EXPERIMANTAL AND NUMERICAL STUDY OF PULSATING TRANSVERSAL JETS

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Paper presents results of joint experimental and numerical investigation of pulsating jet penetration into still air and supersonic flow. Goal of the study is to find conditions for better mixing between air and secondary (injected) gases.

Problem of mixing of different gases in supersonic flows is of great importance for scramjet combustion chamber design. To control the mixing characteristics, different methods are applied including pylon fuel injection, introduction of compression and expansion angles into the channel geometry to induce downstream vortex generation, shock wave interaction with mixing layers, formation of additional recirculation zones in vicinity of the fuel supply location by means of cavity/step construction, etc. All these methods allow to attain good mixing level between the fuel and oxidizer. However the severe requirements specified for the scramjet combustion chambers demand new efficient and robust approaches to improve the primary and secondary flow mixing.

It has been shown previously [1, 2] that from the mixing improvement standpoint it seems promising to apply pulsating regime of the fuel jet injection. One of the possible ways to affect the mixing process is the Hartmann generator implementation. The Hartmann generator is investigated for a long time [3, 4] and there are numerous papers devoted to study of pulsating and acoustic parameters of the generator both for the case of immersed jets and injections into a low subsonic speed flow.

In the paper, a plane analogue of the Hartmann oscillator is used as an unsteady jet source. A test model has been designed on module construction principles (Fig. 1). The model modification allows to perform parametrical investigation on influence of the determining generator characteristics on its gasdynamic properties. The model enables to study the external flow effect on the generator characteristics, jet penetration length and mixing efficiency.

Experimental investigations of the pulsating characteristics of helium and air immersed micro-jets have been performed. It has been shown that varying the nozzle and resonator geometry allows to get high-frequency pressure pulsations of the frequency range from 5 to 100 kHz (Fig. 2).

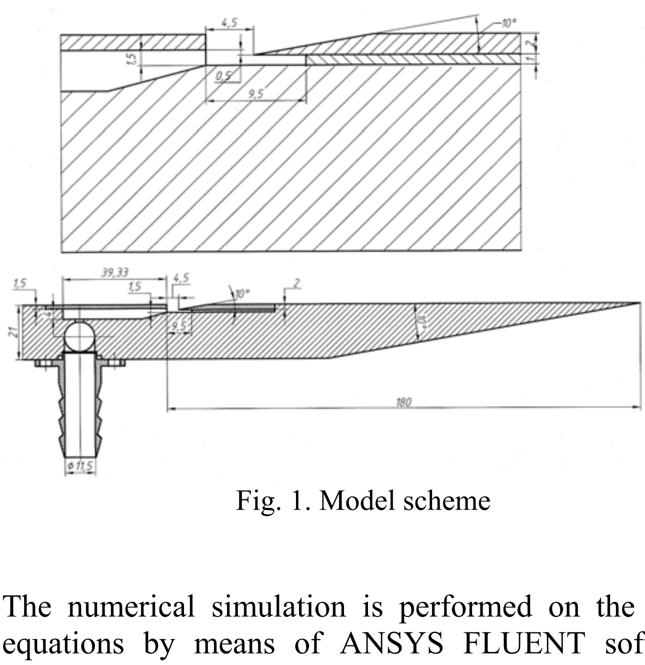

Fig. 1. Model scheme

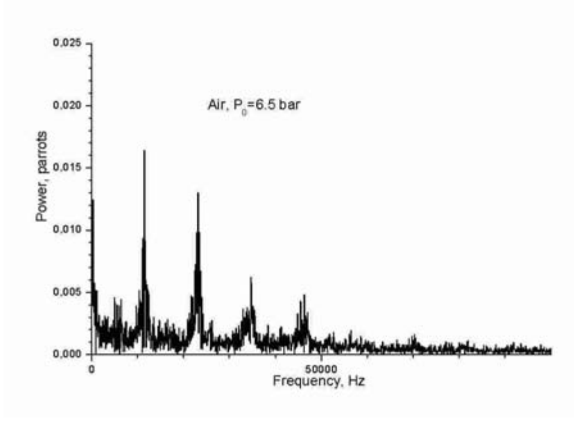

Fig. 2. Frequency of the air jet injected into still environment by the plane Hartmann generator

The numerical simulation is performed on the base of the full Reynolds averaged Navier-Stokes equations by means of ANSYS FLUENT software using two-equation turbulence models. The numerical approach and turbulence models are validated with the aid of experimental data [5], where a sonic nitrogen jet injection into supersonic air flow of M_∞=2.61 is considered. The primary flow static pressure is P∞=7 kPa and the jet pressure varies as P_j=24, 45 and 83 P_∞. Convergence study on a sequence of refined grids is carried out for the case P_j=24 P_∞ with the aid of pressure gradient adaptation function available in ANSYS Fluent. Comparison of the computed and experimental data on the wall pressure distribution is provided in Fig. 3. Satisfying agreement on the pressure level and both on the separation lengths in front and behind the jet is demonstrated. Higher jet pressure level results in higher interaction intensity and separation augmentation.

Further, a number of 2D computations of the problem of pulsating air and helium immersed jets and their injection into supersonic external flow have been carried out (Fig. 4). The computed results are compared to the experimental data on frequency of the Hartmann generator. Details of the flowfield are revealed and mechanisms of the unsteadiness influence on the mixing level between the primary and secondary flows are investigated. Numerical parametrical studies have allowed to find out the pulsation generator geometry and the external flow parameters influence on the channel flow with the jet injection.

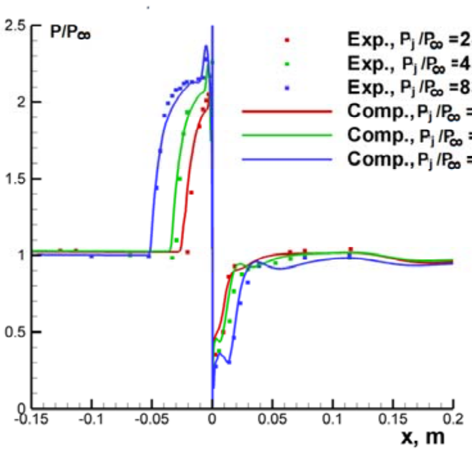

Fig. 3. Comparison of the computed and experimental [5] wall pressure distributions for the problem of the nitrogen jet injection into supersonic air flow

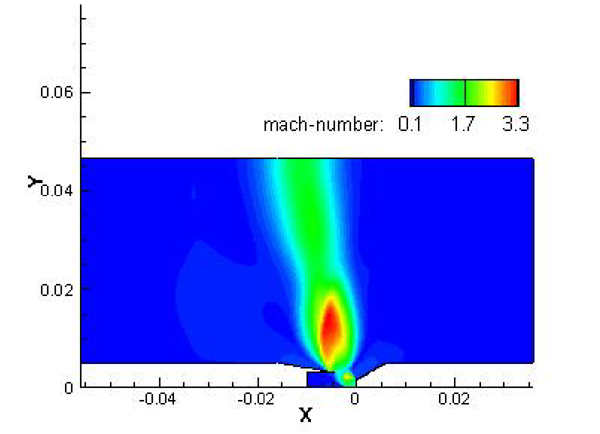

Fig. 4. Instantaneous computed Mach number field for the immersed air jet problem

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