Numerical study of heat transfer enhancement by the passively generated acoustic waves

SEBASTIAN RULIK[1*], WŁODZIMIERZ WRÓBLEWSKI[1]

[1] Institute of Power Engineering and Turbomachinery, Silesian University of Technology, Konarskiego 18 Str., 44-100 Gliwice

sebastian.rulik@polsl.pl, wlodzimierz.wroblewski@polsl.pl

Modern gas turbine systems operate in the range of temperatures from 1200^{0}C to even 1500^{0}C. Due to such high temperature values, the problems related to the blade material thermal strength start to increase considerably. Additionally, the temperature oscillations and the non-uniform temperature distribution on the blade surface cause significant thermal stresses which may shorten the blade system service life. In order to protect blades appropriately, a sophisticated cooling system is used. Currently, emphasis is placed on the application of non-stationary flow effects in order to improve the cooling conditions, e.g. unsteady jet heat transfer or heat transfer enhancement using high amplitude vibratory motion [1]. Presented research follow similar direction. The new concept of intensification of heat transfer in the cooling channels with the use of acoustic wave generator is proposed. The acoustic wave is generated by a properly shaped fixed cavity or group of cavities.

The sound generated by the cavity is a phenomenon analyzed in various publications focused on the methods of its reduction [2][3]. The phenomenon is related to the coupling mechanism between the vortex shedding generated at the leading edge with the acoustic waves generated within the cavity (Fig.1). The acoustic waves are generated by the interaction of vortices with downstream wall of cavity. The detailed explanation of this phenomenon was given by Rossitier [4].

Strong instabilities can be observed within the certain range of free flow velocities. Research presented within this paper are aimed towards the use of described phenomenon in order to intensify the heat transfer process. First part of the work presents numerical model used for the analysis and its validation based on the experimental studies. Additionally, the calculated frequency of the acoustic waves will be compared with the empirical relations. Numerical model has been prepared using commercial CFD program Ansys CFX-17.0.

Analysis of this type of phenomenon is a challenging task. Different time scales related to acoustic wave frequency and heat transfer phenomenon needs to be considered. It concerns, on the one hand the need for proper time discretization in order to correctly model generation and propagation of acoustic waves and on the other hand the necessity to obtain steady state heat transfer conditions which requires a reasonably long period of time.

The study will include determination of the relationship between the amplitude of acoustic vibrations and cooling conditions within the cavity. For given boundary conditions heat transfer coefficient or wall heat flux will be determined on cavity walls. The calculations will be carried out also for variable flow conditions.

The knowledge gained by the presented research can be used for improvement of design of elements dedicated for heat transfer intensification in cooling channels or in places where traditional convection cooling fails, e.g. tip of the blade.

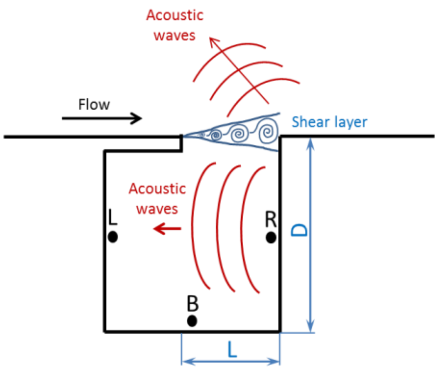

Fig. 1 Sound generation mechanism [5]

References

[1] Florio L., Harnoy A., Natural convection enhancement by a discrete vibrating plate and a cross-flow opening: a numerical investigation, Heat Mass Transfer, Vol. 47, 2011, pp. 655-677

[2] Ashcroft G. B., Takeda K., Zhang X., Computations of self-induced oscillatory flow in an automobile door cavity, NASA/CP-2000-209790, 2000, pp. 355-361.

[3] Henderson, B., Automobile noise involving feedback-sound generation by low speed cavity flows, NASA/CP-2000-209790, 2000, pp. 95-100.

[4] Rossiter J.E., Wind Tunnel Experiments on the Flow over Rectangular Cavities at Subsonic and Transonic Speeds, Royal Aircraft Establishment, Technical Report 64037, 1964

[5] Rulik S., Wróblewski W., Nowak G., Szwedowicz J., Heat transfer intensification using acoustic waves in a cavity, Energy, Vol. 87, 2015, pp. 21-30