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Automated CAE process for thermo-mechanical lifing prediction of a parameterized turbine blade with internal cooling

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In the drive for higher cycle efficiencies in gas turbine engines, turbine blades are exposed to an increasingly high heat load. The highly demanding requirements to endure thermal and structural loads, while aiming for high overall efficiency, lead to the design of a system with complex cooling channels. This in turn demands improvements of the internal cooling system and a better understanding the multidisciplinary prediction of the fluid solid interaction. A typical approach to enhance the internal cooling of the turbine blade is by casting angled low blockage ribs on the walls of the cooling channels. In order to be able simulate different settings of internal cooling channel, it is necessary to build a parametric CAD model of the sophisticated cooling blade, which is capable of reshaping the internal cooling system with all ribs and film cooling tubes (Figure 1).
The lifing analysis of the turbine airfoil requires a very accurate prediction of the internal metal temperature. One way to calculate the life of a turbine blade is the Low Cycle Fatigue lifing where one cycle is defined by the maximum take-off flight condition. A critical section plane is found with an automated routine, which recognizes in the spherical coordinate system the maximum principal stress gradient with the steepest slope. This multiaxial fatigue analysis method is accurate for the prediction of low cycle fatigue, but it requires a high density FEM mesh [1].
This demand of accurate temperature prediction can only be fulfilled with a complex 3D-CFD simulation of the whole internal cooling system. On the other hand a tuned 1D-CFD model predicts the internal temperature within seconds. Nonetheless, the 1D-CFD model has to be able to predict local heat transfer effects which are induced by cooling features like ribs or rotational effects. In this paper an approach is presented where 3D-CFD results are used to improve a 1D-CFD predictions (Figure 2)[2].
Finally, a Design of Experiment (DOE) example will be shown, where 20 different varia-

tions of the blade internal cooling system are assessed with the presented multi-disciplinary process. The design space evaluated turns out to have a range of life expectation from 890 to approx. 30000 cycles.

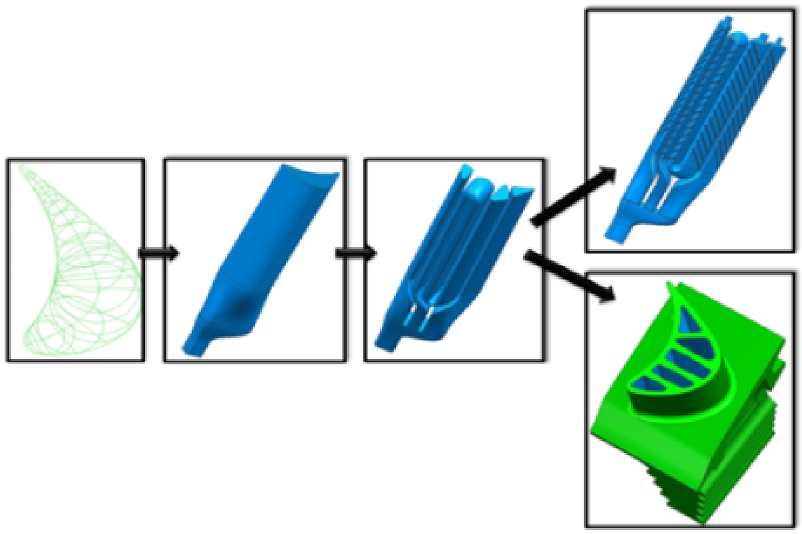

Figure 1: Smartblade: A parametrized scripted UG method to generate a featured CFD geometry and a defeatured metal blade model

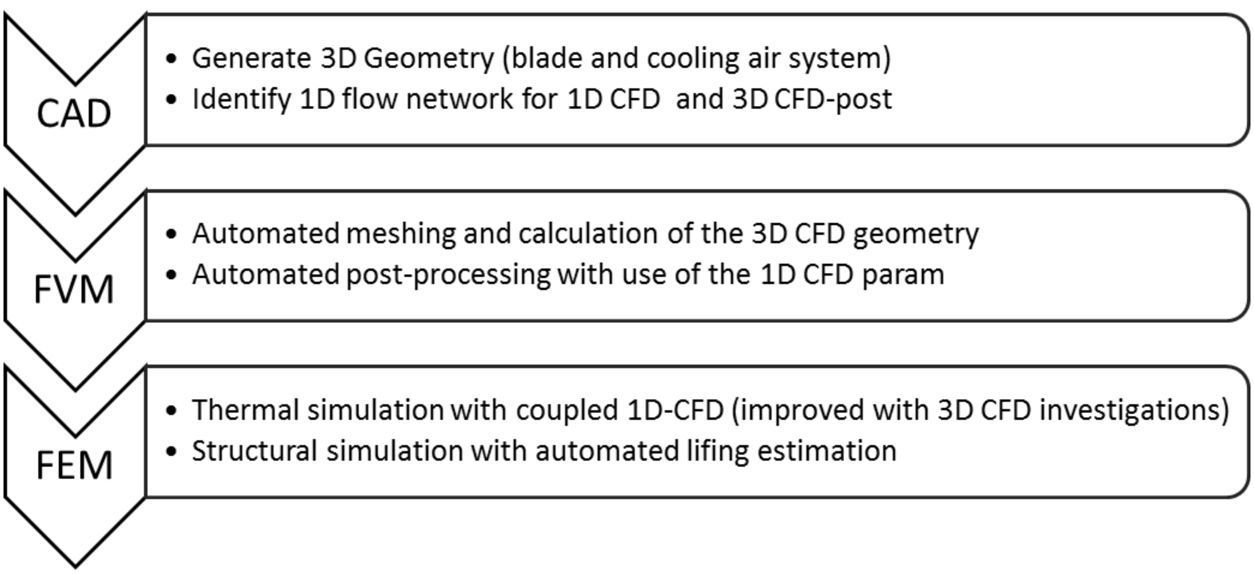

Figure 2: Multidisciplinary CAE process for aero engine cooled turbine blade

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