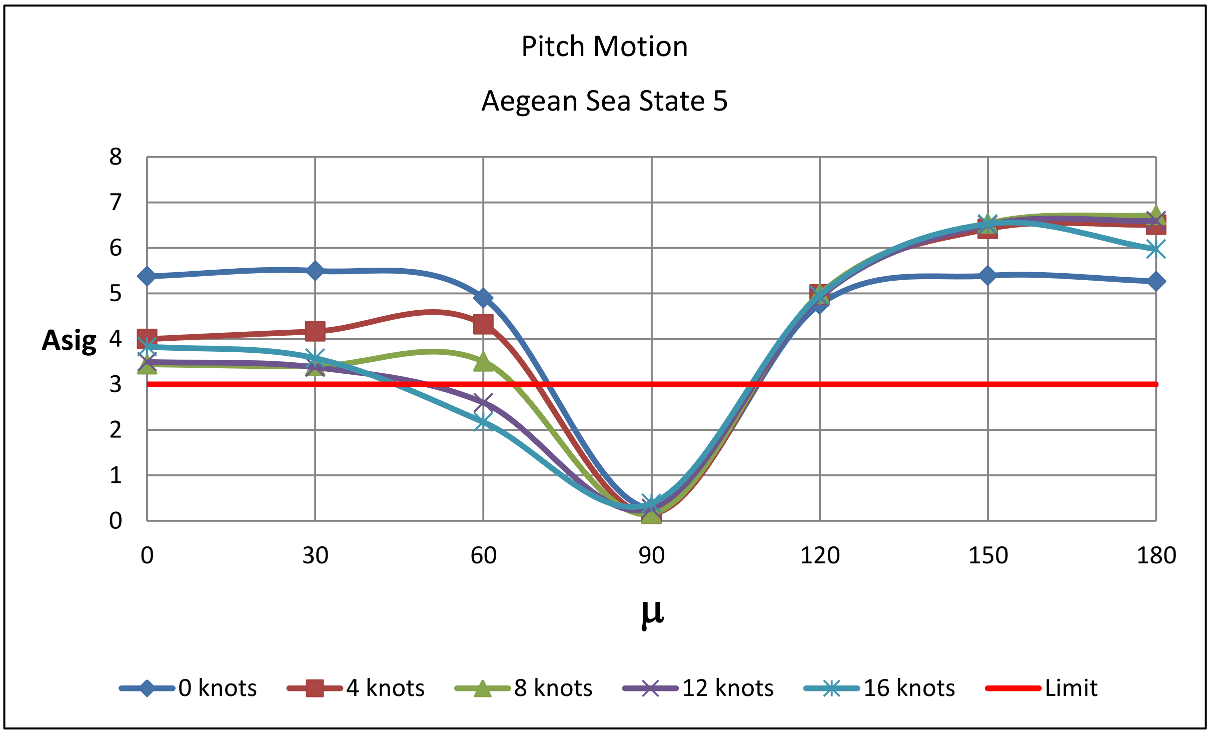


Figure 5-123 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

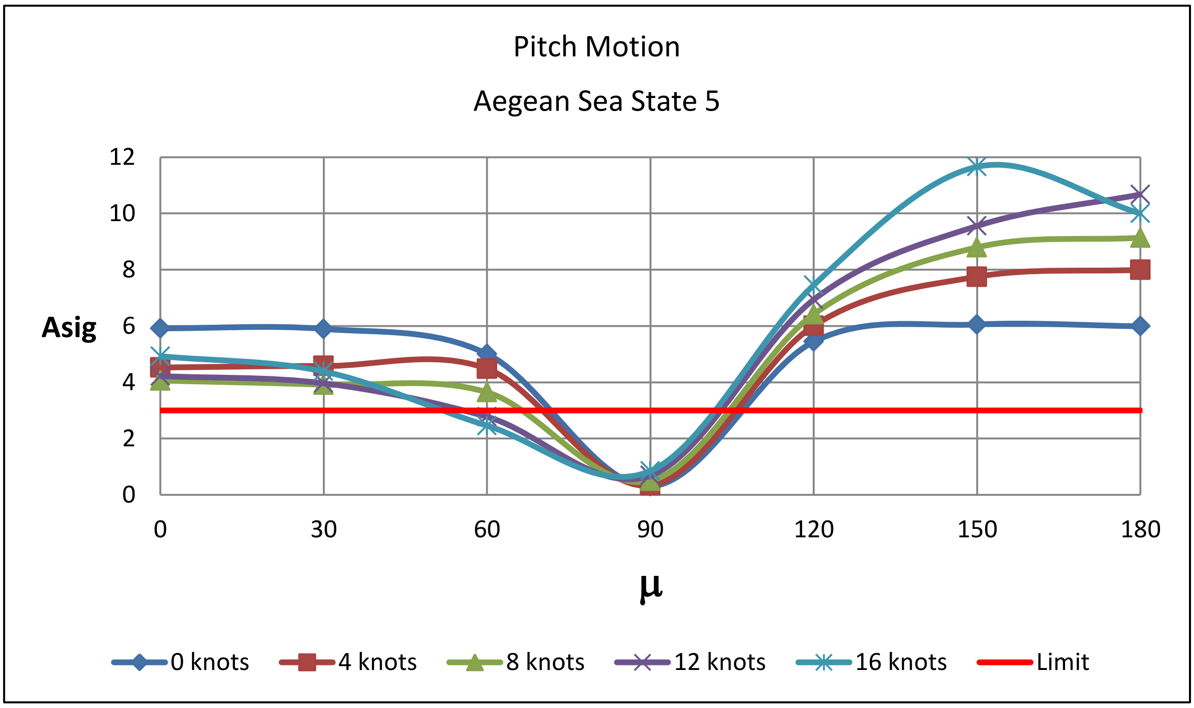


Figure 5-124 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.14.3 Vertical acceleration at owner's cabin (Aegean Sea State 5)

Performance Criteria   Significant acceleration amplitude <= 0.2g

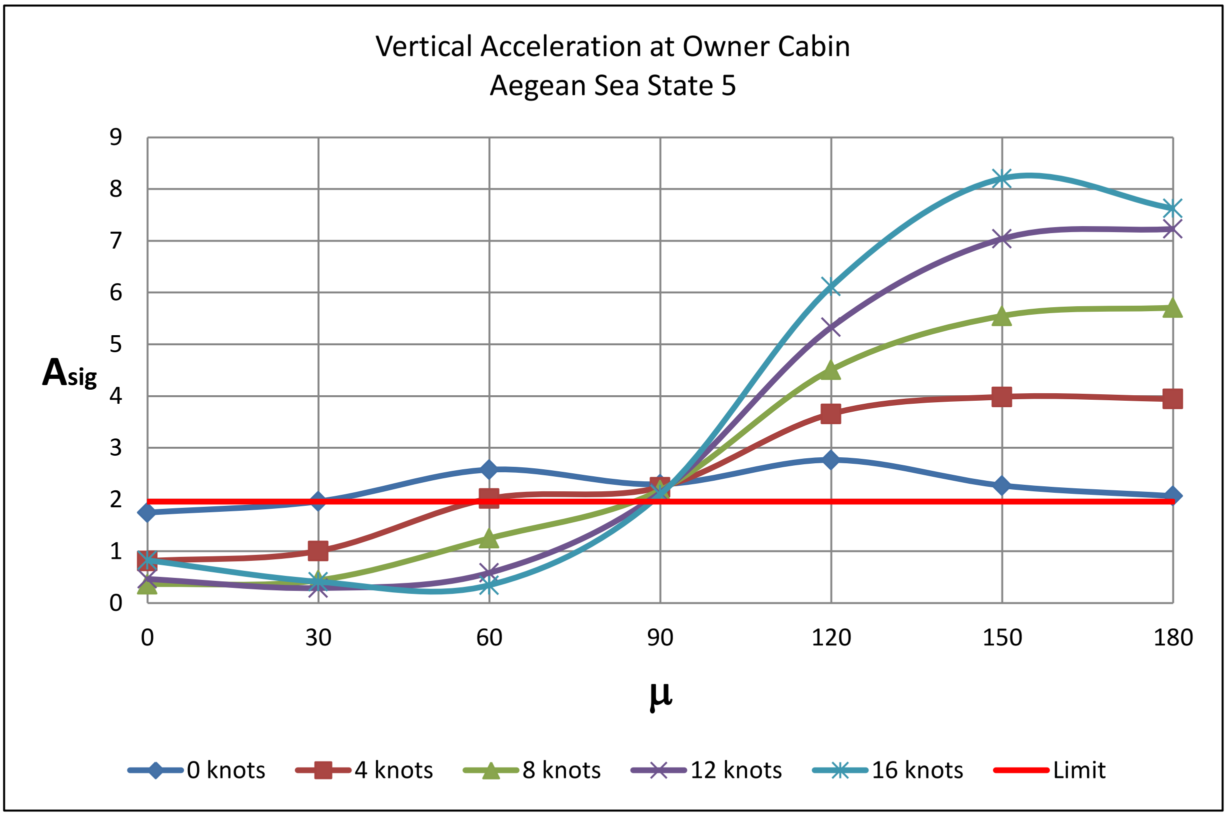


Figure 5-125 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

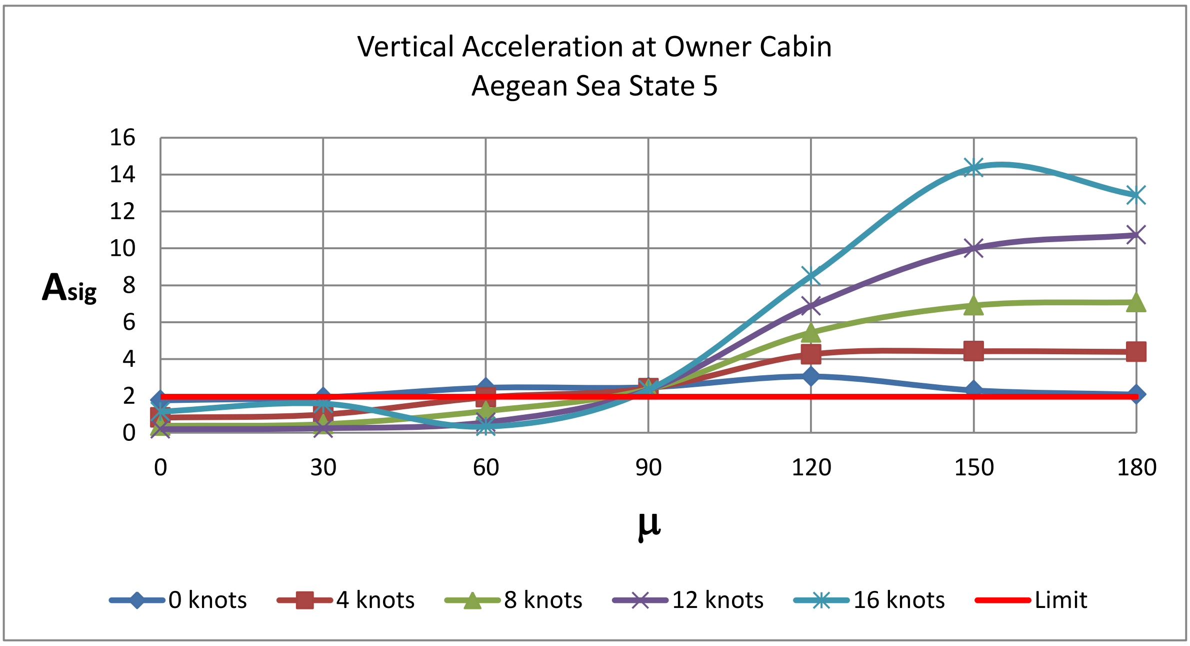


Figure 5-126 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.14.4 Vertical acceleration at bridge (Aegean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

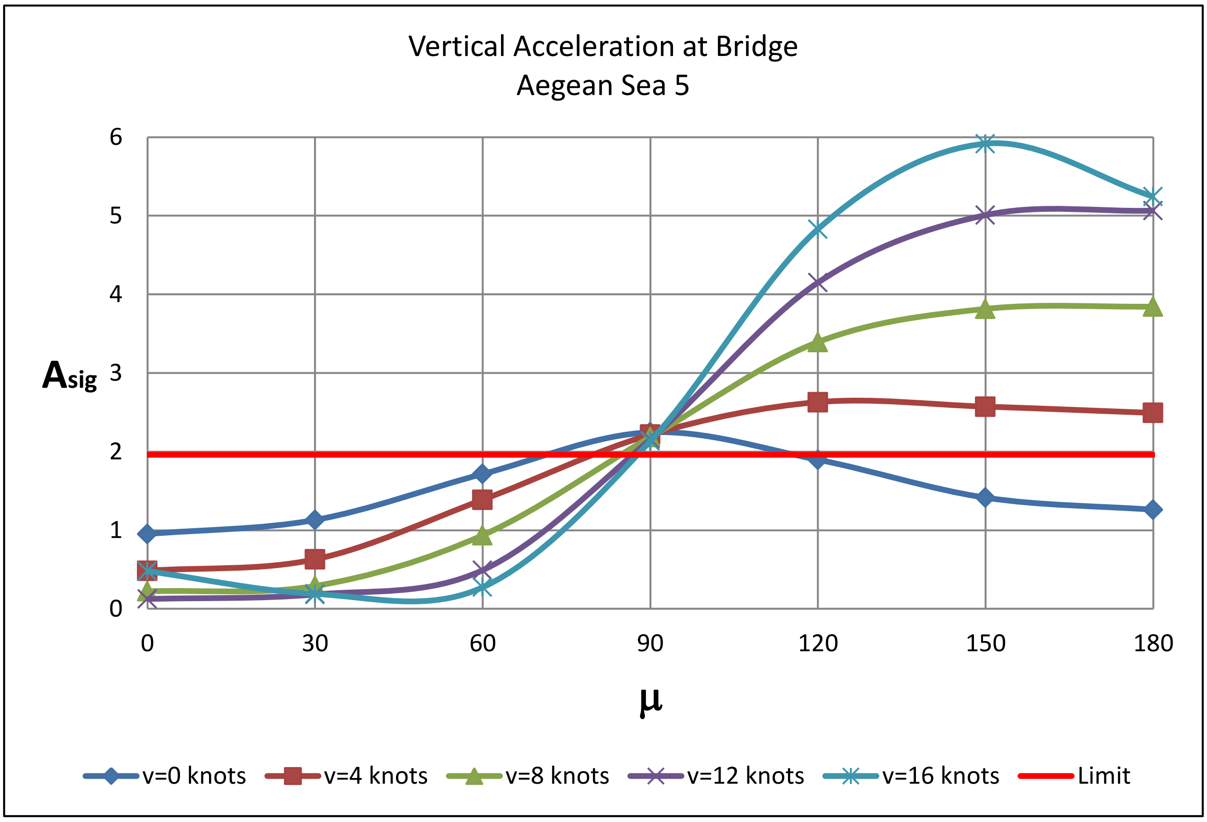


Figure 5-127 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

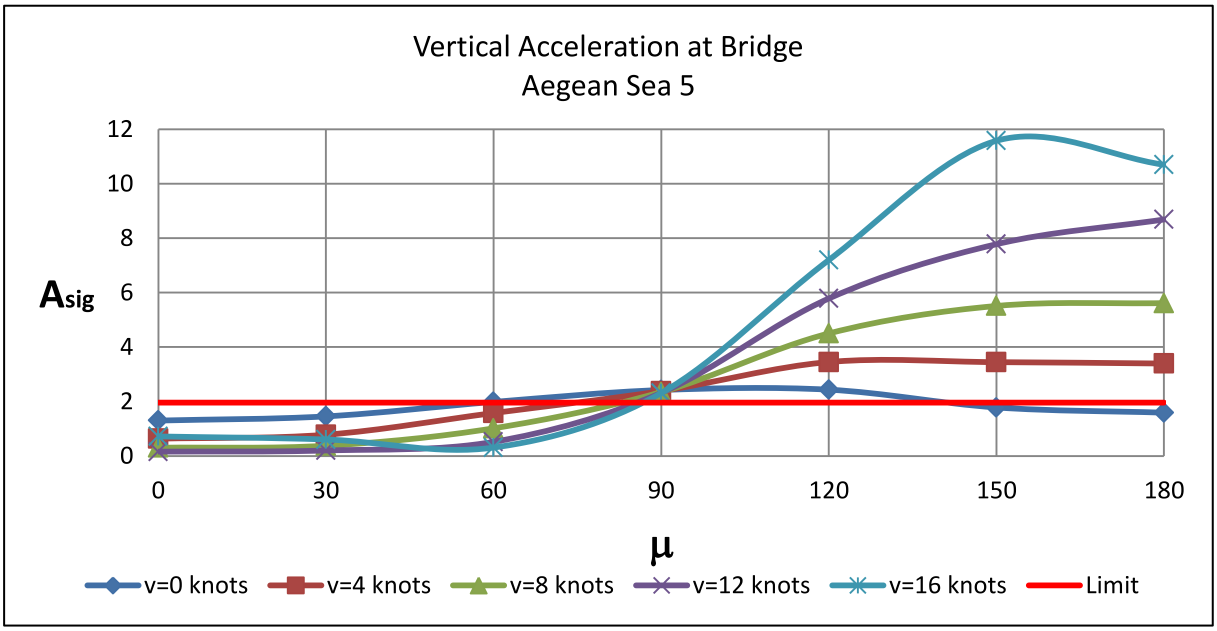


Figure 5-128 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.14.5 Vertical acceleration at saloon (Aegean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

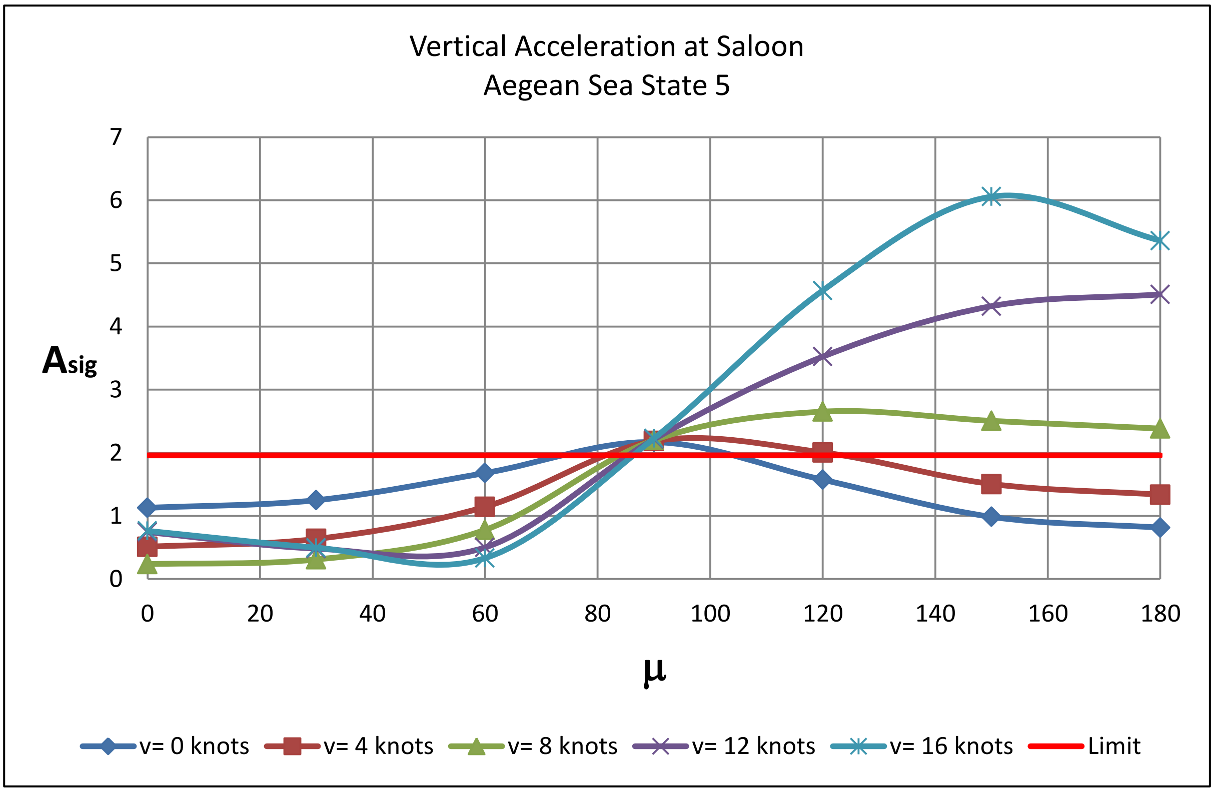


Figure 5-129 53 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

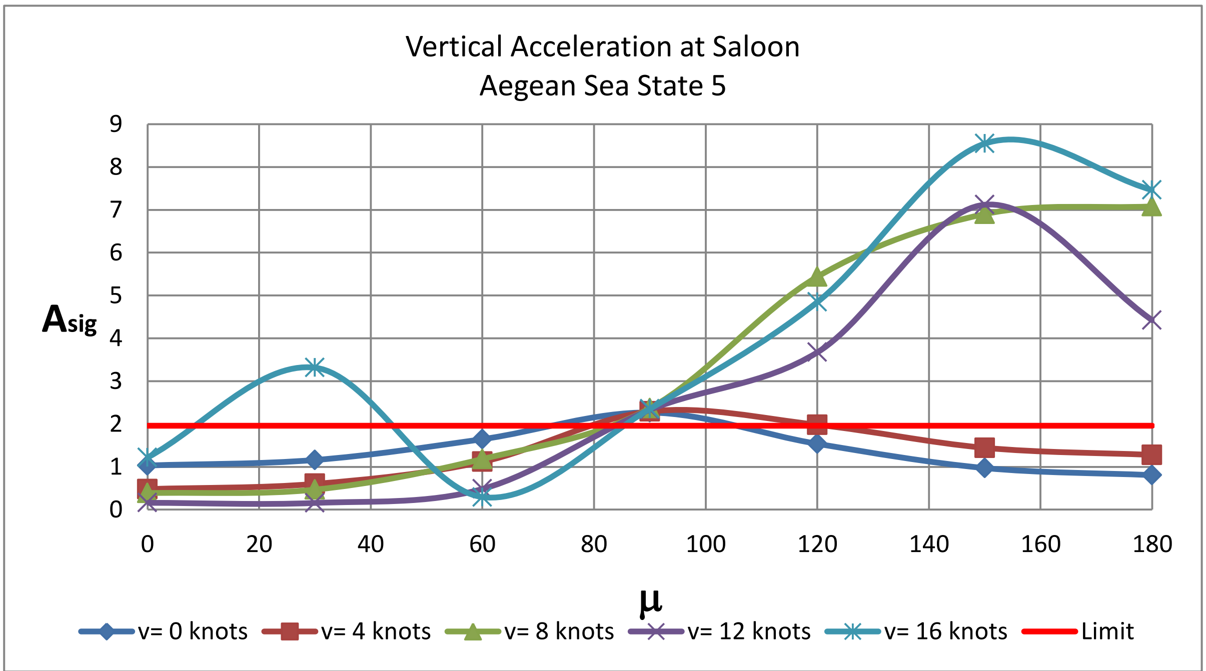


Figure 5-130 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.14.6 Lateral acceleration at bridge (Aegean Sea State 5)

Performance Criteria — Significant acceleration amplitude <= 0.15g

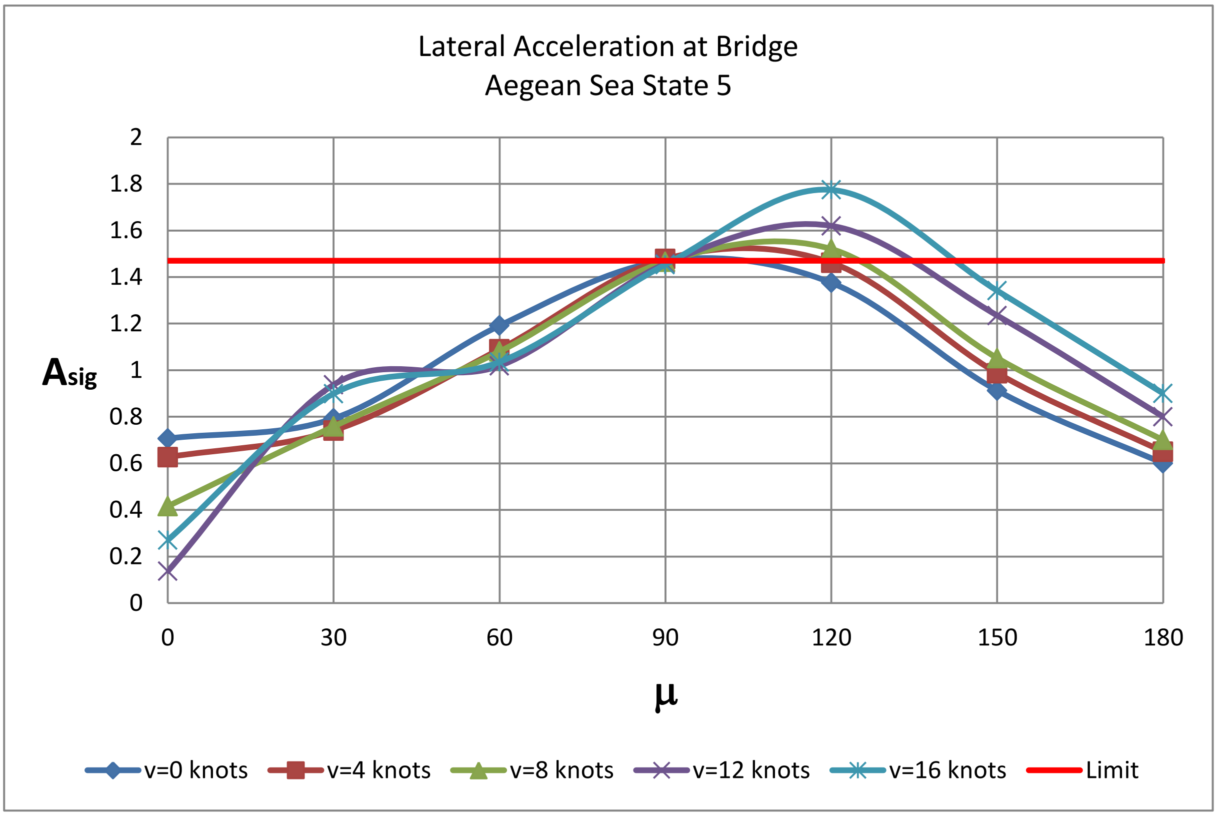


Figure 5-131 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

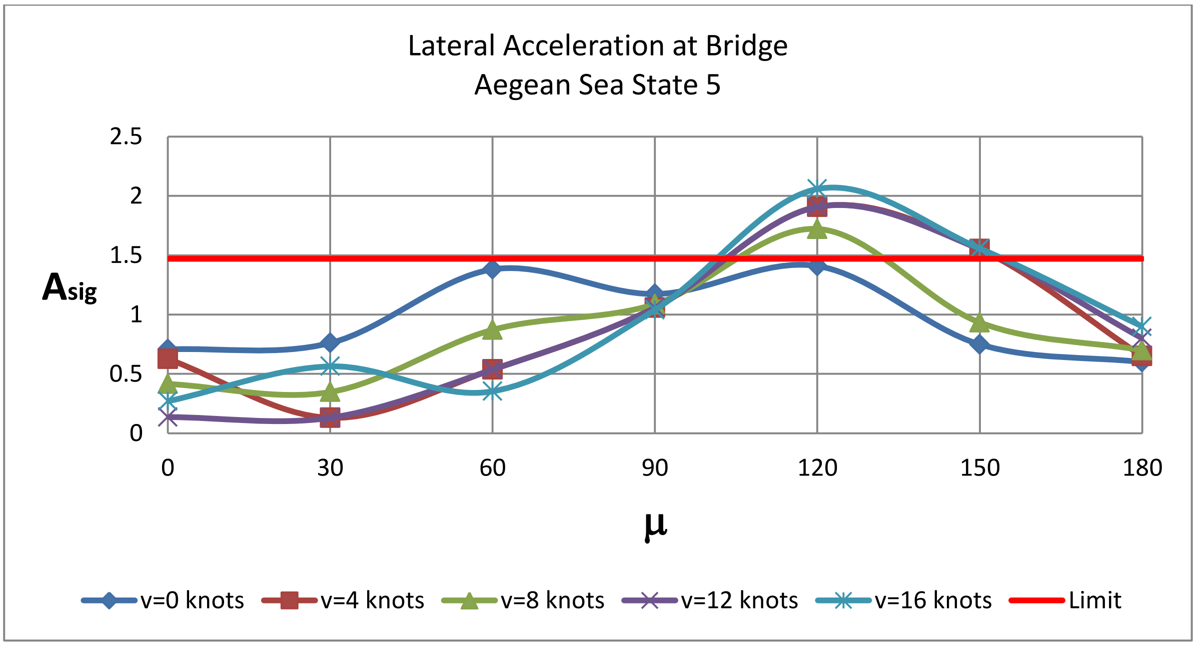


Figure 5-132 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

5.15 Mediterranean Sea State 5

5.15.1.1 Roll Motion (Mediterranean Sea State 5)

Performance Criteria Significant roll motion amplitude <= 6 degree

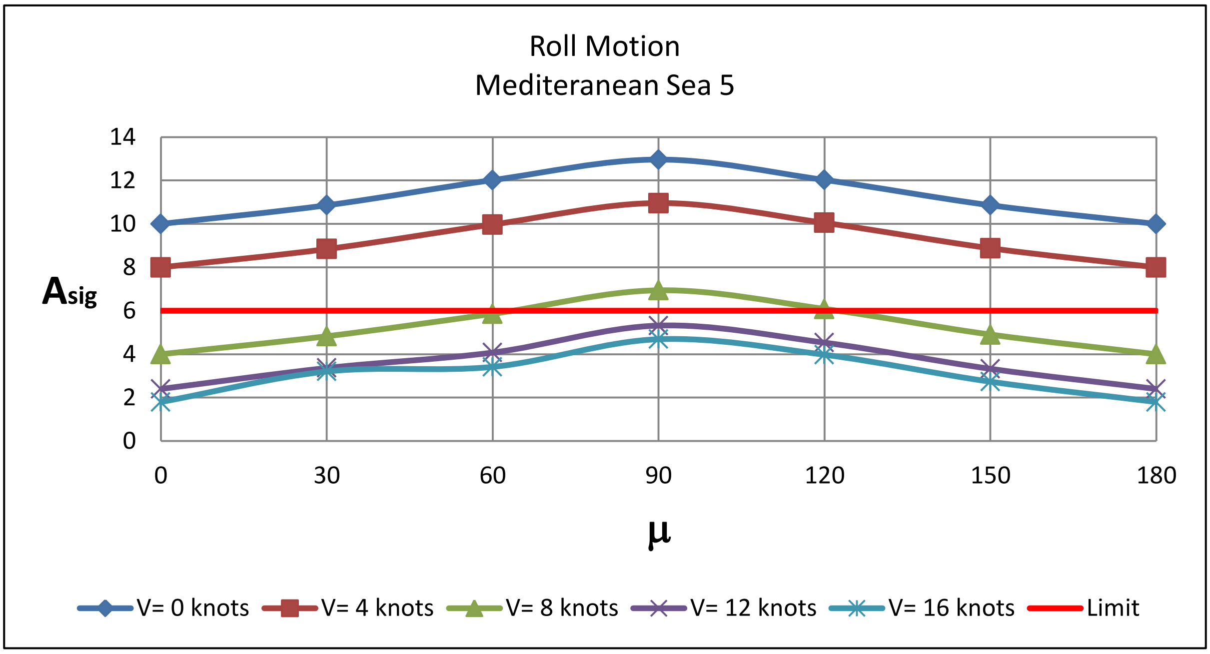


Figure 5-133 53 m motor yacht significant roll motion amplitude

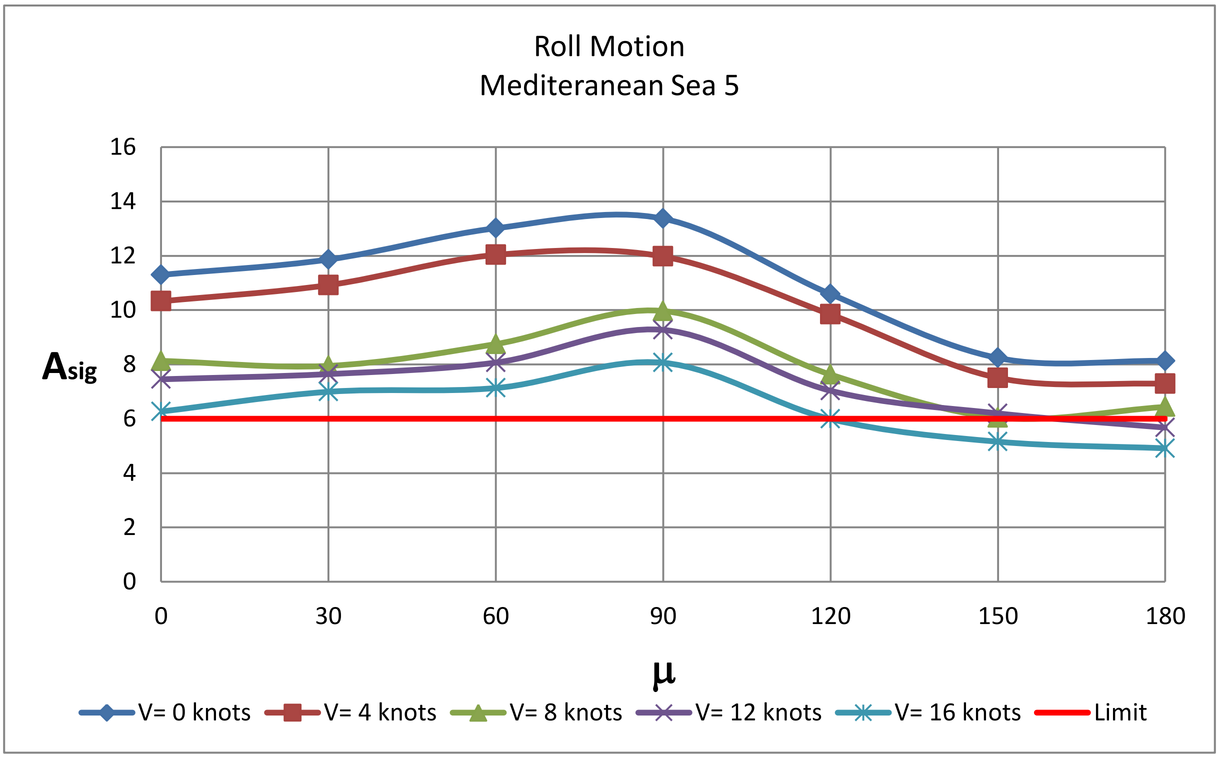


Figure 5-134 46 m motor yacht significant roll motion amplitude

5.15.2 Pitch Motion (Mediterranean Sea State 5)

Performance Criteria Significant pitch motion amplitude <= 3 degree

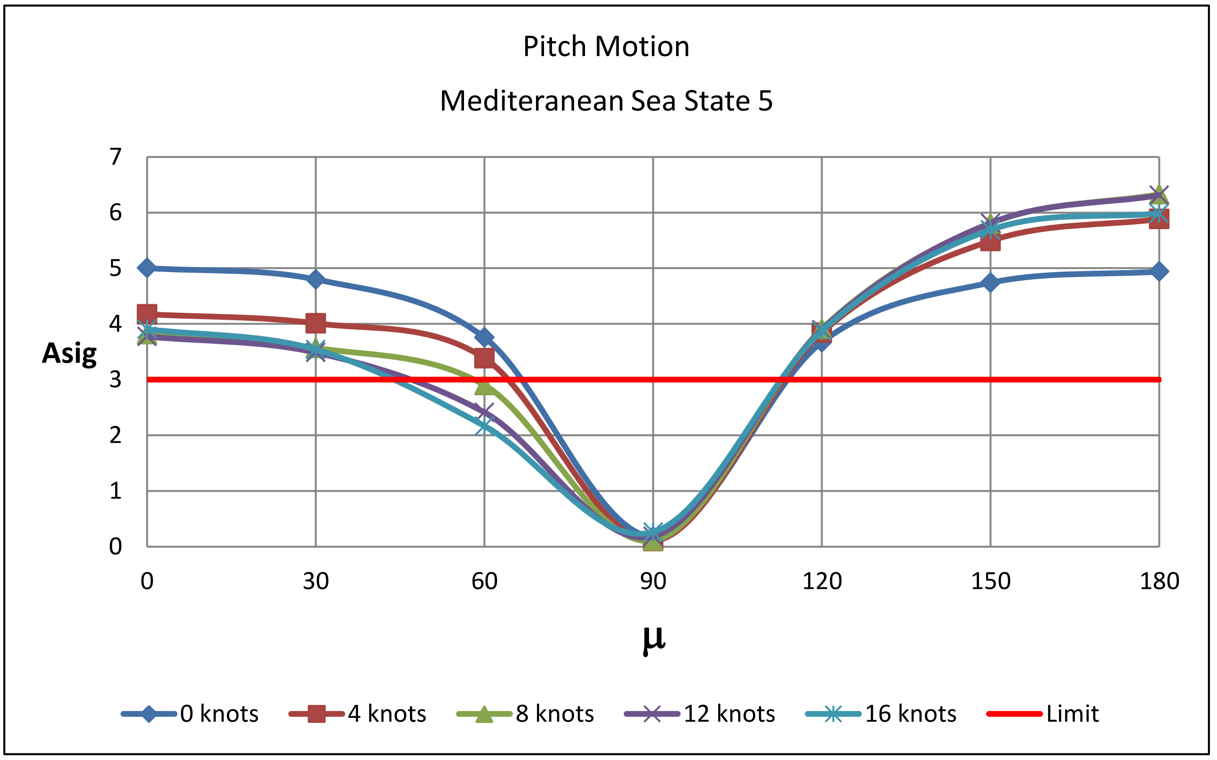


Figure 5-135 53 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

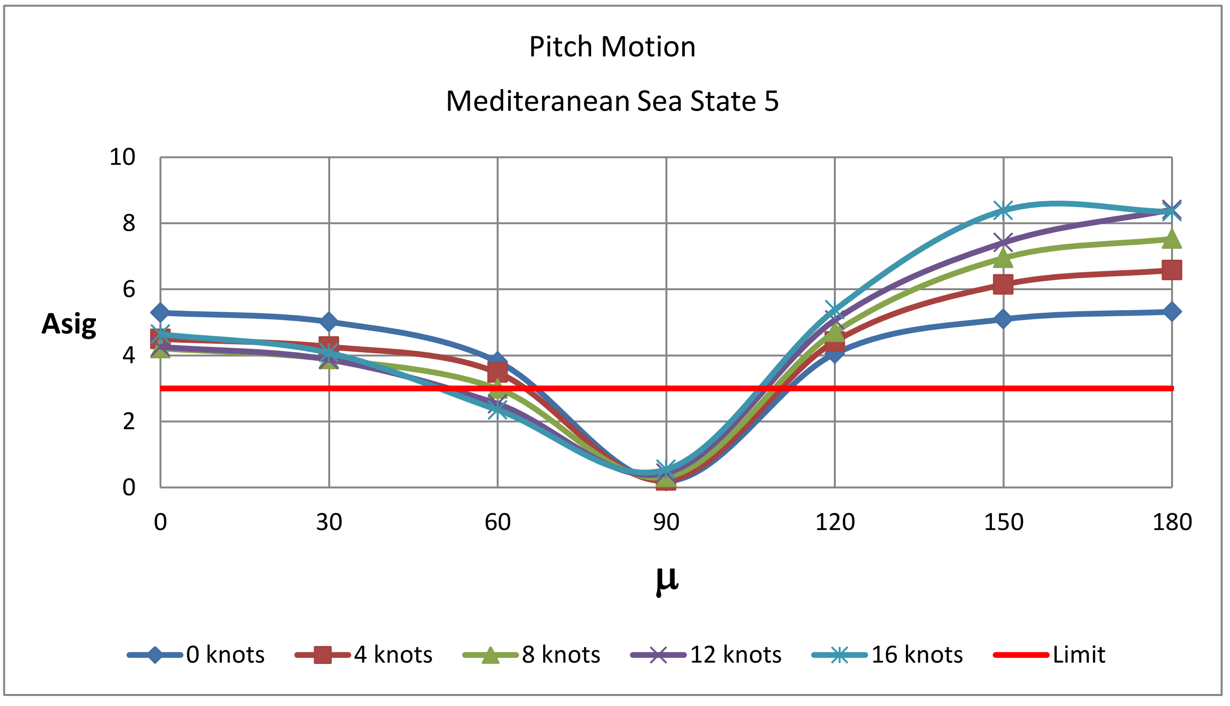


Figure 5-136 46 m motor yacht significant pitch Motion amplitude as a function of relative course and speed[m/s^2]

5.15.3 Vertical acceleration at owner's cabin (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

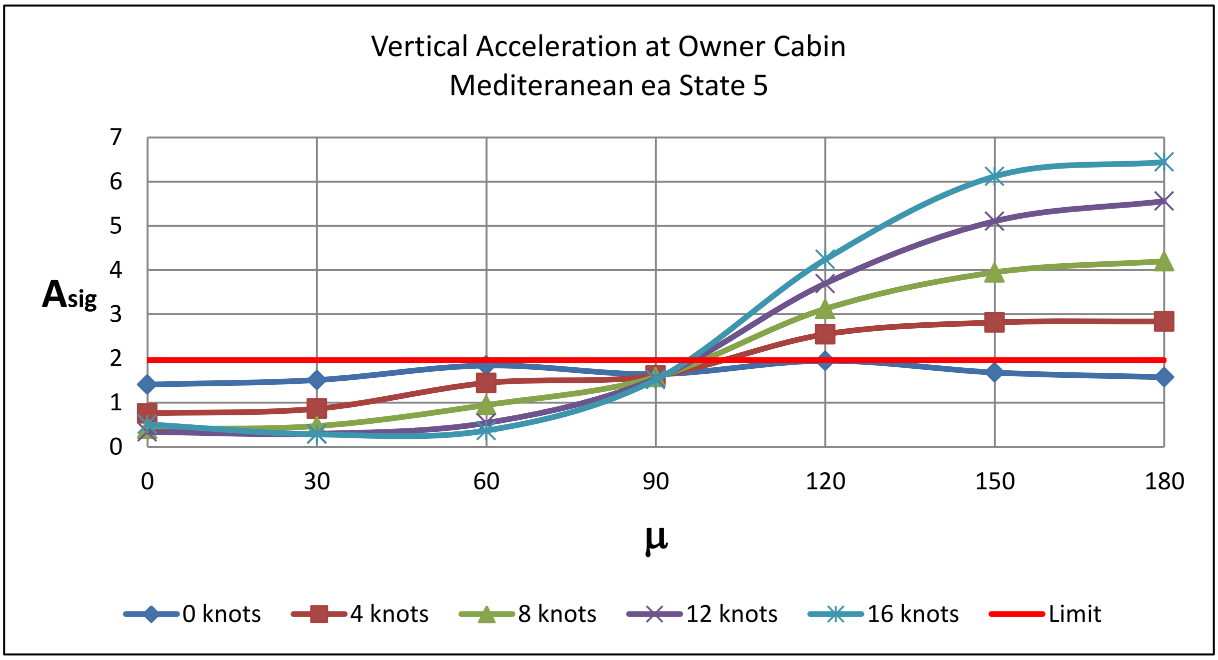


Figure 5-137 53 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

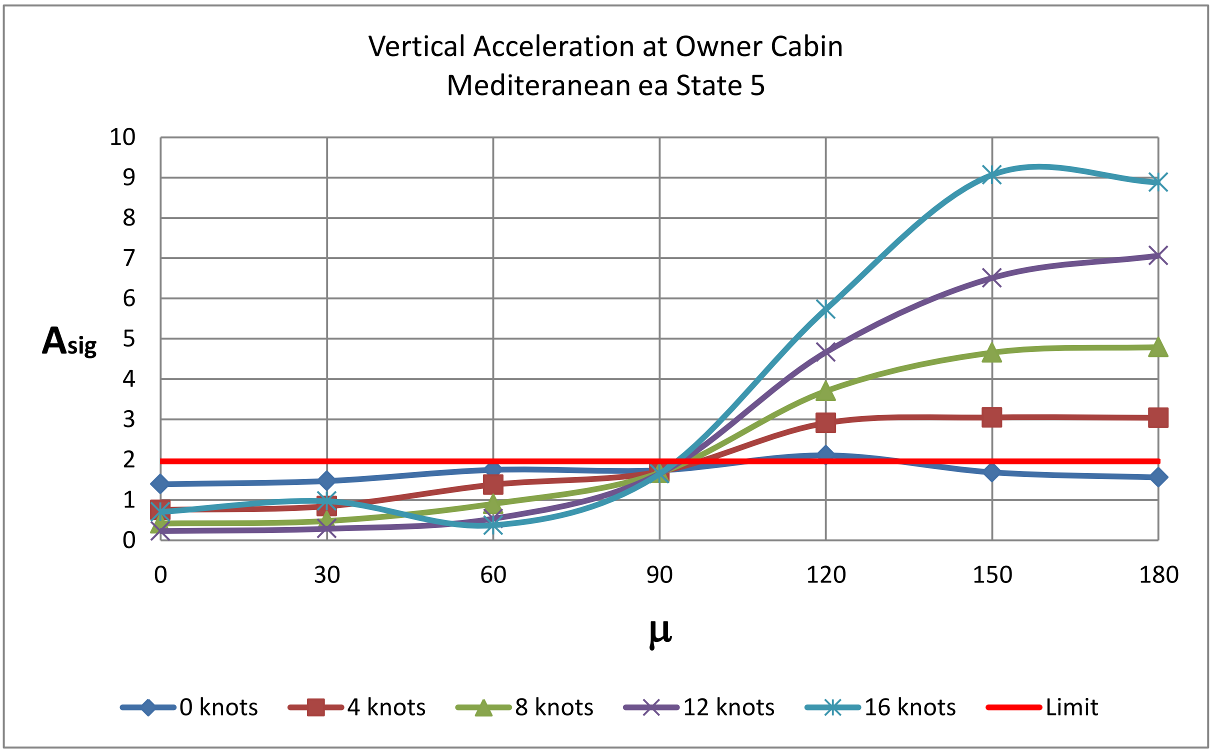


Figure 5-138 46 m motor yacht significant Vertical Acceleration amplitude at the owner's cabin as a function of relative course and speed[m/s^2]

5.15.4 Vertical acceleration at bridge (Mediterranean Sea State 5)

Performance Criteria — Significant acceleration amplitude <= 0.2g

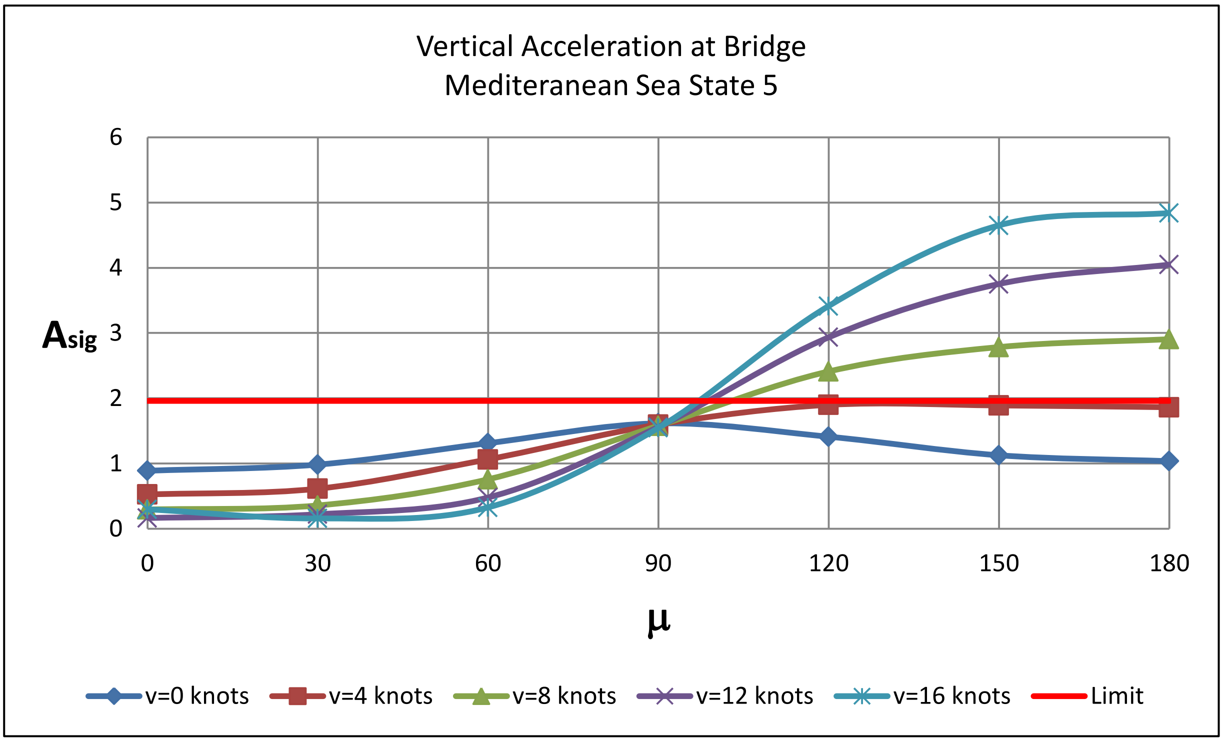


Figure 5-139 53 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

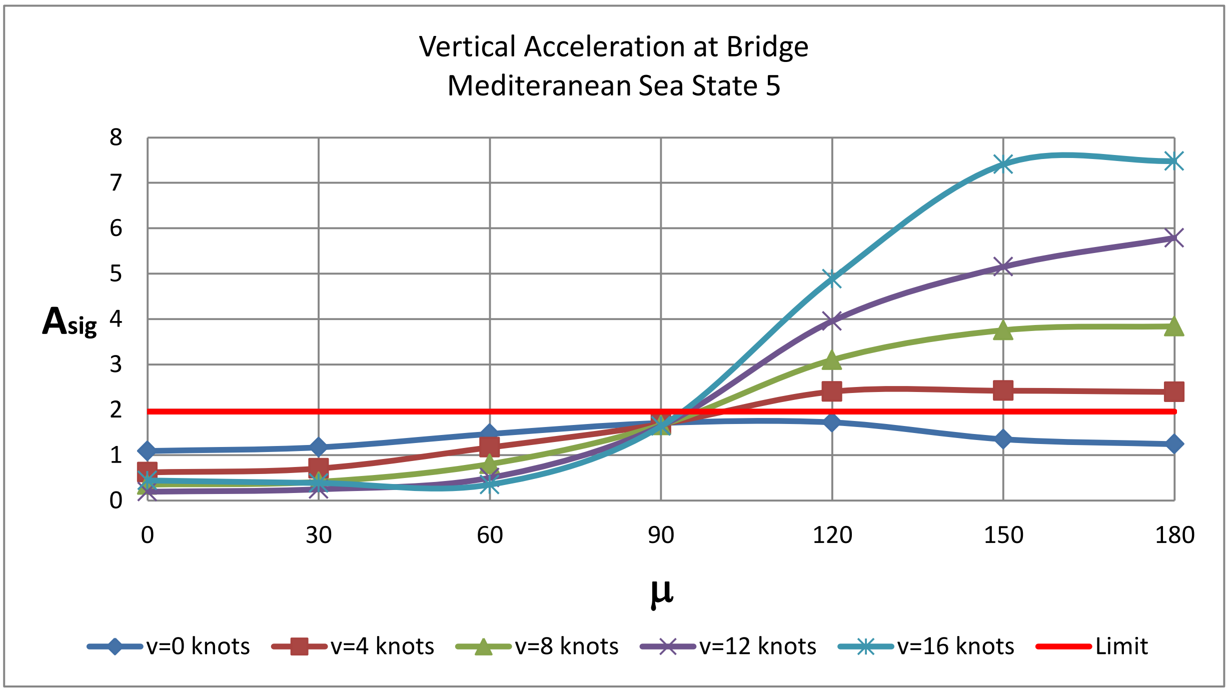


Figure 5-140 46 m motor yacht significant Vertical Acceleration amplitude at Bridge as a function of relative course and speed[m/s^2]

5.15.5 Vertical acceleration at saloon (Mediterranean Sea State 5)

Performance Criteria Significant acceleration amplitude <= 0.2g

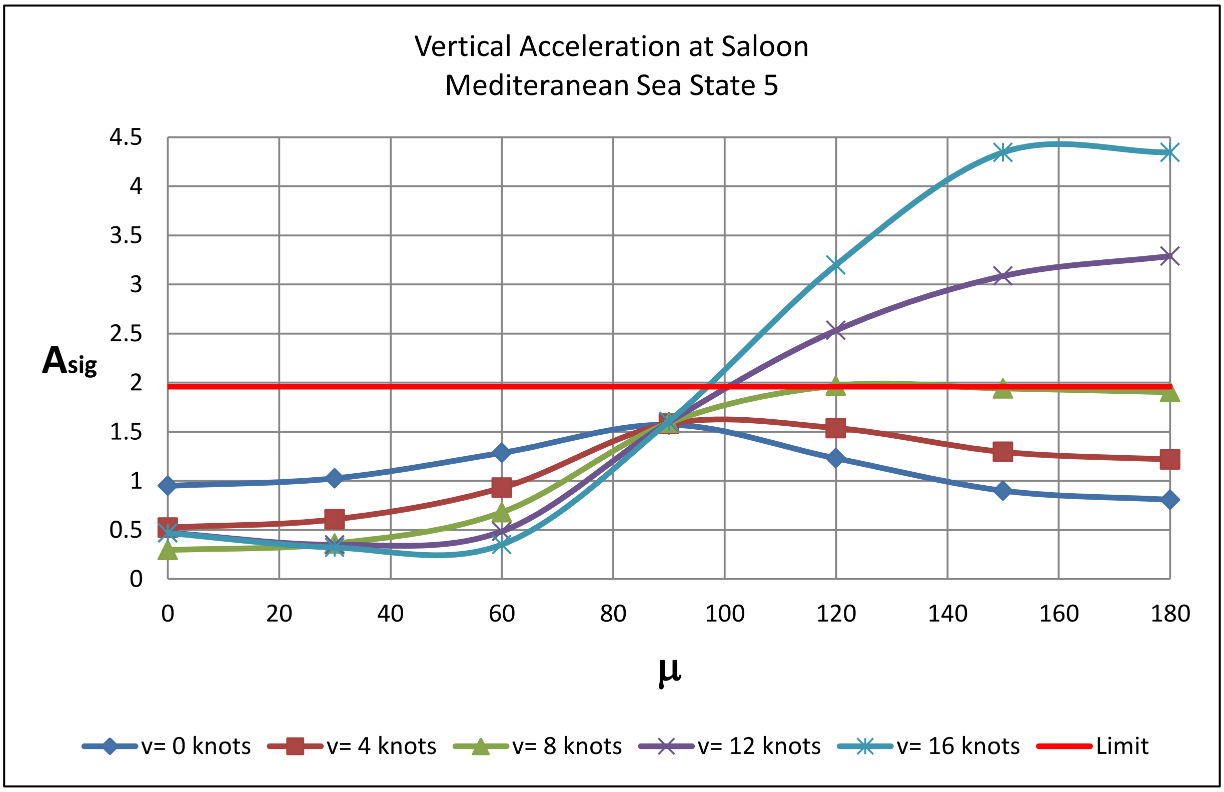


Figure 5-141 53 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

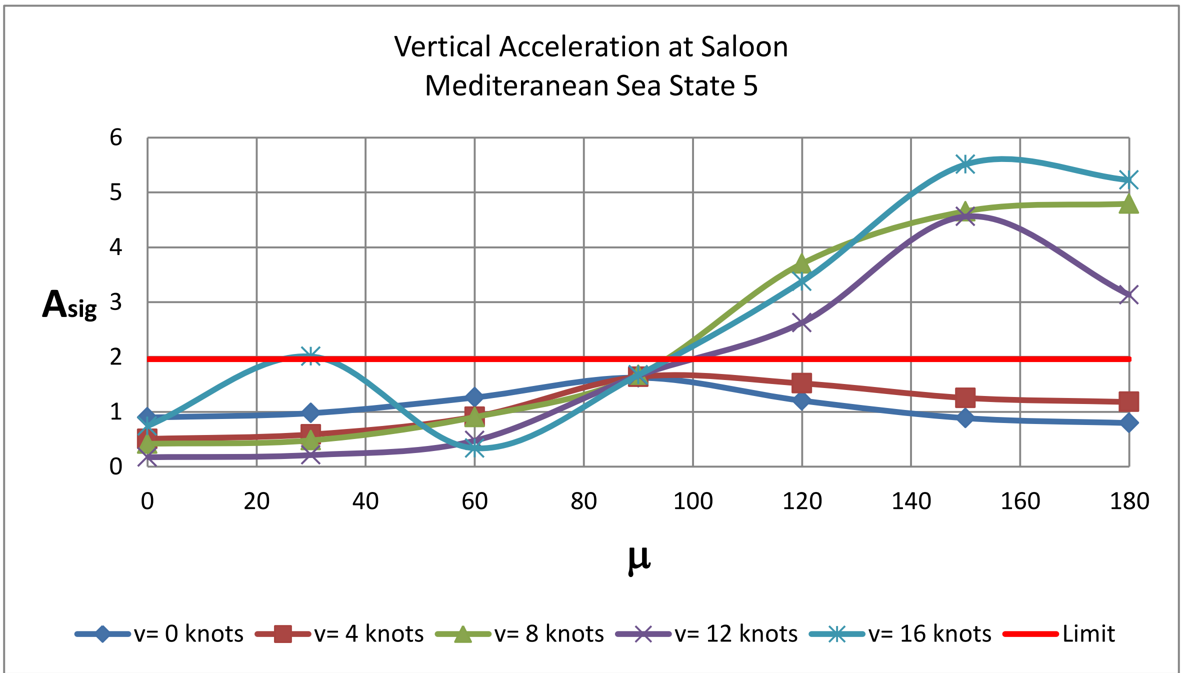


Figure 5-142 46 m motor yacht significant Vertical Acceleration amplitude at saloon as a function of relative course and speed[m/s^2]

5.15.6 Lateral acceleration at bridge (Mediterranean Sea State 5)

Performance Criteria | Significant acceleration amplitude <= 0.15g

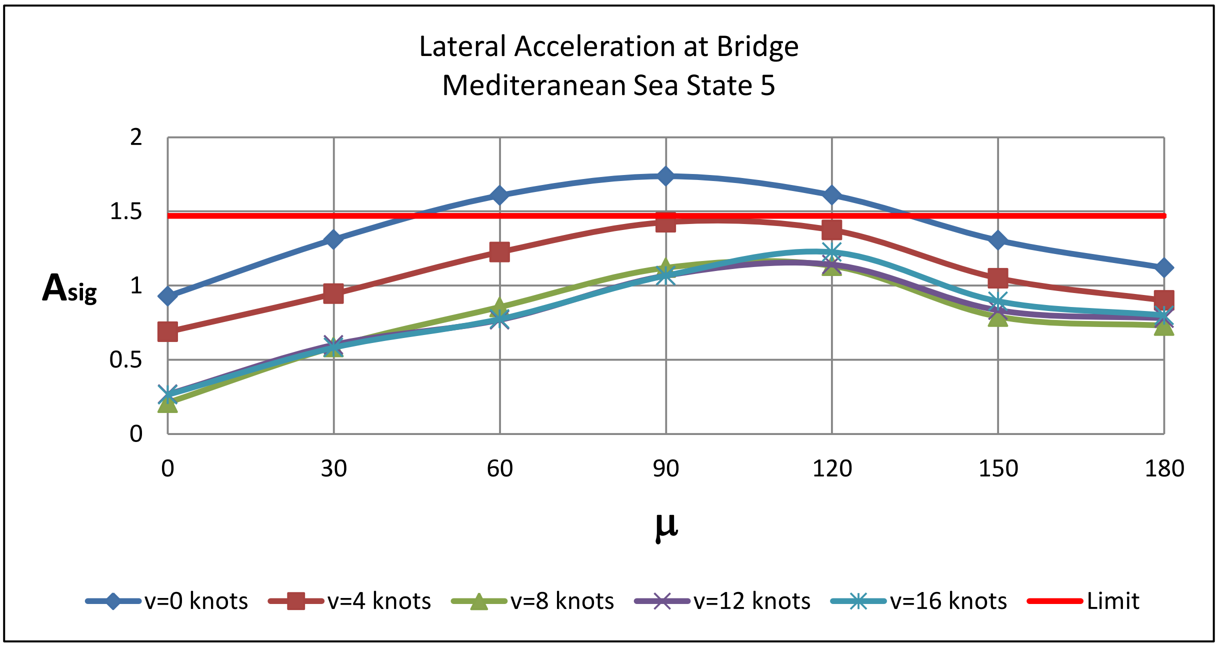


Figure 5-143 53 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2]

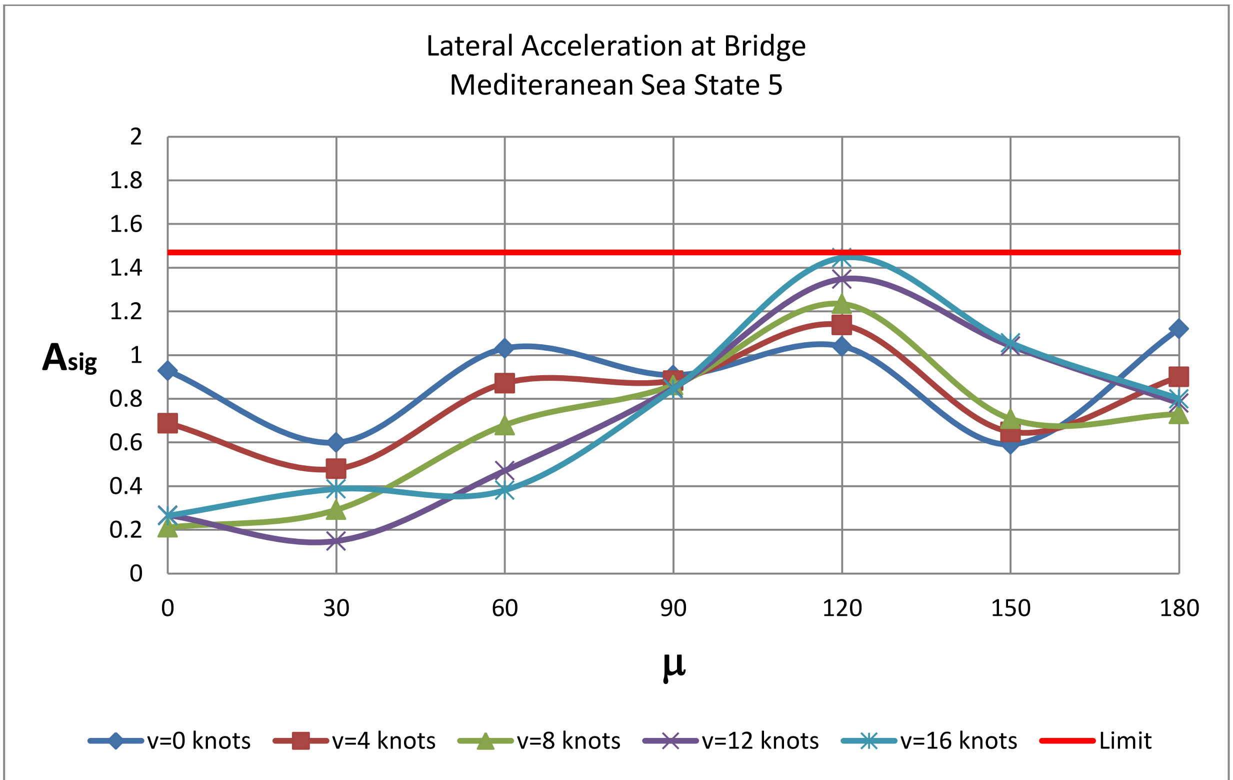


Figure 5-144 46 m motor yacht significant Lateral Acceleration amplitude at Bridge as a function of relative course and speed [m/s^2

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References

[1] Kadar Sarkozy, Ebru Narli, 2005, Effect of criteria on seakeeping performance assessment, OceanEngineering, 32, pp. 1161–1173.

[2] Guedes Soares C.; Moan T., 1991, Uncertainty in the Long Term Distribution of Wave InducedBending Moments for Fatigue Design of Ship Structures, Marine Structures, 4, pp. 294-315.

[3] Fonseca N.; Guedes Soares C., 2002, Sensitivity of the expected ships availability to different seakeeping criteria, Proceedings of the 21th International Conference on Offshore Mechanics and Arctic Engineering (OMAE2002), ASME paper OMAE-28542.

[4] Guedes Soares C.; Fonseca N.; Centeno R., 1995. Seakeeping performance of fishing vessels in the Portuguese economic zone, Proceedings International Conference on Seakeeping and Weather, Royal Institute of Naval Architects, London

[5] Salvesen N., Tuck E.O., Faltinsen O., 1970, Ship motions and sea loads, Transactions Society Naval Architects Marine Engineering, 78, pp. 250-287

[5a] Rusu L., Bernardino M., 2009, Estimation of the operability index of a containership operatingin Black Sea, The Annals of "Dunarea de Jos" University of Galati, Fascicle VIII, Tribology, No.2, http://www.om.ugal.ro/AnnalsFasc8Tribology/index.htm

[6] Gaillarde, G., Jan de Ridder, E., van Walree, F., Konig, J. Hydrodynamic advice of Sailing Yachts through Seakeeping Study, The 18th Chesapeake Sailing Yacht Symposium, Annapolis 03/2007.

[7] Redondo, G., and Bartesaghi, S., Seakeeping analysis and related seasickness: Computational Fluid Dynamics approach, Design and construction of Super and Mega Yacht, 8-9 May 2013, Genoa, Italy.

[8] Bunnik, T., van Daalen, E., Kapsenberg, G., Shin, Y., Deng, G., Delhommeau, G. Kashiwagi, M., and Beck, B., A comparative study on State-of-the-art prediction tools for seakeeping, 28th Symposium on Naval Hydrodynamics, Pasadena, California, 12-17 September 2012.

[9] Ferrant, P., Seakeeping course notes, Ecole Centrale de Nantes, EMSHIP, 2013.

[10] Combourieu, A., Previous sailing yacth seakeeping investigation, EMSHIP Master Thesis, Feb 2013.

[11] Bertram, V., Graf, K., and Soding, H., Une methode des tranches pour la tenue a lamer des Yachts - traitement des Ailerons, 10th Numerical Towing Tank Symposium.

[12] Arribas, P., and Pineiro, L., Seasickness prediction in passenger ships at the design stage, Ocean Engineering 34 (2007), pp.2086-2092.

[13] Larsson, L. and Eliasson E. Rolf, Principle of yacht Design, 3rd Edition, 2008.

[14] Lewis, E.V., Motions in Waves and controllability, Principles of Naval Architecture-Volume III, 1989.

[15] M.I.T., Ocean Wave Motion, free course notes: www.mit.edu

[16] Bertram, V., Practical Ship Hydrodynamics - Ship Seakeeping, Chapter 6, 2nd Edition, 2010, pp.143-199.

[17] Augier, B., Hauville, F., and Bot, P., Numerical Study of a Flexible sail Plan: Effect of Pitching Decomposition and Adjustments, INNOVSAIL 3rd Edition, Saint Lorient, June 2013.

[18] Kohlmos, A., and Bertram, V., Advanced Simulation for and Advanced Sailing Trimaran,Design and construction of Super and Mega Yacht, 8-9 May 2013, Genoa,Italy.

[19] Hydrostar Manual, Beurou Veritas free download.

[20] O'Hanlon, J.F., and McCauley, M.E., Motion sickness as a function of the frequency and acceleration of vertical sinusoidal motion, Aerospace Medicine 45, pp.366-369.

[21] Boote, D., Ragone, M., and Sculati, A., Seaworthiness of Aquastrada Class of Ships, FAST'95, Third International Conference on Fast Sea Transportation, Germany,1995.

[22] Courser, P., Seakeeping analysis for preliminary design, Seakeeper software, Formation Design System.

[23] Balze, R., and Devaux, H., Flutter of Racing Yacht Keels and Appendages, INNOVSAIL 3rd Edition, Saint Lorient, June 2013.

[24] Nabergoj R., Fondamenti di Tenuta della Nave al Mare, University of Trieste, 2010.

[25] Orozco J.M., Raposo C.V. and Malenica S., A Practical Procedure for the Evaluation of the Roll Motions of FPSO's Including the Non potential Damping, Offshore Technology Conference, Houston - Texas USA, 6-9 May 2002.

[26] Virtual Towing Tank training, London, 26-27 August 2013

Annexure I

Vertical acceleration (Significant amplitude at owners cabin 53 m motor yacht)

Aegean Sea

Vertical Acceleration at owner Cabin at sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	0.314873	0.400197	0.966852	0.923124	1.11824	0.619966	0.50549	0.619966	1.11824	0.923124	0.966852	0.400197	0.314873
4	0.188975	0.256873	0.841469	0.888421	1.251321	0.736811	0.588936	0.736811	1.251321	0.888421	0.841469	0.256873	0.188975
8	0.048883	0.037632	0.504864	0.86015	1.21669	0.707719	0.565713	0.707719	1.21669	0.86015	0.504864	0.037632	0.048883
12	0.266743	0.113023	0.16079	0.841901	1.176481	1.010764	1.031707	1.010764	1.176481	0.841901	0.16079	0.113023	0.266743
16	0.499291	0.243011	0.094998	0.835501	1.239511	1.194894	1.250749	1.194894	1.239511	0.835501	0.094998	0.243011	0.499291
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	0.978521	1.205119	1.788732	1.592238	1.944611	1.484867	1.278451	1.484867	1.944611	1.592238	1.788732	1.205119	0.978521
4	0.406278	0.567448	1.402086	1.545455	2.582199	2.560037	2.34996	2.560037	2.582199	1.545455	1.402086	0.567448	0.406278
8	0.155141	0.189967	0.840667	1.500899	3.134886	3.151831	2.881518	3.151831	3.134886	1.500899	0.840667	0.189967	0.155141
12	0.349499	0.171295	0.327983	1.464323	3.631553	3.545978	3.347422	3.545978	3.631553	1.464323	0.327983	0.171295	0.349499
16	0.648514	0.317344	0.175984	1.441618	4.064336	3.840846	3.391469	3.840846	4.064336	1.441618	0.175984	0.317344	0.648514
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 5

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	1.74764	1.964038	2.577922	2.295716	2.765892	2.27057	2.066804	2.27057	2.765892	2.295716	2.577922	1.964038	1.74764
4	0.811947	1.006422	2.017306	2.237124	3.657087	3.984923	3.943051	3.984923	3.657087	2.237124	2.017306	1.006422	0.811947
8	0.362863	0.440303	1.250852	2.181193	4.50829	5.548709	5.709564	5.548709	4.50829	2.181193	1.250852	0.440303	0.362863
12	0.464521	0.290187	0.584105	2.132846	5.328268	7.0378	7.229779	7.0378	5.328268	2.132846	0.584105	0.290187	0.464521
16	0.826092	0.41206	0.345901	2.09805	6.114688	8.204914	7.625858	8.204914	6.114688	2.09805	0.345901	0.41206	0.826092
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at owner Cabin at sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	0.389685	0.519739	0.937294	0.841188	1.034812	0.702342	0.57059	0.702342	1.034812	0.841188	0.937294	0.519739	0.389685
4	0.176392	0.252282	0.748192	0.81245	1.32317	1.076684	0.909241	1.076684	1.32317	0.81245	0.748192	0.252282	0.176392
8	0.054453	0.060228	0.442249	0.785595	1.489068	1.164943	0.96142	1.164943	1.489068	0.785595	0.442249	0.060228	0.054453
12	0.204903	0.090182	0.152154	0.764911	1.615263	1.25411	1.15517	1.25411	1.615263	0.764911	0.152154	0.090182	0.204903
16	0.38337	0.186923	0.080936	0.753776	1.73565	1.329124	1.236414	1.329124	1.73565	0.753776	0.080936	0.186923	0.38337
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	0.985049	1.092217	1.406585	1.252929	1.50463	1.249973	1.147113	1.249973	1.50463	1.252929	1.406585	1.092217	0.985049
4	0.473282	0.573194	1.100962	1.221987	1.984197	2.175999	2.169928	2.175999	1.984197	1.221987	1.100962	0.573194	0.473282
8	0.220497	0.264614	0.689608	1.192399	2.443579	3.057742	3.188385	3.057742	2.443579	1.192399	0.689608	0.264614	0.220497
12	0.25088	0.169077	0.336707	1.166646	2.890946	3.920813	4.096042	3.920813	2.890946	1.166646	0.336707	0.169077	0.25088
16	0.436045	0.220135	0.205713	1.147552	3.321554	4.613676	4.420941	4.613676	3.321554	1.147552	0.205713	0.220135	0.436045
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 5

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity							**Significant amplitude**						
0	1.40774	1.511317	1.840479	1.644455	1.94767	1.681138	1.57531	1.681138	1.94767	1.644455	1.840479	1.511317	1.40774
4	0.758792	0.862921	1.445279	1.609152	2.546667	2.814015	2.836123	2.814015	2.546667	1.609152	1.445279	0.862921	0.758792
8	0.408371	0.470398	0.94644	1.575086	3.122208	3.947283	4.198741	3.947283	3.122208	1.575086	0.94644	0.470398	0.408371
12	0.339761	0.296261	0.540345	1.545009	3.694536	5.103855	5.556253	5.103855	3.694536	1.545009	0.540345	0.296261	0.339761
16	0.508363	0.283289	0.369268	1.52092	4.238402	6.117302	6.441492	6.117302	4.238402	1.52092	0.369268	0.283289	0.508363
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical acceleration (Significant amplitude at Bridge 53 m motor yacht)

Aegean Sea

Vertical Acceleration at Bridge in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.112772	0.166072	0.52164	0.889998	0.679655	0.379993	0.318058	0.379993	0.679655	0.889998	0.52164	0.166072	0.112772
4	0.101696	0.134891	0.501753	0.87238	0.819924	0.456323	0.378396	0.456323	0.819924	0.87238	0.501753	0.134891	0.101696
8	0.020226	0.024973	0.33876	0.858377	0.826269	0.438456	0.357519	0.438456	0.826269	0.858377	0.33876	0.024973	0.020226
12	0.046792	0.064436	0.126339	0.849907	0.797937	0.43012	0.672501	0.43012	0.797937	0.849907	0.126339	0.064436	0.046792
16	0.288099	0.106629	0.036999	0.848284	0.77904	0.481303	0.508225	0.481303	0.77904	0.848284	0.036999	0.106629	0.288099
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at Bridge in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.46709	0.622727	1.121045	1.550711	1.278914	0.891881	0.764931	0.891881	1.278914	1.550711	1.121045	0.622727	0.46709
4	0.217882	0.322057	0.919773	1.526996	1.806424	1.608413	1.451875	1.608413	1.806424	1.526996	0.919773	0.322057	0.217882
8	0.084823	0.112254	0.603278	1.502398	2.306068	2.073863	1.851105	2.073863	2.306068	1.502398	0.603278	0.112254	0.084823
12	0.069441	0.099323	0.268538	1.480613	2.743909	2.331706	2.2353	2.331706	2.743909	1.480613	0.268538	0.099323	0.069441
16	0.375557	0.141627	0.115537	1.466281	3.057633	2.541463	2.102465	2.541463	3.057633	1.466281	0.115537	0.141627	0.375557
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at Bridge in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.951939	1.130786	1.715372	2.245324	1.89677	1.414294	1.261064	1.414294	1.89677	2.245324	1.715372	1.130786	0.951939
4	0.48506	0.630276	1.388275	2.215623	2.629687	2.572376	2.492303	2.572376	2.629687	2.215623	1.388275	0.630276	0.48506
8	0.222931	0.290903	0.936689	2.184958	3.394205	3.815664	3.844651	3.815664	3.394205	2.184958	0.936689	0.290903	0.222931
12	0.125666	0.182908	0.492004	2.156308	4.149753	5.008159	5.065035	5.008159	4.149753	2.156308	0.492004	0.182908	0.125666
16	0.479175	0.189974	0.274326	2.134227	4.829992	5.91703	5.244171	5.91703	4.829992	2.134227	0.274326	0.189974	0.479175
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at Bridge in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.163419	0.243796	0.552159	0.815396	0.656124	0.41875	0.347493	0.41875	0.656124	0.815396	0.552159	0.243796	0.163419
4	0.092649	0.135297	0.470656	0.800781	0.901018	0.665318	0.565041	0.665318	0.901018	0.800781	0.470656	0.135297	0.092649
8	0.026822	0.034897	0.307706	0.786026	1.062661	0.740156	0.600705	0.740156	1.062661	0.786026	0.307706	0.034897	0.026822
12	0.037114	0.051436	0.122607	0.773879	1.173675	0.725248	0.749289	0.725248	1.173675	0.773879	0.122607	0.051436	0.037114
16	0.221715	0.082723	0.090857	0.767072	1.233827	0.746973	0.640918	0.746973	1.233827	0.767072	0.040857	0.082723	0.221715
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at Bridge in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.554443	0.646014	0.949516	1.226575	1.04329	0.789427	0.709087	0.789427	1.04329	1.226575	0.949516	0.646014	0.554443
4	0.29204	0.369014	0.767767	1.210895	1.437386	1.415518	1.381199	1.415518	1.437386	1.210895	0.767767	0.369014	0.29204
8	0.140538	0.180543	0.523232	1.194677	1.84953	2.115596	2.160957	2.115596	1.84953	1.194677	0.523232	0.180543	0.140538
12	0.076656	0.110468	0.286623	1.179421	2.26211	2.815662	2.89813	2.815662	2.26211	1.179421	0.286623	0.110468	0.076656
16	0.253137	0.103721	0.168406	1.167303	2.639175	3.373685	3.113413	3.373685	2.639175	1.167303	0.168406	0.103721	0.253137
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at Bridge in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.889441	0.98403	1.312028	1.615451	1.41147	1.126788	1.036367	1.126788	1.41147	1.615451	1.312028	0.98403	0.889441
4	0.52597	0.614668	1.063874	1.597594	1.899765	1.890369	1.863047	1.890369	1.899765	1.597594	1.063874	0.614668	0.52597
8	0.295776	0.357973	0.758215	1.578874	2.411237	2.784535	2.905304	2.784535	2.411237	1.578874	0.758215	0.357973	0.295776
12	0.165573	0.222345	0.479746	1.561006	2.933405	3.750987	4.047782	3.750987	2.933405	1.561006	0.479746	0.222345	0.165573
16	0.29892	0.15887	0.328104	1.545702	3.413575	4.64932	4.838658	4.64932	3.413575	1.545702	0.328104	0.15887	0.29892
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical acceleration (Significant amplitude at Saloon 53 m motor yacht)

Aegean Sea

Vertical Acceleration at saloon in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.300044	0.334241	0.556575	0.842777	0.455605	0.13746	0.086363	0.13746	0.455605	0.842777	0.556575	0.334241	0.300044
4	0.112912	0.146174	0.335954	0.850815	0.53123	0.210316	0.200026	0.210316	0.53123	0.850815	0.335954	0.146174	0.112912
8	0.04937	0.038454	0.198527	0.862331	0.602165	0.375102	0.303126	0.375102	0.602165	0.862331	0.198527	0.038454	0.04937
12	0.448731	0.279551	0.21179	0.876128	0.708726	0.555113	0.694231	1.155113	0.708726	0.876128	0.11179	0.279551	0.448731
16	0.45786	0.297903	0.562293	0.891683	0.98484	0.669594	0.763082	1.669594	0.98484	0.891683	0.096229	0.297903	0.45786
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at saloon in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.682113	0.774071	1.104434	1.488922	1.006306	0.519372	0.380663	0.519372	1.006306	1.488922	1.104434	0.774071	0.682113
4	0.271701	0.350475	0.71406	1.501701	1.300384	0.834401	0.685578	0.834401	1.300384	1.501701	0.71406	0.350475	0.271701
8	0.107965	0.139382	0.46269	1.51331	1.763843	1.398431	1.196285	1.398431	1.763843	1.51331	0.46269	0.139382	0.107965
12	0.581475	0.365562	0.274085	1.523552	2.352461	2.371888	2.471422	2.371888	2.352461	1.523552	0.274085	0.365562	0.581475
16	0.598635	0.388874	0.177875	1.534056	2.978985	3.175167	2.634303	3.175167	2.978985	1.534056	0.177875	0.388874	0.598635
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at saloon in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	1.128676	1.249828	1.67993	2.170576	1.574137	0.985936	0.815468	0.985936	1.574137	2.170576	1.67993	1.249828	1.128676
4	0.512671	0.636617	1.144586	2.186311	2.006629	1.506873	1.338117	1.506873	2.006629	2.186311	1.144586	0.636617	0.512671
8	0.237057	0.311474	0.780106	2.201413	2.652577	2.506148	2.384202	2.506148	2.652577	2.201413	0.780106	0.311474	0.237057
12	0.743834	0.482795	0.502081	2.21503	3.523375	4.323252	4.509451	4.323252	3.523375	2.21503	0.502081	0.482795	0.743834
16	0.763909	0.498549	0.332796	2.228008	4.570748	6.057287	5.360225	6.057287	4.570748	2.228008	0.332796	0.498549	0.763909
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean Sea

Vertical Acceleration at saloon in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.31529	0.360939	0.551998	0.776961	0.485564	0.199209	0.127478	0.199209	0.485564	0.776961	0.551998	0.360939	0.31529
4	0.119498	0.15567	0.342335	0.784791	0.617964	0.31935	0.261184	0.31935	0.617964	0.784791	0.342335	0.15567	0.119498
8	0.045795	0.050758	0.213709	0.792011	0.803241	0.526589	0.42323	0.526589	0.803241	0.792011	0.213709	0.050758	0.045795
12	0.343918	0.214616	0.120673	0.798503	1.014262	1.036158	1.162751	1.036158	1.014262	0.798503	0.120673	0.214616	0.343918
16	0.352925	0.229399	0.083917	0.805401	1.25737	1.419619	1.159332	1.419619	1.25737	0.805401	0.083917	0.229399	0.352925
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at saloon in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.63708	0.701785	0.929592	1.18742	0.875463	0.569635	0.481481	0.569635	0.875463	1.18742	0.929592	0.701785	0.63708
4	0.302136	0.369684	0.641418	1.195765	1.111741	0.859092	0.774631	0.859092	1.111741	1.195765	0.641418	0.369684	0.302136
8	0.146091	0.189599	0.443652	1.203773	1.458565	1.400383	1.346834	1.400383	1.458565	1.203773	0.443652	0.189599	0.146091
12	0.393885	0.260079	0.292097	1.210986	1.924518	2.388335	2.506596	2.388335	1.924518	1.210986	0.292097	0.260079	0.393885
16	0.403231	0.26424	0.196732	1.217785	2.487902	3.365585	3.067625	3.365585	2.487902	1.217785	0.196732	0.26424	0.403231
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at saloon in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							**Significant amplitude**						
0	0.949269	1.026073	1.285672	1.572043	1.229524	0.900192	0.807922	0.900192	1.229524	1.572043	1.285672	1.026073	0.949269
4	0.525321	0.608942	0.93013	1.581817	1.537916	1.294599	1.217551	1.294599	1.537916	1.581817	0.93013	0.608942	0.525321
8	0.295827	0.362376	0.680808	1.590947	1.969352	1.941274	1.903476	1.941274	1.969352	1.590947	0.680808	0.362376	0.295827
12	0.472813	0.349609	0.486389	1.599024	2.532494	3.085683	3.289039	3.085683	2.532494	1.599024	0.486389	0.349609	0.472813
16	0.468757	0.32118	0.352083	1.606473	3.199039	4.345232	4.344393	4.345232	3.199039	1.606473	0.352083	0.32118	0.468757
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Lateral acceleration (Significant amplitude at Bridge 53 m motor yacht)

Aegean Sea

Lateral acceleration in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	1.5980E-01	1.0269E-01	2.1473E-01	3.4426E-01	2.5527E-01	9.8713E-02	1.2000E-01	9.8713E-02	2.5527E-01	3.4426E-01	2.1473E-01	1.0269E-01	1.2000E-01
4	1.4129E-01	7.6983E-02	1.7240E-01	3.2869E-01	3.1078E-01	1.2510E-01	1.4000E-01	1.2510E-01	3.1078E-01	3.2869E-01	1.7240E-01	7.6983E-02	1.4000E-01
8	1.3706E-01	6.7020E-02	1.3244E-01	3.1484E-01	3.6851E-01	1.5569E-01	1.6000E-01	1.5569E-01	3.6851E-01	3.1484E-01	1.3244E-01	6.7020E-02	1.6000E-01
12	1.2856E-01	2.3794E-01	1.0198E-01	3.0365E-01	4.3363E-01	3.0577E-01	1.9000E-01	3.0577E-01	4.3363E-01	3.0365E-01	1.0198E-01	2.3794E-01	1.9000E-01
16	1.1190E-01	2.0316E-01	1.1986E-01	2.9569E-01	5.4961E-01	3.5156E-01	2.2000E-01	3.5156E-01	5.4961E-01	2.9569E-01	1.1986E-01	2.0316E-01	2.2000E-01
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Lateral acceleration in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	3.80594E-01	4.72291E-01	7.28935E-01	8.71734E-01	7.45363E-01	4.69163E-01	2.90000E-01	4.69163E-01	7.45363E-01	8.71734E-01	7.28935E-01	4.72291E-01	3.00000E-01
4	3.55849E-01	4.16594E-01	6.39876E-01	8.53937E-01	8.21710E-01	5.11877E-01	2.80000E-01	5.11877E-01	8.21710E-01	8.53937E-01	6.39876E-01	4.16594E-01	3.00000E-01
8	2.62852E-01	3.67803E-01	5.59315E-01	8.39713E-01	8.96164E-01	5.61079E-01	2.70000E-01	5.61079E-01	8.96164E-01	8.39713E-01	5.59315E-01	3.67803E-01	3.00000E-01
12	2.06486E-01	5.49557E-01	5.10358E-01	8.29879E-01	9.75545E-01	7.27336E-01	2.60000E-01	7.27336E-01	9.75545E-01	8.29879E-01	5.10358E-01	5.49557E-01	3.00000E-01
16	1.92086E-01	5.12876E-01	5.28209E-01	8.24474E-01	1.10669E+00	8.15789E-01	2.50000E-01	8.15789E-01	1.10669E+00	8.24474E-01	5.28209E-01	5.12876E-01	3.00000E-01
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Lateral Acceleration in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	0.706514	0.792395	1.191308	1.470096	1.375415	0.912467	0.600000	0.792395	1.191308	1.470096	1.375415	0.912467	0.600000
4	0.626561	0.741207	1.089631	1.478076	1.461517	0.987353	0.650000	0.741207	1.089631	1.478076	1.461517	0.987353	0.650000
8	0.415675	0.758394	1.080113	1.465939	1.520345	1.051854	0.700000	0.758394	1.080113	1.465939	1.520345	1.051854	0.700000
12	0.136830	0.937633	1.018700	1.457031	1.619760	1.234562	0.800000	0.937633	1.018700	1.457031	1.619760	1.234562	0.800000
16	0.270069	0.899305	1.035496	1.453509	1.774245	1.341281	0.900000	0.899305	1.035496	1.453509	1.774245	1.341281	0.900000
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Mediteranean Sea

Lateral Acceleration in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	0.1535770	0.1655915	0.2943141	0.3824064	0.3112157	0.1648369	0.0300000	0.1648369	0.3112157	0.3824064	0.2943141	0.1655915	0.1000000
4	0.1443875	0.1414256	0.2484110	0.3711080	0.3555297	0.1864181	0.0700000	0.1864181	0.3555297	0.3711080	0.2484110	0.1414256	0.1000000
8	0.1372086	0.1229296	0.2062541	0.3615655	0.3995386	0.2136093	0.0900000	0.2136093	0.3995386	0.3615655	0.2062541	0.1229296	0.1000000
12	0.1244737	0.2449569	0.1783263	0.3544022	0.4480559	0.3218364	0.1100000	0.3218364	0.4480559	0.3544022	0.1783263	0.2449569	0.1000000
16	0.1150474	0.2204225	0.1911353	0.3498435	0.5325370	0.3677675	0.1500000	0.3677675	0.5325370	0.3498435	0.1911353	0.2204225	0.1000000
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Lateral Acceleration in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	7.2259E-01	1.1927E+00	1.4033E+00	1.5044E+00	1.4088E+00	1.1883E+00	1.0000E+00	1.1883E+00	1.4088E+00	1.5044E+00	1.4033E+00	1.1927E+00	1.0000E+00
4	4.5266E-01	8.4243E-01	1.0369E+00	1.1941E+00	1.1620E+00	9.2261E-01	7.0000E-01	9.2261E-01	1.1620E+00	1.1941E+00	1.0369E+00	8.4243E-01	7.0000E-01
8	3.1420E-01	5.9679E-01	7.7836E-01	9.8670E-01	1.0125E+00	7.5684E-01	4.0000E-01	7.5684E-01	1.0125E+00	9.8670E-01	7.7836E-01	5.9679E-01	5.0000E-01
12	1.7230E-01	6.3328E-01	6.9610E-01	9.3248E-01	1.0147E+00	7.9972E-01	4.5000E-01	7.9972E-01	1.0147E+00	9.3248E-01	6.9610E-01	6.3328E-01	4.5000E-01
16	1.4250E-01	5.7414E-01	6.6413E-01	8.9104E-01	1.0545E+00	8.1520E-01	4.9000E-01	8.1520E-01	1.0545E+00	8.9104E-01	6.6413E-01	5.7414E-01	4.1000E-01
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Lateral acceleration in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	9.285E-01	1.311E+00	1.608E+00	1.737E+00	1.610E+00	1.305E+00	1.120E+00	1.305E+00	1.610E+00	1.737E+00	1.608E+00	1.311E+00	1.000E+00
4	6.881E-01	9.448E-01	1.226E+00	1.427E+00	1.374E+00	1.050E+00	9.000E-01	1.050E+00	1.374E+00	1.427E+00	1.226E+00	9.448E-01	7.000E-01
8	2.107E-01	5.861E-01	8.560E-01	1.120E+00	1.133E+00	7.906E-01	7.300E-01	7.906E-01	1.133E+00	1.120E+00	8.560E-01	5.861E-01	7.511E-17
12	2.674E-01	6.010E-01	7.693E-01	1.067E+00	1.142E+00	8.339E-01	7.800E-01	8.339E-01	1.142E+00	1.067E+00	7.693E-01	6.010E-01	3.500E-01
16	2.645E-01	5.822E-01	7.743E-01	1.067E+00	1.225E+00	8.945E-01	8.000E-01	8.945E-01	1.225E+00	1.067E+00	7.743E-01	5.822E-01	3.500E-01
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Roll Motion(Significant amplitude of Roll motion 53 m motor yacht)

Aegean Sea

Roll Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	5.119E-01	8.531E-01	9.197E-01	1.435E+00	9.228E-01	8.615E-01	7.000E-01	8.615E-01	9.228E-01	1.435E+00	9.197E-01	8.531E-01	7.000E-01
4	9.635E-01	1.570E+00	1.603E+00	2.139E+00	1.314E+00	1.259E+00	1.100E+00	1.259E+00	1.314E+00	1.839E+00	1.303E+00	1.270E+00	1.100E+00
8	4.059E-01	1.133E+00	1.155E+00	1.641E+00	1.124E+00	1.054E+00	9.000E-01	1.054E+00	1.124E+00	1.641E+00	1.155E+00	1.133E+00	9.000E-01
12	5.159E-01	1.379E+00	1.386E+00	1.741E+00	1.226E+00	1.144E+00	1.000E+00	1.144E+00	1.226E+00	1.741E+00	1.386E+00	1.379E+00	1.544E-16
16	5.557E-01	1.514E+00	1.743E+00	1.840E+00	1.314E+00	1.226E+00	1.100E+00	1.226E+00	1.314E+00	1.840E+00	1.743E+00	1.514E+00	1.100E+00
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Roll Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	5.0000	5.2943	5.7779	6.8135	5.7979	5.2966	5.0000	5.2943	5.7779	6.8135	5.7979	5.2966	5.0000
4	6.1000	6.3912	6.8881	6.9166	4.8701	2.9180	2.1000	6.3912	6.8881	6.9166	4.8701	2.9180	2.1000
8	4.0000	4.4131	5.2387	5.8132	4.5586	2.3347	1.0000	4.4131	5.2387	5.8132	4.5586	2.3347	1.0000
12	2.0000	2.7268	3.1716	3.8043	2.7396	1.8430	1.3000	2.7268	3.1716	3.8043	2.7396	1.8430	1.3000
16	1.0000	2.0293	2.8400	2.9916	1.7128	1.3321	0.8000	2.0293	2.8400	2.9916	1.7128	1.3321	0.8000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Roll Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	12.0000	12.5805	13.7622	15.1824	13.7793	10.5860	9.0000	12.5860	13.7793	15.1824	13.7622	12.5805	9.0000
4	9.0000	9.6130	10.7542	12.1831	7.7611	4.5917	2.0000	9.5917	10.7611	12.1831	10.7542	9.6130	2.0000
8	4.0000	4.7831	5.7323	7.1699	5.7566	4.6067	4.0000	4.6067	5.7566	7.1699	5.7323	4.7831	4.0000
12	2.2000	3.4258	3.9271	5.3471	3.9483	2.8157	2.2000	2.8157	3.9483	5.3471	3.9271	3.4258	2.2000
16	1.8000	3.6579	3.8197	4.9192	3.5325	2.4002	1.8000	2.4002	3.5325	4.9192	3.8197	3.6579	1.8000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteranean Sea

Roll Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	2.7000	3.1491	3.8686	4.1101	3.4790	2.4511	1.8000	3.1491	3.8686	4.1101	3.4790	2.4511	1.8000
4	3.0000	3.1420	3.2685	3.8125	3.2628	1.9632	1.3000	3.1420	3.2685	3.8125	3.2628	1.9632	1.3000
8	2.3000	2.7692	3.0179	3.5127	3.0629	1.6697	1.0000	2.7692	3.0179	3.5127	3.0629	1.6697	1.0000
12	2.0000	2.3342	2.4332	2.8106	2.2576	1.1694	0.6000	2.3342	2.4332	2.8106	2.2576	1.1694	0.6000
16	1.2000	1.6339	1.8706	2.0067	1.4454	0.8590	0.5000	1.6339	1.8706	2.0067	1.4454	0.8590	0.5000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteramean Sea

Roll Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	8.0000	8.3690	9.0688	9.8316	9.0768	7.3716	6.0000	8.3716	9.0768	9.8316	9.0688	8.3690	8.0000
4	6.0000	6.5845	7.3592	7.8313	7.0716	5.3745	4.0000	6.3745	7.0716	7.8313	7.0592	6.3845	6.0000
8	3.0000	3.4618	4.0325	4.8229	4.0737	3.3829	3.0000	3.3829	4.0737	4.8229	4.0325	3.4618	3.0000
12	2.0000	2.6844	3.0008	3.8089	3.0749	2.3876	2.0000	2.3876	3.0749	3.8089	3.0008	2.6844	2.0000
16	1.0000	2.0395	2.1205	2.7924	2.0724	1.3795	1.0000	1.3795	2.0724	2.7924	2.1205	2.0395	1.0000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Roll Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity							Significant amplitude						
0	10.0000	10.8583	12.0198	12.9643	12.0257	10.8596	10.0000	10.8596	12.0257	12.9643	12.0198	10.8583	10.0000
4	8.0000	8.8421	9.9738	10.9609	10.0484	8.8792	8.0000	8.8792	10.0484	10.9609	9.9738	8.8421	8.0000
8	4.0000	4.8269	5.8599	6.9431	6.0857	4.9056	4.0000	4.9056	6.0857	6.9431	5.8599	4.8269	4.0000
12	2.4000	3.3642	4.0746	5.3177	4.5309	3.3264	2.4000	3.3264	4.5309	5.3177	4.0746	3.3642	2.4000
16	1.8000	3.2050	3.4167	4.6906	3.9756	2.7343	1.8000	2.7343	3.9756	4.6906	3.4167	3.2050	1.8000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Pitch Motion(Significant amplitude of Pitch motion 53 m motor yacht)

Aegean Sea

Pitch Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	6.94E-01	0.845108	1.478044	0.151052	1.421742	0.84368	6.47E-01	0.84368	1.421742	0.151052	1.478044	0.845108	6.94E-01
4	6.06E-01	0.731655	1.459926	0.083612	1.189907	0.756336	5.85E-01	0.756336	1.189907	0.083612	1.459926	0.731655	6.06E-01
8	2.93E-01	0.312492	1.141918	0.069116	0.961611	0.577309	4.53E-01	0.577309	0.961611	0.069116	1.141918	0.312492	2.93E-01
12	3.38E-01	0.33928	0.597366	0.120091	0.804901	0.439713	3.62E-01	0.439713	0.804901	0.120091	0.597366	0.33928	3.38E-01
16	4.87E-01	0.45386	0.238805	0.175554	0.705424	0.367413	2.88E-01	0.367413	0.705424	0.175554	0.238805	0.45386	4.87E-01
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Aegean Sea

Pitch Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	2.71E+00	3.027394	3.196847	0.209689	3.074705	2.97308	2.66E+00	2.97308	3.074705	0.209689	3.196847	3.027394	2.71E+00
4	1.84E+00	2.133478	2.800015	0.117674	3.133081	3.455335	3.22E+00	3.455335	3.133081	0.117674	2.800015	2.133478	1.84E+00
8	1.45E+00	1.530927	2.174635	0.115548	3.062393	3.216633	2.98E+00	3.216633	3.062393	0.115548	2.174635	1.530927	1.45E+00
12	1.55E+00	1.585464	1.411591	0.194207	3.014107	2.905012	2.69E+00	2.905012	3.014107	0.194207	1.411591	1.585464	1.55E+00
16	1.80E+00	1.795433	1.05625	0.274093	3.017109	2.74034	2.31E+00	2.74034	3.017109	0.274093	1.05625	1.795433	1.80E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Aegean Sea

Roll Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	5.37E+00	5.494685	4.900694	0.278741	4.757193	5.387226	5.26E+00	5.387226	4.757193	0.278741	4.900694	5.494685	5.37E+00
4	3.99E+00	4.164607	4.317558	0.15667	4.97577	6.417282	6.51E+00	6.417282	4.97577	0.15667	4.317558	4.164607	3.99E+00
8	3.44E+00	3.401872	3.502303	0.161177	4.98623	6.538185	6.72E+00	6.538185	4.98623	0.161177	3.502303	3.401872	3.44E+00
12	3.49E+00	3.374924	2.598089	0.272802	4.915408	6.503262	6.59E+00	6.503262	4.915408	0.272802	2.598089	3.374924	3.49E+00
16	3.83E+00	3.575877	2.170487	0.385949	4.957263	6.526548	5.97E+00	6.526548	4.957263	0.385949	2.170487	3.575877	3.83E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Mediteranean Sea

Pitch Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	9.96E-01	1.202318	1.566795	0.121106	1.496649	1.195835	9.70E-01	1.195835	1.496649	0.121106	1.566795	1.202318	9.96E-01
4	6.92E-01	0.852268	1.40604	0.067573	1.436164	1.278615	1.08E+00	1.278615	1.436164	0.067573	1.40604	0.852268	6.92E-01
8	4.58E-01	0.500382	1.071304	0.062495	1.319066	1.078776	9.02E-01	1.078776	1.319066	0.062495	1.071304	0.500382	4.58E-01
12	5.08E-01	0.541195	0.613497	0.105164	1.241568	0.873483	7.49E-01	0.873483	1.241568	0.105164	0.613497	0.541195	5.08E-01
16	6.26E-01	0.657907	0.376322	0.149314	1.191708	0.760749	6.14E-01	0.760749	1.191708	0.149314	0.376322	0.657907	6.26E-01
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Pitch Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	3.12E+00	3.140052	2.713309	0.148982	2.638727	3.08291	3.06E+00	3.08291	2.638727	0.148982	2.713309	3.140052	3.12E+00
4	2.38E+00	2.433251	2.400149	0.083692	2.764474	3.661978	3.77E+00	3.661978	2.764474	0.083692	2.400149	2.433251	2.38E+00
8	2.09E+00	2.033102	1.969916	0.086832	2.782276	3.779157	3.95E+00	3.779157	2.782276	0.086832	1.969916	2.033102	2.09E+00
12	2.10E+00	2.005274	1.502648	0.147314	2.747479	3.772717	3.89E+00	3.772717	2.747479	0.147314	1.502648	2.005274	2.10E+00
16	2.27E+00	2.099298	1.279515	0.209036	2.761357	3.773437	3.57E+00	3.773437	2.761357	0.209036	1.279515	2.099298	2.27E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Pitch Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity	Significant amplitude												
0	5.00E+00	4.798476	3.754926	0.179042	3.673405	4.739777	4.94E+00	4.739777	3.673405	0.179042	3.754926	4.798476	5.00E+00
4	4.17E+00	4.010549	3.383128	0.100747	3.845636	5.490858	5.88E+00	5.490858	3.845636	0.100747	3.383128	4.010549	4.17E+00
8	3.82E+00	3.56854	2.900328	0.10753	3.912512	5.806696	6.33E+00	5.806696	3.912512	0.10753	2.900328	3.56854	3.82E+00
12	3.77E+00	3.48515	2.410298	0.183148	3.89812	5.811468	6.31E+00	5.811468	3.89812	0.183148	2.410298	3.48515	3.77E+00
16	3.90E+00	3.539319	2.166575	0.262356	3.873732	5.689219	5.99E+00	5.689219	3.873732	0.262356	2.166575	3.539319	3.90E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Vertical acceleration (Significant amplitude at owners cabin 46 m motor yacht)

Aegean Sea

Vertical Acceleration at owner Cabin at sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.344578	0.44481	0.951265	1.067925	1.39365	0.716907	0.530392	0.716907	1.39365	1.067925	0.951265	0.44481	0.344578
4	0.163471	0.241581	0.805822	1.027262	1.836308	1.112243	0.832224	1.112243	1.836308	1.027262	0.805822	0.241581	0.163471
8	0.032576	0.041177	0.462247	0.993592	1.962685	1.164678	0.889521	1.164678	1.962685	0.993592	0.462247	0.041177	0.032576
12	0.067525	0.046362	0.132717	0.978499	1.863431	2.50947	0.832472	2.50947	1.863431	0.978499	0.132717	0.046362	0.067525
16	0.698211	0.963296	0.031131	0.988137	1.870791	2.965229	2.866624	2.965229	1.870791	0.988137	0.031131	0.963296	0.698211
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	1.044935	1.215258	1.690396	1.737655	2.183361	1.556074	1.33808	1.556074	2.183361	1.737655	1.690396	1.215258	1.044935
4	0.420179	0.56405	1.334195	1.691931	3.0853	3.096072	2.931533	3.096072	3.0853	1.691931	1.334195	0.56405	0.420179
8	0.170402	0.215757	0.784741	1.65311	4.013043	4.640615	4.175973	4.640615	4.013043	1.65311	0.784741	0.215757	0.170402
12	0.108442	0.1165	0.309083	1.630704	5.234985	5.805257	5.062971	5.805257	5.234985	1.630704	0.309083	0.1165	0.108442
16	0.906404	1.24603	0.149256	1.632375	6.503176	7.271459	6.370206	7.271459	6.503176	1.632375	0.149256	1.24603	0.906404
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 5

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	1.762614	1.925568	2.442163	2.472066	3.058528	2.303563	2.074817	2.303563	3.058528	2.472066	2.442163	1.925568	1.762614
4	0.824672	0.99383	1.924476	2.414962	4.253542	4.419584	4.389934	4.419584	4.253542	2.414962	1.924476	0.99383	0.824672
8	0.386503	0.468517	1.182412	2.366793	5.437091	6.90178	7.080842	6.90178	5.437091	2.366793	1.182412	0.468517	0.386503
12	0.20034	0.250188	0.572323	2.337701	6.879744	9.998106	10.71922	9.998106	6.879744	2.337701	0.572323	0.250188	0.20034
16	1.15364	1.58524	0.337829	2.333327	8.498512	14.36424	12.88508	14.36424	8.498512	2.333327	0.337829	1.58524	1.15364
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at owner Cabin at sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.436561	0.550783	0.887815	0.931446	1.192174	0.770169	0.613277	0.770169	1.192174	0.931446	0.887815	0.550783	0.436561
4	0.168317	0.245441	0.709329	0.901918	1.70683	1.447785	1.237621	1.447785	1.70683	0.901918	0.709329	0.245441	0.168317
8	0.054598	0.071028	0.406472	0.876432	2.118557	1.9105	1.548235	1.9105	2.118557	0.876432	0.406472	0.071028	0.054598
12	0.055054	0.046215	0.133221	0.862646	2.497483	2.4644	1.525448	2.4644	2.497483	0.862646	0.133221	0.046215	0.055054
16	0.536035	0.737827	0.048719	0.866214	2.911926	2.823104	2.583565	2.823104	2.911926	0.866214	0.048719	0.737827	0.536035
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.986298	1.067795	1.333084	1.343812	1.656733	1.263402	1.145737	1.263402	1.656733	1.343812	1.333084	1.067795	0.986298
4	0.477646	0.564748	1.050416	1.313564	2.300034	2.391435	2.381516	2.391435	2.300034	1.313564	1.050416	0.564748	0.477646
8	0.232295	0.278173	0.653311	1.287923	2.9317	3.724239	3.853568	3.724239	2.9317	1.287923	0.653311	0.278173	0.232295
12	0.119879	0.151268	0.331294	1.272258	3.692895	5.413435	5.870153	5.413435	3.692895	1.272258	0.331294	0.151268	0.119879
16	0.608611	0.836386	0.203627	1.269385	4.550453	7.783369	7.129114	7.783369	4.550453	1.269385	0.203627	0.836386	0.608611
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical Acceleration at owner Cabin at sea state 5

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	1.390209	1.470991	1.747446	1.737016	2.107459	1.685564	1.559595	1.685564	2.107459	1.737016	1.747446	1.470991	1.390209
4	0.753165	0.845616	1.380634	1.702183	2.909096	3.048536	3.039792	3.048536	2.909096	1.702183	1.380634	0.845616	0.753165
8	0.41687	0.479623	0.904095	1.671943	3.701654	4.65563	4.793884	4.65563	3.701654	1.671943	0.904095	0.479623	0.41687
12	0.2294	0.28571	0.535898	1.652691	4.665552	6.509466	7.062588	6.509466	4.665552	1.652691	0.535898	0.28571	0.2294
16	0.704842	0.969031	0.372602	1.647808	5.732308	9.066297	8.878394	9.066297	5.732308	1.647808	0.372602	0.969031	0.704842
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical acceleration (Significant amplitude at Bridge 53 m motor yacht)

Aegean Sea

Vertical Acceleration at Bridge in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.215511	0.290206	0.709381	1.03474	1.054109	0.545443	0.40927	0.545443	1.054109	1.03474	0.709381	0.290206	0.215511
4	0.117948	0.173464	0.618753	1.005613	1.439509	0.860677	0.648936	0.860677	1.439509	1.005613	0.618753	0.173464	0.117948
8	0.02463	0.031726	0.377514	0.979298	1.5711	0.911965	0.697505	0.911965	1.5711	0.979298	0.377514	0.031726	0.02463
12	0.052845	0.03468	0.117981	0.965219	1.510774	1.344956	0.655902	1.344956	1.510774	0.965219	0.117981	0.03468	0.052845
16	0.431681	0.364757	0.025561	0.970017	1.527366	1.885164	2.704074	1.885164	1.527366	0.970017	0.025561	0.364757	0.431681
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Aegean Sea

Vertical Acceleration at Bridge in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.730563	0.875352	1.338528	1.697772	1.706792	1.179733	1.010404	1.179733	1.706792	1.697772	1.338528	0.875352	0.730563
4	0.307273	0.422541	1.068513	1.665136	2.473126	2.389209	2.249522	2.389209	2.473126	1.665136	1.068513	0.422541	0.307273
8	0.12799	0.164638	0.659326	1.634665	3.288295	3.657779	3.263834	3.657779	3.288295	1.634665	0.659326	0.164638	0.12799
12	0.084494	0.089437	0.275865	1.614207	4.352778	4.241664	4.049745	4.241664	4.352778	1.614207	0.275865	0.089437	0.084494
16	0.562879	0.473357	0.131347	1.611578	5.426405	5.601625	5.432218	5.601625	5.426405	1.611578	0.131347	0.473357	0.562879
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Aegean Sea

Vertical Acceleration at Bridge in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	1.300707	1.453811	1.985386	2.422389	2.43459	1.78188	1.590788	1.78188	2.43459	2.422389	1.985386	1.453811	1.300707
4	0.635011	0.780485	1.577728	2.381972	3.451219	3.446363	3.395451	3.446363	3.451219	2.381972	1.577728	0.780485	0.635011
8	0.302894	0.376633	1.015729	2.344595	4.500836	5.510952	5.615166	5.510952	4.500836	2.344595	1.015729	0.376633	0.302894
12	0.15871	0.201395	0.51955	2.31864	5.785248	7.779442	8.686974	7.779442	5.785248	2.31864	0.51955	0.201395	0.15871
16	0.717734	0.606067	0.307609	2.310462	7.197213	11.57868	10.69818	11.57868	7.197213	2.310462	0.307609	0.606067	0.717734
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at Bridge in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.290274	0.380485	0.685438	0.907747	0.917313	0.579919	0.464685	0.579919	0.917313	0.907747	0.685438	0.380485	0.290274
4	0.120544	0.178331	0.557412	0.886472	1.352401	1.113424	0.9522	1.113424	1.352401	0.886472	0.557412	0.178331	0.120544
8	0.040527	0.053046	0.336628	0.866219	1.716227	1.495912	1.203694	1.495912	1.716227	0.866219	0.336628	0.053046	0.040527
12	0.043033	0.034697	0.118476	0.853344	2.053016	1.598118	1.207681	1.598118	2.053016	0.853344	0.118476	0.034697	0.043033
16	0.332333	0.279818	0.041299	0.853618	2.403837	1.981538	2.338913	1.981538	2.403837	0.853618	0.041299	0.279818	0.332333
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at Bridge in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.737711	0.81564	1.090931	1.317915	1.325319	0.983907	0.884612	0.983907	1.325319	1.317915	1.090931	0.81564	0.737711
4	0.373181	0.449307	0.866915	1.296525	1.872185	1.87138	1.84801	1.87138	1.872185	1.296525	0.866915	0.449307	0.373181
8	0.184804	0.226998	0.565061	1.276646	2.432623	2.980563	3.062939	2.980563	2.432623	1.276646	0.565061	0.226998	0.184804
12	0.096089	0.123726	0.302555	1.262727	3.111251	4.234238	4.769638	4.234238	3.111251	1.262727	0.302555	0.123726	0.096089
16	0.378942	0.321075	0.186916	1.257999	3.861031	6.299456	5.9322	6.299456	3.861031	1.257999	0.186916	0.321075	0.378942
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean sea

Vertical Acceleration at Bridge in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	1.092127	1.172576	1.467459	1.709086	1.721872	1.350542	1.242155	1.350542	1.721872	1.709086	1.467459	1.172576	1.092127
4	0.620871	0.706151	1.171364	1.684496	2.399968	2.419983	2.392878	2.419983	2.399968	1.684496	1.171364	0.706151	0.620871
8	0.351092	0.412817	0.804313	1.661067	3.099941	3.753728	3.840009	3.753728	3.099941	1.661067	0.804313	0.412817	0.351092
12	0.194602	0.247793	0.500912	1.644136	3.953998	5.148633	5.787156	5.148633	3.953998	1.644136	0.500912	0.247793	0.194602
16	0.442662	0.38706	0.351157	1.637612	4.883584	7.406313	7.48023	7.406313	4.883584	1.637612	0.351157	0.38706	0.442662
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Vertical acceleration (Significant amplitude at Saloon 46 m motor yacht)

Aegean Sea

Vertical Acceleration at saloon in sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.272365	0.307924	0.547345	0.929418	0.44219	0.144983	0.089676	0.144983	0.44219	0.929418	0.547345	0.307924	0.272365
4	0.100786	0.130311	0.325408	0.947303	0.533995	0.176476	0.182349	0.176476	0.533995	0.947303	0.325408	0.130311	0.100786
8	0.032576	0.041177	0.462247	0.993592	1.962685	1.164678	0.889521	1.164678	1.962685	0.993592	0.462247	0.041177	0.032576
12	0.07608	0.036337	0.101765	0.974987	0.725176	3.575924	0.348327	3.575924	0.725176	0.974987	0.101765	0.036337	0.07608
16	0.736369	2.018455	0.029306	0.990827	0.832539	3.142313	2.9832	3.142313	0.832539	0.990827	0.029306	2.018455	0.736369
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Aegean Sea

Vertical Acceleration at saloon in sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.615276	0.706065	1.079881	1.573564	0.983833	0.515792	0.382042	0.515792	0.983833	1.573564	1.079881	0.706065	0.615276
4	0.245212	0.321149	0.696735	1.592657	1.288794	0.778558	0.630427	0.778558	1.288794	1.592657	0.696735	0.321149	0.245212
8	0.170402	0.215757	0.784741	1.65311	4.013043	4.640615	4.175973	4.640615	4.013043	1.65311	0.784741	0.215757	0.170402
12	0.106527	0.070599	0.257014	1.621657	2.60804	4.996612	1.920254	4.996612	2.60804	1.621657	0.257014	0.070599	0.106527
16	0.957146	2.609385	0.130334	1.638811	3.432641	4.998079	4.465468	4.998079	3.432641	1.638811	0.130334	2.609385	0.957146
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Aegean Sea

Vertical Acceleration at saloon in sea state 5

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	1.031299	1.160004	1.645443	2.267967	1.537324	0.972247	0.806622	0.972247	1.537324	2.267967	1.645443	1.160004	1.031299
4	0.480829	0.601809	1.117998	2.292641	1.981983	1.44395	1.27895	1.44395	1.981983	2.292641	1.117998	0.601809	0.480829
8	0.386503	0.468517	1.182412	2.366793	5.437091	6.90178	7.080842	6.90178	5.437091	2.366793	1.182412	0.468517	0.386503
12	0.160182	0.156985	0.482962	2.332038	3.672298	7.119611	4.423387	7.119611	3.672298	2.332038	0.482962	0.156985	0.160182
16	1.218293	3.314885	0.294314	2.353703	4.846362	8.546043	7.462412	8.546043	4.846362	2.353703	0.294314	3.314885	1.218293
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean Sea

Vertical Acceleration at saloon in sea state 3

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.285256	0.32908	0.541467	0.833757	0.475327	0.199835	0.132232	0.199835	0.475327	0.833757	0.541467	0.32908	0.285256
4	0.106473	0.139849	0.333659	0.845354	0.618886	0.284023	0.237589	0.284023	0.618886	0.845354	0.333659	0.139849	0.106473
8	0.054598	0.071028	0.406472	0.876432	2.118557	1.9105	1.548235	1.9105	2.118557	0.876432	0.406472	0.071028	0.054598
12	0.060229	0.031411	0.110083	0.860472	1.139316	2.791518	0.551391	2.791518	1.139316	0.860472	0.110083	0.031411	0.060229
16	0.565719	1.545663	0.044344	0.869998	1.428568	2.518179	2.352012	2.518179	1.428568	0.869998	0.044344	1.545663	0.565719
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Mediteranean Sea

Vertical Acceleration at saloon in sea state 4

Headings	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**360**
Velocity													
0	0.586221	0.654937	0.910876	1.237476	0.855169	0.561117	0.475357	0.561117	0.855169	1.237476	0.910876	0.654937	0.586221
4	0.28547	0.351392	0.626789	1.250495	1.097749	0.825701	0.743641	0.825701	1.097749	1.250495	0.626789	0.351392	0.28547
8	0.232295	0.278173	0.653311	1.287923	2.9317	3.724239	3.853568	3.724239	2.9317	1.287923	0.653311	0.278173	0.232295
12	0.092168	0.098073	0.282058	1.271059	1.995983	3.814591	2.460222	3.814591	1.995983	1.271059	0.282058	0.098073	0.092168
16	0.642538	1.747397	0.178517	1.282306	2.620584	4.631461	4.111328	4.631461	2.620584	1.282306	0.178517	1.747397	0.642538
Limit	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**	**1.96**

Lateral acceleration (Significant amplitude at Bridge 53 m motor yacht)

Aegean Sea

Lateral acceleration in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	1.60E-01	0.151122	0.463818	0.451679	0.519015	0.149886	0.12	0.149886	0.519015	0.451679	0.463818	0.151122	0.12
4	1.41E-01	0.103356	0.36508	0.420115	0.622739	0.207327	0.14	0.207327	0.622739	0.420115	0.36508	0.103356	0.14
8	1.37E-01	0.064213	0.276646	0.391515	0.728533	0.274217	0.16	0.274217	0.728533	0.391515	0.276646	0.064213	0.16
12	1.29E-01	0.052211	0.153455	0.367627	0.852461	0.762816	0.19	0.762816	0.852461	0.367627	0.153455	0.052211	0.19
16	1.12E-01	0.290884	0.072255	0.349046	0.939385	0.730609	0.22	0.730609	0.939385	0.349046	0.072255	0.290884	0.22
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Aegean Sea

Lateral acceleration in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	3.81E-01	0.457571	0.923843	0.782008	0.950648	0.452236	0.29	0.452236	0.950648	0.782008	0.923843	0.457571	0.3
4	3.56E-01	0.35641	0.756345	0.743925	1.072214	0.523312	0.28	0.523312	1.072214	0.743925	0.756345	0.35641	0.3
8	2.63E-01	0.204151	0.570844	0.709767	1.197879	0.610129	0.27	0.610129	1.197879	0.709767	0.570844	0.204151	0.3
12	2.06E-01	0.078165	0.32982	0.682919	1.345593	1.142686	0.26	1.142686	1.345593	0.682919	0.32982	0.078165	0.3
16	1.92E-01	0.414368	0.174678	0.664486	1.459945	1.142844	0.25	1.142844	1.459945	0.664486	0.174678	0.414368	0.3
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Aegean Sea

Lateral Acceleration in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.70651	0.76036	1.38062	1.17330	1.40904	0.74888	0.60000	0.74888	1.40904	1.17330	1.38062	0.76036	0.60000
4	0.62656	0.13049	0.53699	1.05775	1.90705	1.55123	0.65000	1.55123	1.90705	1.05775	0.53699	0.13049	0.65000
8	0.415675	0.347520	0.871494	1.087606	1.721502	0.933343	0.700000	0.933343	1.721502	1.087606	0.871494	0.347520	0.700000
12	0.13683	0.13049	0.53699	1.05775	1.90705	1.55123	0.80000	1.55123	1.90705	1.05775	0.53699	0.13049	0.80000
16	0.270069	0.563622	0.353479	1.039934	2.058013	1.556929	0.900000	1.556929	2.058013	1.039934	0.353479	0.563622	0.900000
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Mediteranean Sea

Lateral Acceleration in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	0.153577	0.19416	0.466078	0.405139	0.487944	0.195749	0.03	0.195749	0.487944	0.405139	0.466078	0.19416	0.1
4	0.144387	0.148246	0.375406	0.381618	0.562231	0.239651	0.07	0.239651	0.562231	0.381618	0.375406	0.148246	0.1
8	0.137209	0.085876	0.283236	0.360446	0.639117	0.295119	0.09	0.295119	0.639117	0.360446	0.283236	0.085876	0.1
12	0.124474	0.041933	0.158539	0.343261	0.729363	0.635982	0.11	0.635982	0.729363	0.343261	0.158539	0.041933	0.1
16	0.115047	0.232765	0.071918	0.330623	0.796663	0.628406	0.15	0.628406	0.796663	0.330623	0.071918	0.232765	0.1
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Mediteramean Sea

Lateral Acceleration in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	7.23E-01	0.425032	0.759866	0.648853	0.773667	0.418708	1	0.418708	0.773667	0.648853	0.759866	0.425032	1
4	4.53E-01	0.336115	0.633012	0.625444	0.856587	0.464345	0.7	0.464345	0.856587	0.625444	0.633012	0.336115	0.7
8	3.14E-01	0.196091	0.483188	0.6046	0.939131	0.515949	0.4	0.515949	0.939131	0.6046	0.483188	0.196091	0.5
12	1.72E-01	0.077145	0.304311	0.58959	1.037066	0.833965	0.45	0.833965	1.037066	0.58959	0.304311	0.077145	0.45
16	1.43E-01	0.303381	0.210649	0.581152	1.117751	0.838398	0.49	0.838398	1.117751	0.581152	0.210649	0.303381	0.41
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Mediteranean Sea

Lateral acceleration in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	9.28E-01	0.599649	1.030733	0.908142	1.040351	0.591461	1.12	0.591461	1.040351	0.908142	1.030733	0.599649	1
4	6.88E-01	0.479281	0.871457	0.883369	1.137888	0.648905	0.9	0.648905	1.137888	0.883369	0.871457	0.479281	0.7
8	2.11E-01	0.291224	0.679586	0.861852	1.234263	0.70815	0.73	0.70815	1.234263	0.861852	0.679586	0.291224	7.51E-17
12	2.67E-01	0.148545	0.470687	0.848681	1.347948	1.041894	0.78	1.041894	1.347948	0.848681	0.470687	0.148545	0.35
16	2.64E-01	0.386741	0.381405	0.844115	1.445442	1.055805	0.8	1.055805	1.445442	0.844115	0.381405	0.386741	0.35
Limit	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**	**1.47**

Roll Motion(Significant amplitude of Roll motion 53 m motor yacht)

Aegean Sea

Roll Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	2.9118855	3.5721	3.8126	4.4429	3.7990	3.5680	2.2000	3.5721	3.8126	4.4429	3.7990	3.5680	2.2000
4	2.8635117	3.1961	3.4373	4.3319	3.7247	3.4408	2.6000	3.1961	3.4373	4.3319	3.7247	3.4408	2.6000
8	2.6058959	2.9321	3.1765	3.7242	3.1369	3.7536	1.9000	2.9321	3.1765	3.7242	3.1369	3.7536	1.9000
12	2.4158798	2.8642	3.1505	3.5192848	2.7355485	2.2083	1.5000	2.8642	3.1505	3.5193	2.7355	2.2083	1.5000
16	1.9557169	2.1847	2.6143	2.8163839	2.0232914	1.4939	1.2000	2.1847	2.6143	2.8164	2.0233	1.4939	1.2000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Aegean Sea

Roll Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	10.53696	10.906089	11.512713	12.811869	10.534371	8.9019175	7.27552	10.906089	11.512713	12.811869	10.534371	8.9019175	7.27552
4	9.65888	10.024117	10.647415	11.686795	8.9941304	6.7963084	4.64128	10.024117	10.647415	11.686795	8.9941304	6.7963084	4.64128
8	8.02816	8.546323	9.5819331	10.30266	8.7289227	6.1900334	3.26144	8.546323	9.5819331	10.30266	8.7289227	6.1900334	3.26144
12	6.77376	7.6854172	8.2434259	9.0371124	7.7015106	5.5732954	3.63776	7.6854172	8.2434259	9.0371124	7.7015106	5.5732954	3.63776
16	5.51936	6.8104855	7.8274291	8.0175956	6.4134795	4.9323784	3.01056	6.8104855	7.8274291	8.0175956	6.4134795	4.9323784	3.01056
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Aegean Sea

Roll Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	12.992	13.642109	14.96568	17.676333	16.104818	12.528369	10.752	13.642109	14.96568	17.676333	16.104818	12.528369	10.752
4	11.872	12.558579	13.836729	15.437064	14.964421	11.414749	9.632	12.558579	13.836729	15.437064	14.964421	11.414749	9.632
8	10.752	10.509114	11.572197	13.182342	11.599375	9.191483	8.512	10.509114	11.572197	13.182342	11.599375	9.191483	8.512
12	9.856	10.108869	10.670354	12.260782	10.694144	9.4255772	7.504	10.108869	10.670354	12.260782	10.694144	9.4255772	7.504
16	8.288	9.2488732	9.4300182	10.661509	9.1084268	7.8402302	6.496	9.2488732	9.4300182	10.661509	9.1084268	7.8402302	6.496
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteranean Sea

Roll Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	1.8118855	2.5720976	2.8125796	3.5429256	2.7990076	2.5680407	1.4	2.5720976	2.8125796	3.5429256	2.7990076	2.5680407	1.4
4	1.7735117	2.2961103	2.5373096	3.531916	2.8247378	2.5408329	1.8	2.2961103	2.5373096	3.531916	2.8247378	2.5408329	1.8
8	1.7058959	2.1320631	2.3764953	3.0242229	2.3368504	2.4536016	1.1	2.1320631	2.3764953	3.0242229	2.3368504	2.4536016	1.1
12	1.4158798	1.9642326	2.2504618	2.7192848	2.2355485	1.7082889	0.7	1.9642326	2.2504618	2.7192848	2.2355485	1.7082889	0.7
16	1.2557169	1.5846942	2.014288	2.3163839	1.8232914	1.2938625	0.4	1.5846942	2.014288	2.3163839	1.8232914	1.2938625	0.4
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteramean Sea

Roll Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	7.5000	7.7943	8.2779	9.3135	7.5979	6.2966	5.7000	7.7943	8.2779	9.3135	7.5979	6.2966	5.7000
4	6.8000	7.0912	7.5881	8.4166	6.7701	4.9180	3.8000	7.0912	7.5881	8.4166	6.7701	4.9180	3.8000
8	5.5000	5.9131	6.7387	7.3132	6.0586	4.0347	2.0000	5.9131	6.7387	7.3132	6.0586	4.0347	2.0000
12	4.4000	5.1268	5.5716	6.2043	5.1396	3.4430	1.9000	5.1268	5.5716	6.2043	5.1396	3.4430	1.9000
16	3.4000	4.4293	5.2400	5.3916	4.1128	2.9321	1.4000	4.4293	5.2400	5.3916	4.1128	2.9321	1.4000
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteranean Sea

Roll Motion in sea state 5

	0	30	60	90	120	150	180	210	240	270	300	330	360
0	11.297391	11.862703	13.013635	13.365848	10.589179	8.2376057	8.1300567	11.862703	13.013635	15.370725	14.004189	10.894234	9.3495652
4	10.323478	10.920503	12.031938	11.972638	9.8393496	7.505383	7.2831758	10.920503	12.031938	13.423534	13.01254	9.925869	8.3756522
8	8.1300567	7.9463998	8.7502435	9.9677443	7.6267776	6.0435493	6.4362949	9.1383597	10.06278	11.462906	10.086413	7.9925939	7.4017391
12	7.452552	7.6437572	8.0683209	9.2709126	7.0315731	6.19747	5.6741021	8.7903208	9.278569	10.66155	9.2992555	8.1961541	6.5252174
16	6.2669187	6.9934769	7.1304485	8.0616323	5.9889384	5.1550786	4.9119093	8.0424985	8.2000158	9.2708771	7.9203711	6.8175915	5.6486957
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Pitch Motion(Significant amplitude of Pitch motion 53 m motor yacht)

Aegean Sea

Pitch Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	8.80E-01	1.066395	1.605489	0.166318	1.966617	1.155323	8.43E-01	1.155323	1.966617	0.166318	1.605489	1.066395	8.80E-01
4	6.47E-01	0.809093	1.546113	0.180486	1.912742	1.220205	9.35E-01	1.220205	1.912742	0.180486	1.546113	0.809093	6.47E-01
8	3.60E-01	0.388901	1.151464	0.263113	1.653064	1.029769	7.89E-01	1.029769	1.653064	0.263113	1.151464	0.388901	3.60E-01
12	4.68E-01	0.466624	0.554088	0.35633	1.391438	0.7334	6.30E-01	0.7334	1.391438	0.35633	0.554088	0.466624	4.68E-01
16	6.54E-01	0.63557	0.317553	0.436185	1.276247	0.6765	5.14E-01	0.6765	1.276247	0.436185	0.317553	0.63557	6.54E-01
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Aegean Sea

Pitch Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	3.18E+00	3.392581	3.29311	0.231388	3.663118	3.551882	3.25E+00	3.551882	3.663118	0.231388	3.29311	3.392581	3.18E+00
4	2.18E+00	2.407595	2.916063	0.255488	4.051256	4.622978	4.44E+00	4.622978	4.051256	0.255488	2.916063	2.407595	2.18E+00
8	1.85E+00	1.878889	2.256248	0.37427	4.335709	5.019159	4.58E+00	5.019159	4.335709	0.37427	2.256248	1.878889	1.85E+00
12	2.03E+00	1.988754	1.505155	0.51021	4.830726	4.558206	4.61E+00	4.558206	4.830726	0.51021	1.505155	1.988754	2.03E+00
16	2.51E+00	2.360109	1.263227	0.629726	5.223113	5.063177	4.07E+00	5.063177	5.223113	0.629726	1.263227	2.360109	2.51E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Aegean Sea

Roll Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	5.92E+00	5.896978	5.007101	0.307741	5.442822	6.055403	5.99E+00	6.055403	5.442822	0.307741	5.007101	5.896978	5.92E+00
4	4.53E+00	4.579259	4.480585	0.340497	6.01098	7.751494	8.00E+00	7.751494	6.01098	0.340497	4.480585	4.579259	4.53E+00
8	4.06E+00	3.916317	3.646485	0.501416	6.419567	8.795549	9.14E+00	8.795549	6.419567	0.501416	3.646485	3.916317	4.06E+00
12	4.22E+00	3.965951	2.775622	0.686414	6.938984	9.555131	1.07E+01	9.555131	6.938984	0.686414	2.775622	3.965951	4.22E+00
16	4.93E+00	4.384421	2.460349	0.850765	7.455058	11.65656	1.00E+01	11.65656	7.455058	0.850765	2.460349	4.384421	4.93E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Mediteranean Sea

Pitch Motion in sea state 3

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	1.24E+00	1.423436	1.635031	0.130645	1.878599	1.522952	1.25E+00	1.522952	1.878599	0.130645	1.635031	1.423436	1.24E+00
4	8.03E-01	0.964455	1.465578	0.14365	2.042276	1.879884	1.64E+00	1.879884	2.042276	0.14365	1.465578	0.964455	8.03E-01
8	6.06E-01	0.64434	1.094058	0.210684	2.056869	1.859813	1.51E+00	1.859813	2.056869	0.210684	1.094058	0.64434	6.06E-01
12	7.12E-01	0.72805	0.623891	0.286458	2.122516	1.420794	1.29E+00	1.420794	2.122516	0.286458	0.623891	0.72805	7.12E-01
16	9.20E-01	0.92252	0.477399	0.3523	2.191919	1.392165	1.09E+00	1.392165	2.191919	0.3523	0.477399	0.92252	9.20E-01
Limit	6	6	6	6	6	6	6	6	6	6	6	6	6

Mediteramean Sea

Pitch Motion in sea state 4

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	3.40E+00	3.3465	2.767737	0.163745	2.994071	3.425958	3.44E+00	3.425958	2.994071	0.163745	2.767737	3.3465	3.40E+00
4	2.67E+00	2.654846	2.485915	0.181327	3.299949	4.335636	4.52E+00	4.335636	3.299949	0.181327	2.485915	2.654846	2.67E+00
8	2.42E+00	2.3082	2.048204	0.267624	3.520607	4.932404	5.20E+00	4.932404	3.520607	0.267624	2.048204	2.3082	2.42E+00
12	2.49E+00	2.323826	1.600058	0.366692	3.794006	5.38116	6.06E+00	5.38116	3.794006	0.366692	1.600058	2.323826	2.49E+00
16	2.86E+00	2.535509	1.434242	0.454947	4.061721	6.489464	5.76E+00	6.489464	4.061721	0.454947	1.434242	2.535509	2.86E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Mediteranean Sea

Pitch Motion in sea state 5

Headings	0	30	60	90	120	150	180	210	240	270	300	330	360
Velocity													
0	5.29E+00	5.014635	3.808944	0.192934	4.051563	5.093208	5.32E+00	5.093208	4.051563	0.192934	3.808944	5.014635	5.29E+00
4	4.50E+00	4.261705	3.47508	0.214562	4.421333	6.142082	6.58E+00	6.142082	4.421333	0.214562	3.47508	4.261705	4.50E+00
8	4.21E+00	3.886441	2.992412	0.319486	4.706645	6.945152	7.53E+00	6.945152	4.706645	0.319486	2.992412	3.886441	4.21E+00
12	4.26E+00	3.86975	2.529545	0.438952	5.069896	7.409491	8.41E+00	7.409491	5.069896	0.438952	2.529545	3.86975	4.26E+00
16	4.64E+00	4.07673	2.347979	0.545924	5.377414	8.383498	8.35E+00	8.383498	5.377414	0.545924	2.347979	4.07673	4.64E+00
Limit	3	3	3	3	3	3	3	3	3	3	3	3	3

Annexure II

Load RAO

```
function [freq,Amp,Phase, headings, ftitle, unit]=loadrao(filename);

inname =[filename,'.rao'];
outname = [filename,'.tmp'];

fid = fopen(inname,'r');
fidw = fopen(outname,'w');
tline = fgetl(fid);
headings=[];
format = '%s';

while ischar(tline)
    line_string = sprintf('%s',tline);
    u = strfind(line_string, '#');

    if (u==1)
        if strfind(line_string, 'File')
            C=textscan(line_string, '%s %s %s %s');
            ftitle=char(C{4});
        end
        if strfind(line_string, 'NBHEADING')
            D=textscan(line_string, '%s %d');
            NH=D{2};

            for k=1:NH
                format=[format, ' %d'];
        end
        if strfind(line_string, '#HEADING')
            CC=textscan(line_string, format);
            for k=2:(NH+1)
                headings=[headings,CC{k}];
                    end
        if strfind(line_string, '#UNIT')
            CC=textscan(line_string, '%s %s %s');
            unit = CC{3};
    else
    fprintf(fidw,'%s\n',line_string);

    end
    tline = fgetl(fid);

end

fclose(fid);
fclose(fidw);

Nh = size(headings,2);
RAOMatrix = load(outname);
Omega = RAOMatrix(:,1);
Amp = RAOMatrix(:,2:Nh+1);
Phase = RAOMatrix(:,Nh+2:end)*pi/180; %in radian !
freq = Omega/(2*pi);
delete(outname);
```

Plot RAO

```
function [maxi, hmax, fmax, Tmax,lmax] = plotrao(filename, hlist, xT)


    if (nargin<3)
        xT=0;
    end

    if (xT==0)
        [abs,amp,phase, headings, ftitle, unit] = loadrao(filename);
    else
        [abs,amp,phase, headings, ftitle, unit] = loadrao2(filename);
    end

    if (nargin==1)
        hlist = headings;

    %get some results
    Nh = size(headings,2);
    [vmax,line] = max(amp);
    [maxi, col] = max(vmax);
    fmax = abs(line(col),1);
    hmax = headings(col);
    Tmax=(1/fmax);
    lmax=Tmax^2*1.56;
    T=1./abs;
    %set options for plot
    atitle=['amplitude ',ftitle];
    %figure('name',atitle)
    figure
    title(atitle)
    if (xT>0)
        xlabel('lambda (m)');
    else
        xlabel('f (Hz)');
    yla=[ftitle, '(', unit, ')'];
    ylabel(yla);

    l1={};
    symbs = {'-.','-o','-x','-+','-*','-s','-d','-v','-^','-<','->','-p','-
h'};


    %plot
    for j=1:Nh
        if (sum(hlist==headings(j))>0)
            rng(j)
            color = rand(1,3);
            rsi = uint8(12*rand()+1);
            sy = symbs{rsi};

            [l1,{[num2str(headings(j)), '°']}];
            plot(abs,amp(:,j)',sy,'Color',color);
```

Significant Amplitude

```
function [Ys,freq] = significanAmp(filename)
%% ciccio for significant

%load rao data
[f,amp,phase, headings] = loadrao('insert file name');

Hs = 0.88; %Significant wave height
Tp = 4.8; %Peak period
% alfa = 1; %Initial suggested value
gamma = 3.3; %Initial suggested value
%ceate sea State spec
fp=1/Tp;
fmax=max(f);
fmax = max(fmax,3*fp);
Nf=2000;
Df = fmax/(Nf);
freq = (Df:Df:fmax)';
sigma = 0.07*(freq<fp)+0.09*(freq>=fp);
Wspec = 5/16./freq.^5*Hs^2/Tp^4.*exp(-5/(4*Tp^4)./(freq.^4)).*gamma.^(exp(-
(freq-1/Tp).^2*Tp^2./(2*sigma.^2)));
alpha=Hs^2/16/trapz(freq,Wspec);
Wspec = alpha*Wspec;

%correct Nf if necessary
Nf = size(freq,1);

heading=1
%interpolate RAO
j=find(headings==heading);
for j=1:13
intRAO = interp1(f,amp(:,j),freq);
intPhi = interp1(f,phase(:,j),freq);

%trick to put to 0 values of the RAO that can not be interpolated
intRAO(isnan(intRAO))=0;
intPhi(isnan(intPhi))=0;

%compute output spectrum OF THE BOAT
Sout= intRAO.*intRAO.*Wspec;

figure (1)
plot(freq,Sout,freq,Wspec,freq,intRAO)
legend('Sout(boatResponse)','Spectrum(Jonswap)','RAO')

%calculating boat Stateistics
    m0 = trapz(freq,Sout);
    m2 = trapz(freq,Sout.*freq.*freq);
    outYs = 2*sqrt(m0); %%% Significant amplitude
    Ys(j)=outYs;
  outTy0 = sqrt(m0/m2);
figure (2)
plot(freq,Sout,[0:max(freq)],[Ys:Ys],'r-')
legend('Sout','Ys')
end
```

JONSWAP

```
close all;
clear all;
%clc;
%Define input data
gamma = 3.3; %Initial suggested value
n = 1000; %Number of frequencies
beg = 0.002;
last = 1;
f = linspace(beg, last, n);
step = 0.005;

%Calculate momentum for suggested Hs
moH = Hs^2/16;
moS = 1; %Initial value

%Starting loop
accur = 0.010; %Suggested accuracy
while  (abs(moH - moS) / moH) > accur

    alfa = alfa - step;

    %Find variance spectrum density
    for i = 1:n;
    if f(i) < 1/Tp;
    sigma = 0.07;
    elseif f(i) > 1/Tp;
        sigma = 0.09;
    else
        disp('error');
    end
    Sf(i) = alfa * 5 * Hs^2 ./ (16 .* f(i).^5 .* Tp^4) .* exp(-5 ./ (4 *
Tp^4 .* f(i).^4)) * gamma^(exp(-(f(i)-1/Tp).^2 * Tp.^2 / (2 *sigma).^2));
    end
        %Calculate momentum for spectrum
        moS = sum (Sf .* 1/n);
end
%.......................................................................
```