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Optimization of blade cooling system with use of conjugate heat transfer approach

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A B S T R A C T

This paper discusses an optimization problem of internal cooling passages within a turbine blade with Conjugate Heat Transfer (CHT) analysis involved. However, to make the problem computationally feasible it was necessary to reduce the CHT predictions by fixing the external flow and solving the task for the interior only (solid and coolant). The optimization is done with an evolutionary algorithm within a 30 dimensional design space which use of the Pareto approach. Results showed more reliable thermal field predictions comparing to the classical approach and possible improvements in the design obtained.

1. Introduction

The main goal of gas turbine development is to increase its thermodynamic efficiency which depends on several factors, where the most significant are the turbine inlet temperature, the selection of the optimal compression ratio and the application of an adequate system configuration (intercasing cooling, sequential burning, regeneration, etc.). However, nowadays the most substantial seems to be the temperature increase at the inlet to the turbine, which draws the most attention of engineering activity both for land based turbines and aircraft engines [29]. Hot gas temperature raise affects the level of both the specific power and thermal efficiency of the cycle. In consequence, it improves weight/power ratio of the engine, which is one of the major goals of aerospace propulsion design [16]. The development in this area is possible due to the progress in material engineering as well as the prevention of high temperature effects within the materials. Modern materials additionally covered with Thermal Barrier Coatings (TBC) should meet the requirements concerning the operation regime of hot gas path components. The temperatures however are nowadays so high, that the material engineering activity is not sufficient and the application of cooling for the hot components is necessary. Bunker [2] specifies the engineering activities which should be taken up to counteract the elevated thermal conditions:

- Selection of materials and coatings
- Application of internal cooling
- Application of film cooling
- Selection of coolant
- Choice of appropriate component design to meet the thermo-mechanical criteria

Making allowances for all these factors concurrently, they determine the potential and parameter limits for modern gas turbines. The parameters are to be assessed for the maximum output power, since the components must meet any operating conditions.

Application of cooling for the turbine components results in additional loss generation, which is connected with the coolant flow. The structure of cooling system and resulting mass flow rate of the cooling air affects the effectiveness of energy conversion to a great extend. On the other hand, the cooling system applied, should provide keeping the component's maximum temperature below the allowable limit. This limit depends on the component's material and results from melting temperature, thermal strength and creep resistance.

Taking into account different aspects of airfoil manufacturing and the turbine performance, the most convenient way of component temperature reduction is internal convective cooling. It is based on the coolant flow, mainly air, extracted from the compressor bleed, via internal cooling passages. In the most simple form a passage is cylindrical and is supplied with air at the blade root. Coolant flows out into the hot gas at the blade tip. More

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