HEAT TRANSFER AND MULTI DISCIPLINARY OPTIMIZATION APPLIED ON MICRO GASTURBINES

Tom Verstraete, Belgium
Supervisor: Prof. R.A. Van den Braembussche
Promoter: Prof. P. Verleysen (Universiteit Gent)

Micro gasturbines have an up to ten times larger power to weight ratio than batteries and might replace them for some applications in the near future. Reduction of weight is important in mobile applications as it helps increasing the autonomy. This explains the huge interest nowadays in research on the micro gasturbines.
This project concentrates on the turbomachinery components. Two main aspects in particular are investigated.

The first one concerns the numerical simulation of the heat transfer inside a micro gasturbine and its impact on the performance. The high temperature difference between turbine and compressor in combination with the small dimensions results in a high heat transfer causing a drop in efficiency of both components. This heat transfer is quantified and the different mechanisms that contribute to it are revealed.
A conjugate heat transfer solver has been developed for this purpose. It combines a 3D conduction calculation inside the rotor and the stator with a 3D flow calculation in the radial compressor, turbine and cavities between stator and rotor. Fig. 1 shows the computed temperature distribution inside the entire micro gasturbine hardware.

Secondly, the optimization algorithm developed at VKI for the creation of highly performant geometries is extended with a structural analysis, resulting in a multidisciplinary optimization system for the design of radial compressor and turbine impellers. The method uses a genetic algorithm and artificial neural network to find a compromise between the conflicting demands of high efficiency and low centrifugal stress in the blades. A simultaneous analysis of the aero performance and stress distributions is made, replacing the traditional time consuming iterative design approach. Aerodynamic performance, predicted by a 3D Navier-Stokes solver, is maximized while limiting the mechanical stresses, calculated by means of a finite element analysis. Stresses are controlled by modifying the blade camber, blade lean and the thickness at the hub.
This multidisciplinary optimization tool is applied on both compressor and turbine components. Significant reduction in stress levels are obtained compared to the simple aerodynamic optimization algorithm without structural analysis.
The efficiency versus stress is plotted in Fig. 2 for different compressor geometries. It is clear from this picture that a reduction in stress from 800 MPa to 400 MPa is achieved at the cost of only a 2% point lower efficiency. The results show that it is possible to obtain a significant reduction of the centrifugal stresses in the blades without penalizing the performance.

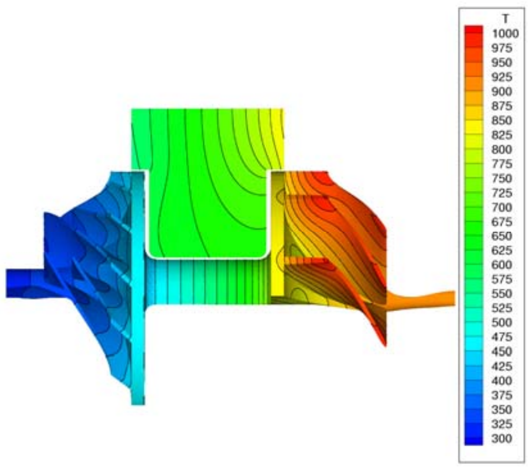

Figure 1: Temperature distribution (K) inside the micro gasturbine

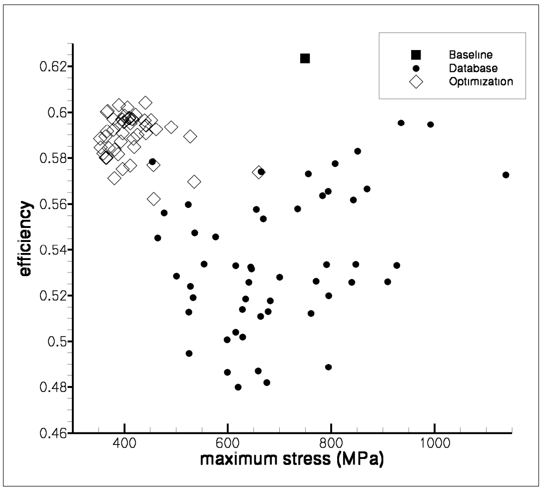

Figure 2: Efficiency versus stress for several compressor impellers generated during the optimization