Numerical study of a turbulent impinging jet for different jet-to-plate distances using two-equation turbulence models

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Long Abstract

Abstract

Impinging jets are a common technique also widely used in modern aero engines. Achieving high heat transfer coefficients, impingement cooling is an efficient way to counteract locally occurring high heat loads. For cooling large areas, impinging jets are arranged in rows or arrays.
This cooling concept finds application as a temperature control for turbine casings. Depending on engine operating conditions, considerable variations of thermal loads lead to a change in blade tip clearances. A reduction of these clearances is essential to increase the efficiency of aero engines. By directing a controlled flow of impinging air onto the turbine casing, clearances remain nearly constant at their optimum. The so-called active clearance control (ACC) system consists of several tubes surrounding the turbine. After entering the tubes, coolant air exits via numerous holes directed to the external side of the casing.
Regarding the highly complex flow mechanisms, it is necessary to get a deeper understanding of the ACC system. Therefore, we are investigating flow and heat transfer characteristics numerically at the Institute of Aerospace Thermodynamics (ITLR) at the University of Stuttgart. Due to the geometry's complexity and an enormous number of impinging jets, the use of RANS simulations is indispensable. Hence, turbulent structures inside the jets need to be modelled. To make sure that the numerical setup is able to reproduce flow and heat transfer characteristics correctly, a validation is necessary.

This paper compares numerical results of a round impinging jet with experimental data given by ERCOFTAC [1]. While Baughn and Shimizu [2] and Baughn et al. [3] [4] focused on the heat transfer characteristics at different jet-to-plate distances, Cooper et al. [5] described the flow mechanisms. Besides, the authors varied the Reynolds number from Re=23,000 to Re=70,000.
There exist several studies depending the influence of turbulence models with the described data set. Coussirat et al. [6] compared one-, two- and four-equation models varying the jet-to-plate distance H/D=2, 6 and 10 as well as the Reynolds number. The v2f model showed the best agreement to experimental data. Draksler and Končar [7] combined the standard SST turbulence model with a turbulence production limiter given by Kato and Launder [8]. They concentrated their study on a jet-to-plate distance of two. The Kato-Launder limiter improved the numerical accuracy regarding heat transfer prediction.
The work of this paper combines the described studies [6] [7]. We applied the Kato-Launder production limiter to the in [2] [3] [4] available jet-to-plate distances H/D=2, 6, 10 and 14. The Reynolds number was set to 23,000. Figure 1 gives an overview of the Nusselt number in the stagnation point. For all jet-to-plate distances, the Kato-Launder limiter leads to a reduction of the local heat transfer. With H/D=2 and 6, the use of this limiter provides better results compared to the standard SST model. For higher values of H/D, the production limiter under predicts the local heat

transfer, whereas the standard SST model reproduces the experimental results very well.
Looking at the Nusselt number over the radial distance r/D, Figure 2 shows a substantial difference between both turbulence models in the stagnation zone for H/D=6. While the SST model with Kato-Launder limiter gives a better prediction of the heat transfer magnitude, the standard SST model reproduces the general trend more accurate. For larger radial distances, both turbulence models achieve the same results.

The final paper will contain a detailed description of flow and heat transfer characteristics for all jet-to-plate distances. Furthermore, the influence of mesh topology and the height of the first cell will be discussed.

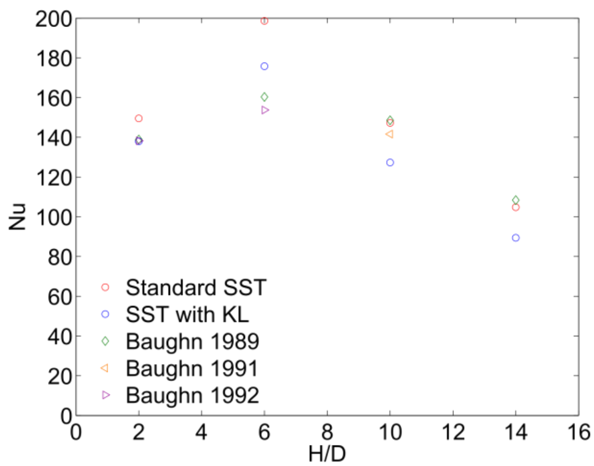

Figure 1. Nusselt number at the stagnation point for different jet-to-plate distances

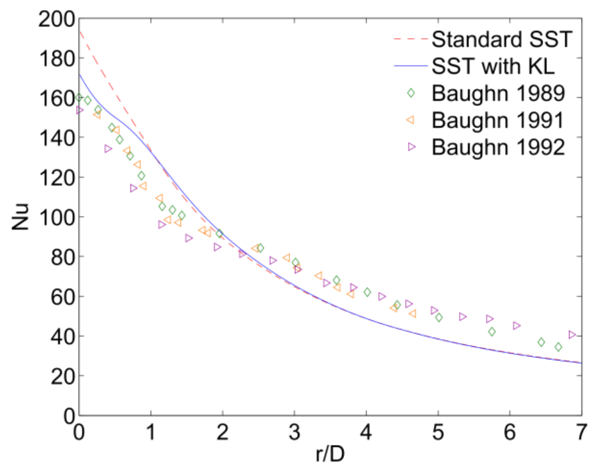

Figure 2. Nusselt number over radial distance with H/D=6

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