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# Final work : Numerical analysis of surface roughness impact on the aerodynamic damping of an axial transonic compressor

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MSc in Turbomachinery Aeromechanics (THRUST)
Université de Liège, School of Engineering and Computer Science
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*Master Thesis: Summary and relevant figures*

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# Numerical analysis of surface roughness impact on the aerodynamic damping of an axial transonic compressor

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Graduation Studies conducted for obtaining the Master's degree in Civil engineer in aerospace, specialized in "turbomachinery aeromechanics"
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Current trends in advanced design of turbomachinery structures are leading to more loaded, lighter and slender blades. These characteristics make them prone to aeroelastic instabilities, such as flutter. Moreover, blades are continuously exposed to the incoming flow carrying pollutants and external particles that can affect the smoothness of the blade surface. It is well known the detrimental effect that surface roughness has in the performance of the machine. However, there is a lack of studies regarding the effects of surface roughness in the aeroelastic stability. This is the main focus of this thesis.

Studies regarding surface roughness modelling are scattered and contain very diverse information and conclusions on the topic. There exists a wide range of parameters and equations to correlate physical measurements and equivalent sandgrain roughness height, $k_s$. From a turbomachinery perspective, a literature review on the current stage of surface roughness modelling has been performed. A final correlation is chosen as the most suitable to model surface roughness in compressors, based on the simplicity to measure the physical parameters included, and the high degree of correlation with $k_s$.

A numerical study using ANSYS CFX is performed to evaluate the impact of surface roughness in the aeroelastic stability of a transonic axial compressor. The study case is the first stage (R1S1B) of the VINK compressor. First, a set of 7 different $k_s$ values are evaluated with a steady-state analysis. Results show a negative impact on performance, reducing efficiency, mass flow rate and pressure ratio. Due to blockage effects, a change in incidence angle is found, causing a change in passage shock location and strength. A smaller set of just 3 $k_s$ values is selected for the flutter analysis just on the rotor domain. The aerodynamic damping is computed for nodal diameters 0, ±3 and ±15. Results show different trends depending on the nodal diameter evaluated. According to the study, surface roughness has a small positive impact for the least stable modes, slightly increasing the aerodynamic damping. The contrary happens for the most stable NDs, where surface roughness induces a reduction in the aerodynamic damping, but without being enough to shift the value to the unstable region. Some limitations are encountered, mainly due to the oversimplification of roughness with $k_s$, and the assumption of a tuned system, removing the effects of mistuning. Future work is proposed in order to reduce and overcome the limitations here identified.

**Keywords: Surface roughness correlation, equivalent sandgrain height, transonic compressor, flutter, aerodynamic damping, VINK, CFD**

# Relevant figures

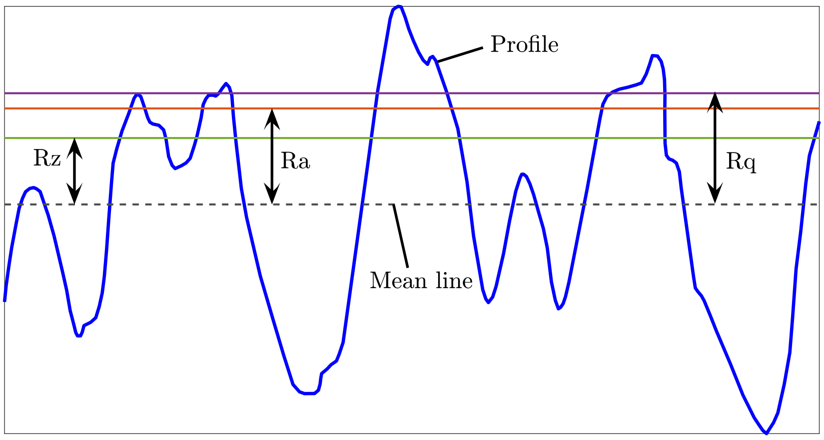


Fig. 1. Schematic representation of roughness height parameters: *Ra, Rq, Rz*

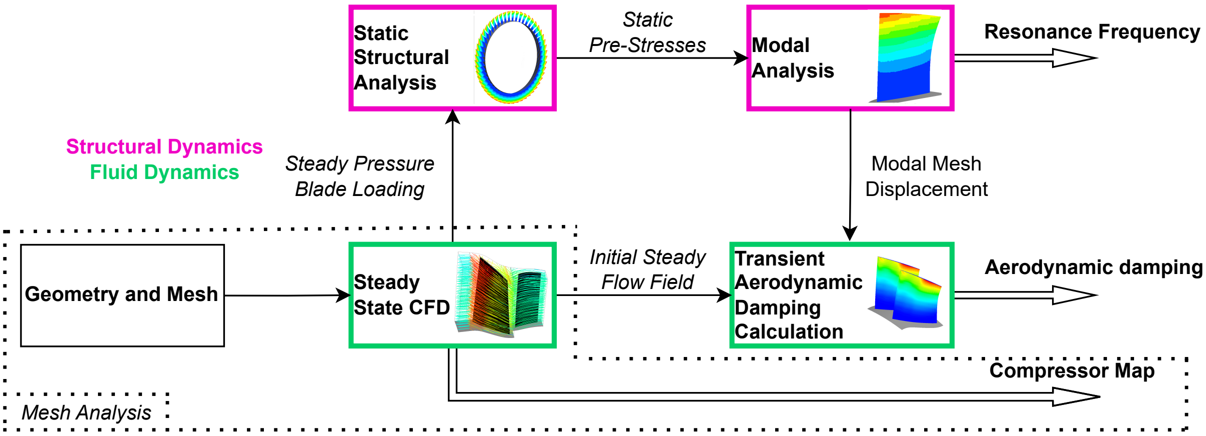
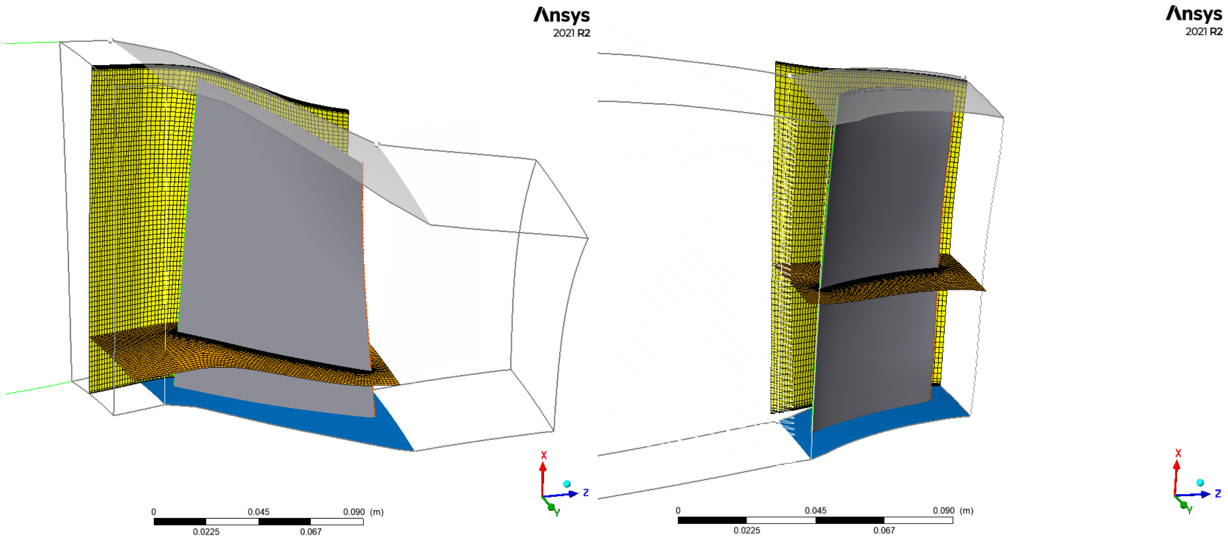
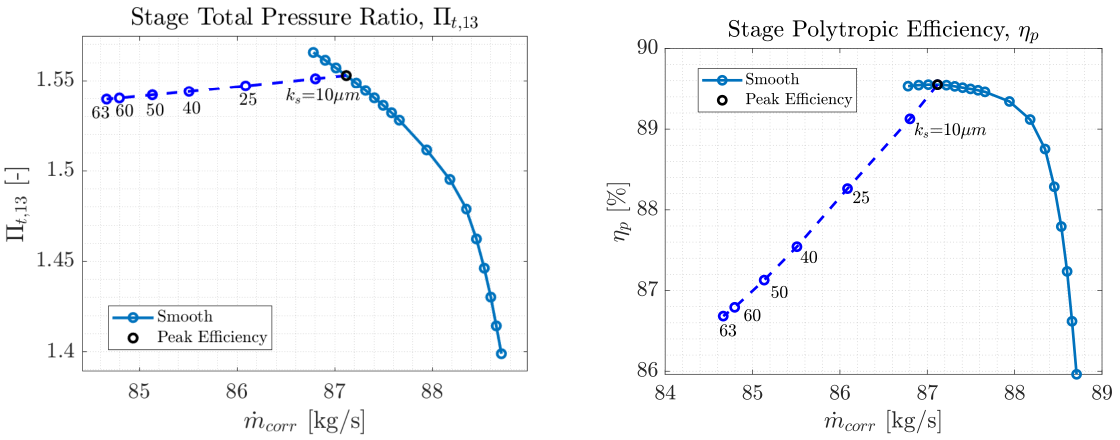


Fig. 2. Aerodynamic damping prediction workflow



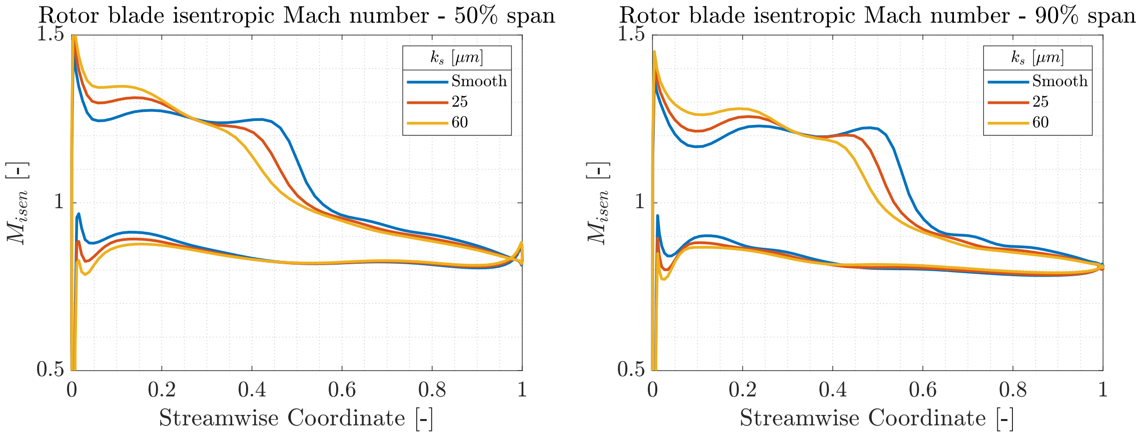
(a) Rotor mesh (b) Stator mesh

Fig. 3. Mesh generation in *Turbogrid*



(a) Stage total pressure ratio (b) Polytropic efficiency

Fig. 4. Roughness effects on compressor map variables



(a) 50% span

(b) 90% span

Fig. 5. Roughness effects on rotor blade isentropic Mach number distribution

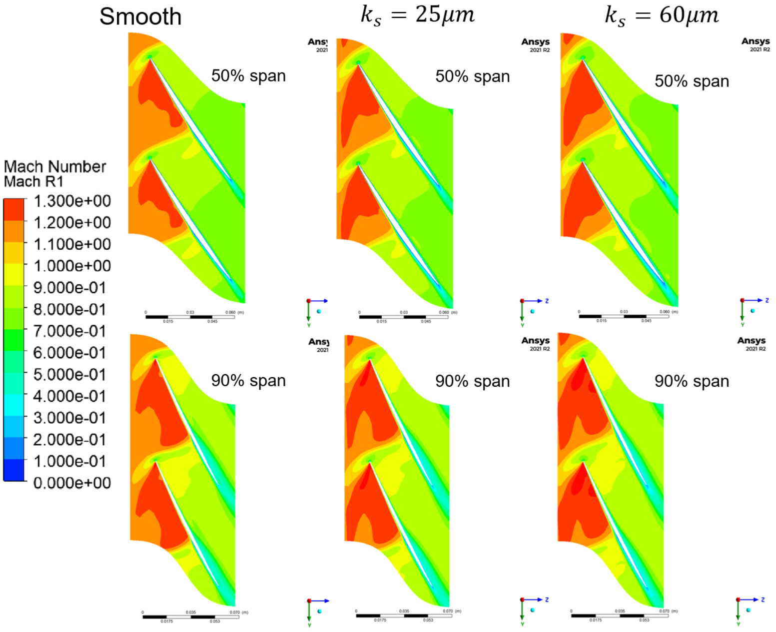


Fig. 6. Mach number contours - $k_s$ = 0, 25, 60$\mu$m - Rotor Domain

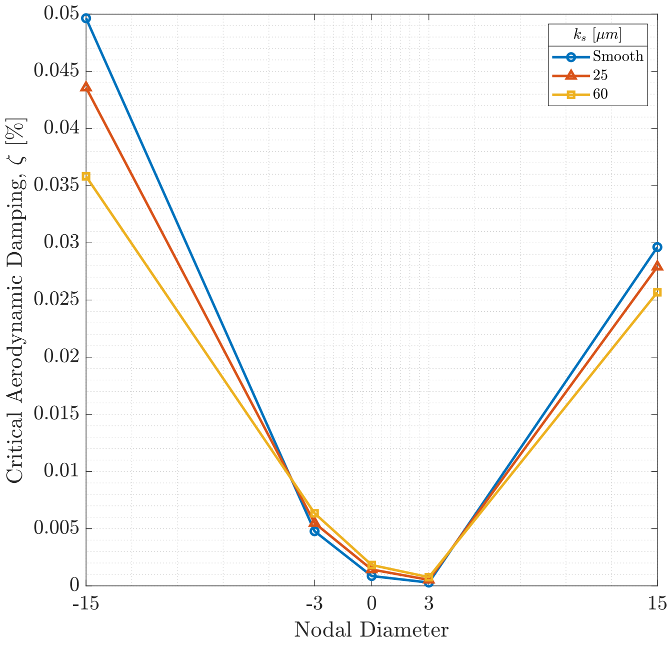


Fig. 7. Aerodynamic damping curve - Roughness impact

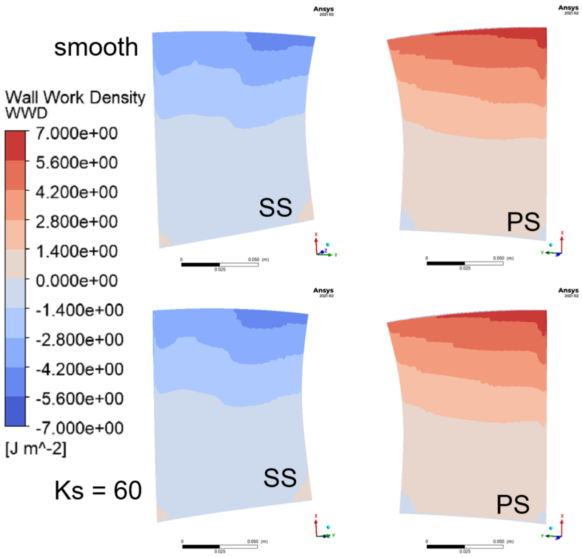
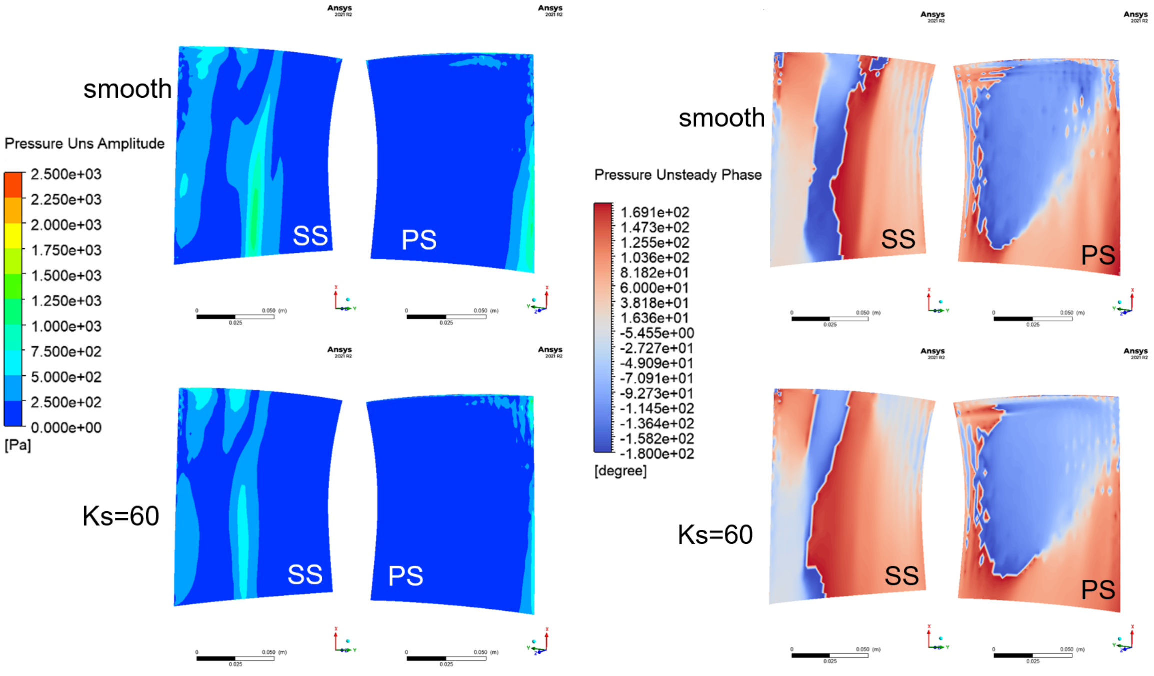


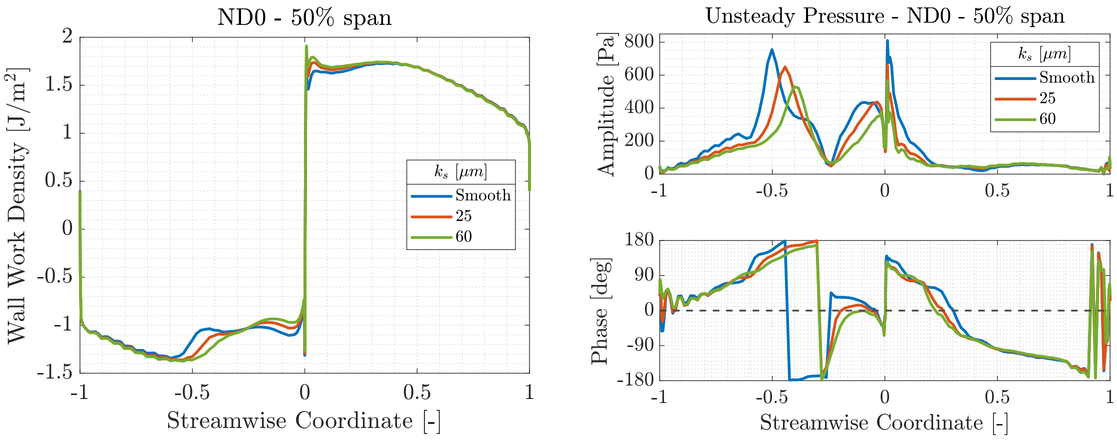
Fig. 8. Wall work density contour for ND=0. Roughness comparison: $k_s$= 0$\mu$m (top) Vs. $k_s$= 60$\mu$m (bottom)



(a) Unsteady pressure amplitude: $k_s$= 0$\mu$m (top) Vs. $k_s$= 60$\mu$m (bottom)

(b) Unsteady pressure phase: $k_s$= 0$\mu$m (top) Vs. $k_s$= 60$\mu$m (bottom)

Fig. 9. Unsteady pressure amplitude and phase for ND=0. Roughness comparison.



(a) Wall work density

(b) Unsteady pressure: Amplitude & phase

Fig. 10. ND=0 at 50% span. Roughness comparison