Final work : Design of the first stage of a centrifugal compressor with R1234ze(E) for heat pump in district heating

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DESIGN OF THE FIRST STAGE OF A CENTRIFUGAL COMPRESSOR WITH R1234ZE(E) FOR HEAT PUMP IN DISTRICT HEATING

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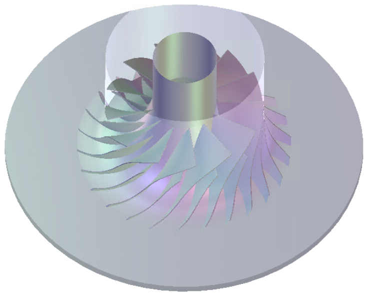

District heating is expected to play a key role in the energy grid and supply, particularly when heat pumps are connected to the system, and could cover up to 50% of the heating demand in Europe with heat pumps delivering around 25% of the energy transported by the district heating grid. In particular, HTHP, i.e heat pumps with heat sink temperatures equal or greater than 100°C, are regarded as excellent solutions for the district heating when the used electricity is green and there is a growing market in that area. However, the mass-production of these technologies is hindered by factors such as lack of available refrigerants with low GWP in the high temperature range and the technical challenges related to the compression process at high temperatures. This work addresses one of the main challenges currently present in the heat pump industry: to increase the COP of a high temperature heat pump with a temperature lift of 105°C through the coupling of the thermodynamic cycle and centrifugal compressor design. In particular, an alternative approach to the optimization of the cycle is presented, researching the pressure ratio of the first stage that delivers the highest COP possible for given evaporator and condensing temperatures. Once this optimum pressure ratio is selected, the 1D meanline design of the compressor is assessed, an iteration loop between these two steps is followed until the efficiency resulting from the 1D design matches the one used in the thermodynamic cycle. A 3D CFD simulation is then assessed and its results are compared with the results of the two previous phases. The results obtained are promising, showing a COP of 2.61 that significantly higher compared to the ones of state-of-art heat pumps with similar temperature lifts. Moreover, the results between thermodynamic cycle, 1D meanline design and CFD simulations have shown a strong agreement in the parameters observed, namely mass flow rate $\dot{m}$, total inlet and outlet temperatures T_{01} and T_{02}, total-to-total pressure ratio Π_{tt} and isentropic efficiency η^{is}, with a maximum variance of 4.6 % showed for the mass flow obtained in CFD. Additionally, the compressor design also addresses another industry challenge, that is to deliver high efficiencies and wide operating range at the same time. The present work present a centrifugal compressor with a 80% efficiency and able to operate at mass flow in the range [115-85]% before choking and surge.