Experimental analysis of the effect of external forcing upon the free jet

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Introduction

The main aim of the investigation is to complete the experimental verification of the new mechanism of laminar-turbulent transition in round free jets, which has been found numerically by Boguslawski et al. [1]. Instability processes in shear flows are of primary importance in fluid dynamics since transitional free flows are present in many technical applications, but first of all it is a scientific challenge, since the explanation of the transition mechanisms may result in better understanding of turbulence and vortex dynamics. There are two main instability types of shear flows i.e. convective and absolute regimes. Convective instability is determined by shear layer characteristics, it scales on the shear layer thickness and the perturbation eigenfunctions are of local type limited to the shear layer zone. The absolute instability is characterized by perturbation growth in time, scales on the jet diameter and the perturbation eigenfunctions are global i.e. the flow oscillations are present in the whole jet cross-section. Absolute instability can be triggered in many ways, but the most convincing way seems to be the application of variable density. Interestingly, according to numerical evidence obtained by Boguslawski et al. [1] for sufficiently thin shear layer (i.e. $R/\theta > 25$, where R-jet exit radius and θ-momentum thickness of the shear layer) the initial perturbation grows sufficiently fast to generate large scale vortex in the jet near field. As a consequence the back flow at the jet external periphery acts as a feedback loop and amplifies the initial perturbation leading to self-sustained oscillations, very much like the in absolute instability, but without any density difference between the jet and the ambient surroundings. The numerical simulations confirmed the existence of self-sustained oscillations [2] and demonstrated the generation of jet bifurcation under the proper forcing [3]. Presented results are the next part of the experimental verification of the new type of instability and will show potential of flow control in the regime of self-sustained oscillations.

Description of experimental work

Two different designs of Synthetic Jet (SJ) generators were developed and tested. The design with flat membrane was selected for further investigations, as it allows to minimize the parasitic volume and produces a cleaner signal. The SJ generator must perform as the point source of acoustic wave, that in turn requires that the value of Holman's parameter must be lower than 0.2 [4]. The commonly used methodology of Holman's parameter determination (e.g. [5]) appears to be not fully reliable and a new method based on phase averaging is proposed. This methodology was developed within the investigation, then the LabView and Fortran software were elaborated and finally characteristics of SJ generators was determined.

The numerical investigations performed within the NCN 2011/03/B/ST8/06401grant demonstrated, that under the properly controlled forcing the jet bifurcation appears, that increases substantially the turbulent mixing and allows for control the jet spreading rate [3]. The SJ generators and the LabView software were applied to generate forcing to the jet at the following conditions: $Re = 5 \times 10^3, 10 \times 10^3$ and 20×10^3 for isothermal jet. The response of the jet was evaluated at the point located at the jet axis where a characteristic plateau appears, that corresponds to maximum amplitude of coherent structures. However, despite the early stage of research, we were able to observe a clear response of the flow for some cases for external forcing.

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