Noise characterization of short duration and conventional hypersonic wind tunnels

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Noise characterization of the wind tunnel has to be the first step for any boundary layer stability/transition experimental study. This kind of data allows comparing the transition experiments performed in various facilities.

The noise characterization techniques for the conventional or blowdown wind tunnels are based mainly on the hot-wire application and were successfully used in many studies. Application of hot-wire anemometry and modal analysis allowed to discover that acoustic radiation from the nozzle walls is the main source of the disturbances in the hypersonic blowdown wind tunnels. Today there is a tendency to use hypersonic short duration wind tunnels for boundary layer transition studies. The advantage of this kind of facilities is relatively inexpensive testing. Using of modern high speed acquisition systems allows gathering all necessary data during runtime of about 50÷100 ms. At the same time the design features of these wind tunnels may result in appearance of additional disturbances in the settling chamber and affect the modal and spectral content of disturbances.

The current study was performed for characterization of the freestream disturbances in two wind tunnels planned for boundary layer stability experiments in framework of FP7 project TransHyberiAN: Tranzit-M (ITAM SB RAS) and U6 (TsNIIMash). Tranzit-M is an impulse type aerodynamic facility equipped with fast opening valve. U6 is a conventional wind tunnel of blowdown type. Wind tunnel were operated at conditions designed for transition experiments, namely $M=6$, $Re_1 = 5\div30\cdot10^6$ m^{-1} and $T_0 = 400\div500$ K.

The main technique of the noise characterization in the current study was unsteady pressure measurements at stagnation point of the blunt probe. Additional measurements of the heat flux were performed in the same manner. The shape of the probe was designed to ensure the constant distribution of pressure and heat flux on the surface of the sensors installed. 5 probes of the same shape were assembled in a rake what allows estimating of spatial distribution of the noise in the test section. The measurement of pressure pulsations was carried out by high frequency piezoelectric sensor PCB 113B28, the heat flux pulsations was measured by ALTP sensor. Mean flow characteristics, RMS values of pulsations were obtained and their spectral characteristics were analyzed. Priory to experiments the CFD analysis was done to calculate the relation between freestream pressure pulsations and pulsations on the wall measured by the sensor and transformation coefficients were found.

It was assumed from the beginning that the cause of the fluctuations in the flow of "Tranzit-M" may be disturbances formed in the prechamber, and the acoustic emitted by a turbulent boundary layer of the walls of the nozzle. It was obtained in the experiments that variation of the total pressure and Reynolds number has strong effect on the measured pressure pulsations. It can be seen from the Figure 1 that increasing of Re_1 significantly decreases the noise level in the test chamber. This effect is most likely connected with increasing of the boundary layer thickness on the nozzle wall and growth of the acoustic generation by the boundary layer. Maximum level of pressure pulsations in this case is about 3%. If all the pressure pulsations in Fig.1 are assumed to be excited by the slow acoustic waves the value of pressure pulsations in free stream may be estimated basing on results of CFD simulations. The resulting value is two times higher then data presented in Figure 1.

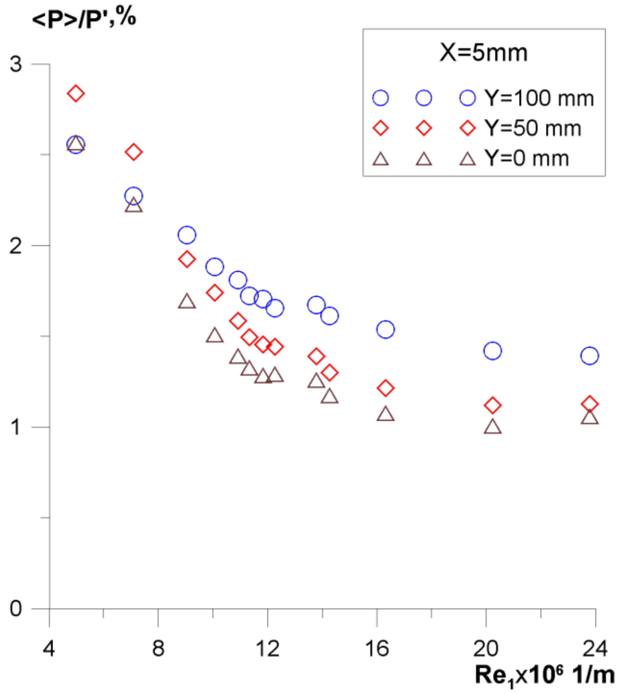

Fig.1 Dependence of the pressure pulsations on Re_1

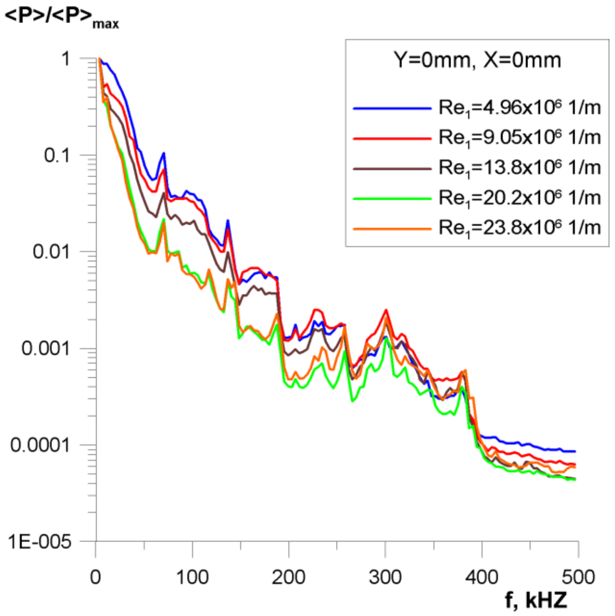

Fig.2 Dependence of the pressure pulsations spectra on Re_1

Fig. 2 shows the power spectra of the pressure pulsations measured normalized by their maximum amplitude. Data were obtained for various Re_1 at the nozzle exit on the axis. For all the graphs there is strong decrease of pulsations level with growth of frequency. It can be seen on the graphs, that with increasing of Re_1 the normalized values of pulsations decrease in the frequency range $f = 10 \div 300$ kHz, and the main change happens in the frequency range $f = 10 \div 175$ kHz. Taking into account that all the spectra are normalized by the power of fluctuations with frequency $f \approx 3.9$ kHz, the data demonstrate a relative decreasing of the high-frequency component of the signal with increasing of Reynolds number.

As estimation of background noise in U6 wind tunnel a results of static pressure fluctuations measurements on side surface of sharp cone with half-angle 7,5° also was used. The B&K (Belgium) acoustic measurement system (microphones 4136 and other relevant equipment) was utilized. Variation of root mean square values of pressure fluctuation σ normalized by free stream static pressure p_{st} with unit Reynolds number is presented in Fig. 3

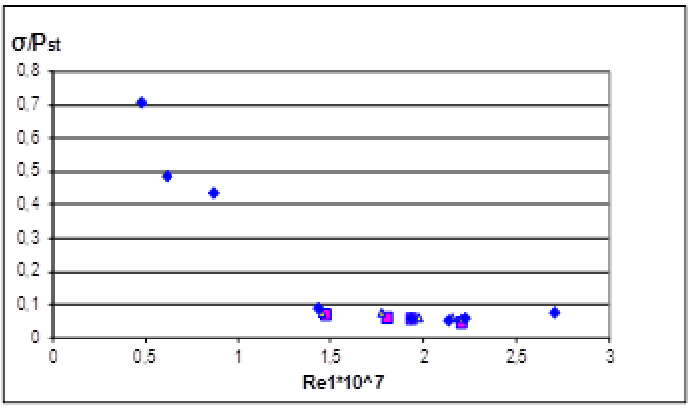

Fig.3

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