Project title:
An influence of geometrical conditions of synthetic jet generation on its flow characteristics and potential to enhance convective heat transfer

A synthetic jet actuator is a device that enables the generation of a new type of flow, i.e. a synthetic jet. A characteristic feature of this device is the lack of an external fluid supply – the working fluid is the fluid surrounding the device. Additionally, the time-average mass flow rate in the orifice cross section is exactly equal to zero because the working fluid is periodically sucked into and ejected out through the orifice.

The synthetic jet actuator consists of a vibrating element (e.g. loudspeaker diaphragm), a cavity and an orifice. A loudspeaker used to build the synthetic jet actuator, powered by a sinusoidal signal, causes cyclical changes in the volume of the generator cavity, which results in periodic suction and ejection of fluid through the orifice. Under certain conditions, called the criterion of the formation of a synthetic jet, when the fluid is ejected through the orifice, a vortex structure is formed at the edge of the orifice and propagates under self-induced velocity. During the continuous operation of the synthetic jet actuator, a sequence of vortex structures is created which creates a synthetic jet. At some distance from the orifice, these vortex structures collapse to create a turbulent flow. Considered over a long period of time, this flow is similar to a continuous flow. However, due to its highly turbulent nature and the resulting parameters, scientists are looking for many interesting applications of a synthetic jet, and the most perspective application appears to be heat dissipation.

Scientific research on synthetic jet began in 1998 after the publication of "Smith, B. L., & Glezer, A. (1998). The formation and evolution of synthetic jets. Physics of Fluids, 10 (9), 2281-2297". Since then, there have been many publications on synthetic jet formation, vortex dynamics, and the use of synthetic jet in the turbulence of laminar flows, as well as in impingement cooling. Despite many publications, there is no single collective database on the influence of geometrical conditions of synthetic jet generation on its flow characteristics and its potential to enhance convective heat transfer, as well as there is no information on the effect of vortex structures on the noise generated by the synthetic jet actuator.

The aim of the project is to study influence of geometrical conditions of synthetic jet generation on its flow characteristics, generated noise and potential to enhance convective heat transfer. For this purpose, 32 geometries of the synthetic jet actuator will be tested. The project involves 4 stages. In the first stage, the innovative research method will be used, consisting of measuring the reaction force of the synthetic jet actuator and thus determining the characteristic velocity and energetic efficiency of the synthetic jet actuator. In the second stage, the radial velocity profiles of the synthetic jet will be determined. In the third stage, the velocity fields will be measured using the time-resolved PIV (Particle Image Velocimetry) laser techniques. In the fourth stage, thermal measurements will be made to determine the maps of convective heat transfer coefficients during impinging cooling with the use of synthetic jet.

Based on the research conducted as part of the project, we expect to find relationships between the geometric conditions of synthetic jet generation and the flow characteristics and the potential of synthetic jet to enhance convective heat transfer. Moreover, from time-resolved PIV studies, it will be possible to perform the so-called POD (Proper Orthogonal Decomposition) analysis, which will help to explain the phenomena affecting convective heat transfer and the noise generated by the device. The completion of the project will provide a collective database where the geometry of the synthetic jet actuator tested in a wide range will allow comparison of flow parameters and assessment of the relationship of these results with the potential of a synthetic jet to enhance convective heat transfer.