DEVELOPMENT OF A MICRO GAS TURBINE WITH CERAMIC IMPELLER: SCAI TOOLS FOR STRESS AND VIBRATION ANALYSES

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ABSTRACT

Fraunhofer Institute of Scientific Computing and Algorithms (SCAI) is partner in the Fraunhofer project “TurboKeramik”. In order to increase efficiency of micro gas turbines (with power cogeneration) by higher gas temperatures, it is necessary to consider new material concepts for the high temperature loaded parts. As a first step, the goal of “TurboKeramik” is a feasibility study of a full ceramic rotor. The advantages of using ceramic lie in the small thermal expansion ratio and the bearing of high temperatures which makes internal and external cooling unnecessary.

The two most challenging tasks in the project are the following:

- Development of a ***defect free injection molding*** procedure for the ceramic rotor, since the size of the rotor is relatively large for ceramic injection molding.
- Development of a ***suitable-to-ceramic design of the rotor***, i.e. a design which stands the high centrifugal loads and temperature gradients. The maximum allowable tensile stress is 340 MPa for a long-term loading.

In order to estimate the stresses in the ceramic material, Fraunhofer SCAI did static stress analyses with centrifugal and thermal load in operation.

The prevailing thermal load was obtained by a coupled thermal simulation between Fine/Turbo and Abaqus with code coupling environment MpCCI, see Figure 1.

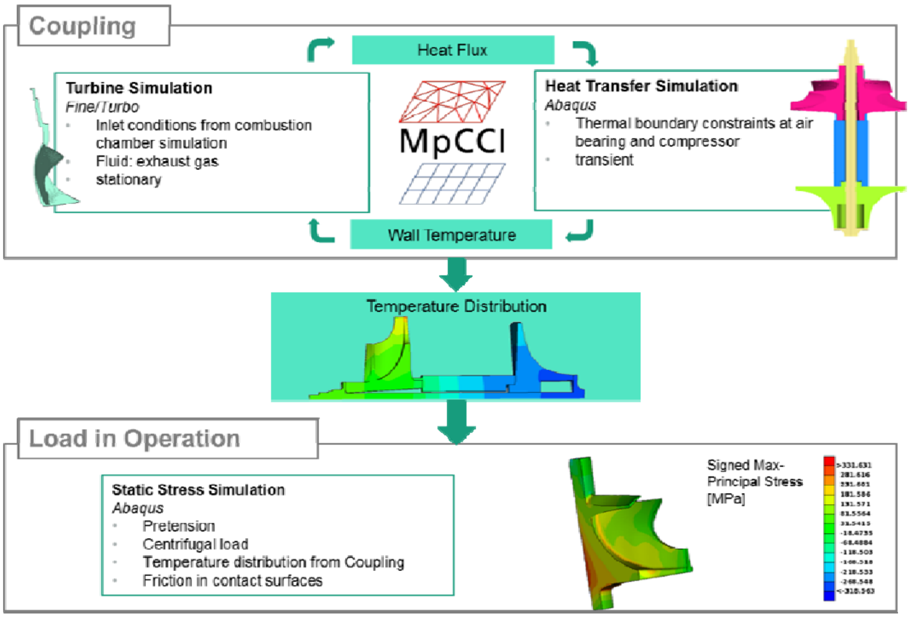

Figure 1: Scheme of Simulations

For this purpose MpCCI was extended for easier handling of periodic models, cf. Figure 2.

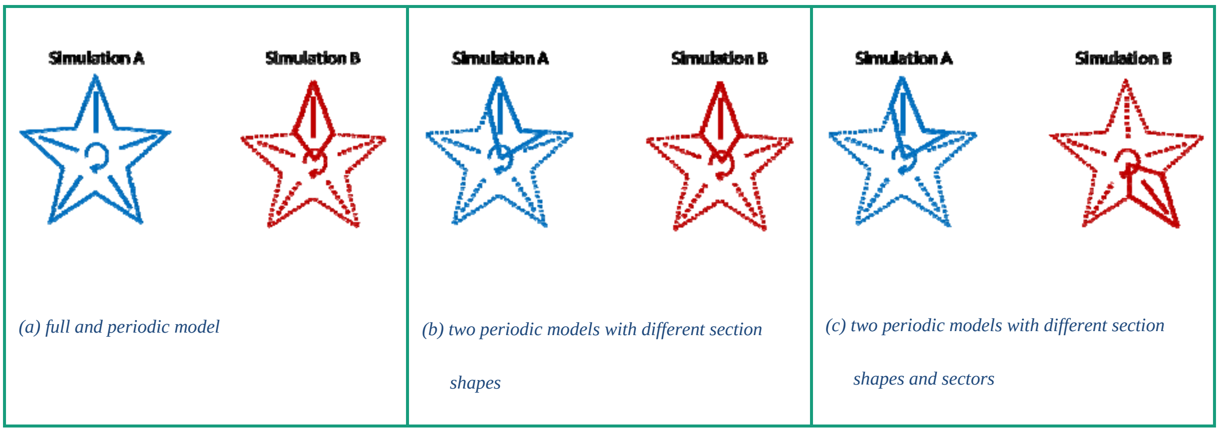

Figure 2: new possible coupling pairings

With these enhancements the occurring stresses in the ceramic rotor could be estimated more realistically and faster. Based on these analyses, it was possible to improve the geometry of the rotor with regard to durability in operation by an automatic optimization.

To estimate the long term behavior and high cycle fatigue in operation it is necessary to know the periodic pressure oscillations of the flow (i.e. due to stator vanes) and thus excited oscillations of the turbine blades.

Numeca's Non Linear Harmonics method (NLH) provides transient flow fields which are derived from a time averaged solution plus a sum of harmonic oscillations (to the blade passing frequency). The solver operates in frequency domain, so there is a fast approximated solution to the fully transient case.

In order to calculate the response of the structure the complex pressure amplitudes (of the different harmonics) were transferred by FSIMapper to a frequency response analysis in Abaqus. In this way the influence of the vibrational excitation by transient pressure loads on blade oscillation could be investigated. Here all advantages of frequency domain based solution methods in CFD and FEM could be exploited. Hotspots with high stress oscillation amplitudes could be located.

Further steps would be to provide a fully coupled frequency domain based simulation (via MpCCI) where also aerodynamic damping and interdependencies between flow oscillations and dynamic excitation of the structure are taken into account.