PULSATIONS OF PRESSURE AT A CYLINDER IN A SUBSONIC STREAM OF GAS.

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Summary The distribution of root-mean-square values and spectral characteristics of pulsations of pressure at a cross flow of the cylinder in a subsonic stream of gas (M = 0.44 - 0.88) are investigated.

The flow of the cylinder is well enough studied, many works concern to an incompressible liquid, for example, in [1] distribution of pressure, in [2] - pulsations of pressure were experimentally learnt. A number of researches on a cross flow of the cylinder is executed at supersonic speeds, for example, [3]. However, for subsonic numbers of the Mach there are only sketchy data on measurements of pressure on the cylinder [4] and researches on pulsations of pressure are not known. In the given work pulsations of pressure are investigated at a cross flow of the cylinder in a subsonic stream of gas (M = 0.44 - 0.88). The data of the present experiments may be used at studying areas of compression and expansion of a stream, occurrence of local supersonic zones, and also for an estimation of pulsations of pressure on the blunted bodies. The model of the cylinder in diameter D = 50 mm and by length 200 mm was tested. Established across a stream on the thin lateral plates fixed on the bottom wall of a wind tunnel. Tests in a wind tunnel with section of a working part 600x600 mm were carried. Numbers Reynolds determined on parameters of an undisturbed stream and referred to diameter of models, made $Re_D = 0.6 - 1.5 x 10^6$.

Sensor averaging pressure and pulsations of pressure settled down in the central section of the cylinder. Measurements on an angle φ it was made at rotation of model around of an axis, normal to a stream. Sensor Endevco 8514 to measurements of pulsations of pressure, working in a range 50 - 20000 Hz and also a special sensor with a glow-charge were applied. This sensor had the following design: platinum electrodes were mounted in a porcelain cylinder with wedge shaped nose section.

Let's consider a picture of pressure on a surface of the cylinder. Growth of number of the Move causes reduction of pressure by a rear surface of the cylinder, and at M = 0.54 a lateral surface there are local supersonic zones. Beginning from a forward point of a body (φ = 0) pressure decrease on a site is observed up to $\varphi = 80^0$, and then it raises and leveled on a rear part of the cylinder.

During experiments total levels of pulsations of pressure $L_\Sigma = 20\lg\left[\left(\overline{P^2}\right)^{0,5} \Big/ P_0\right]$, (where $\overline{P^2} = \int_0^\infty \overline{P^2(f)}df$ - an average square of pulsations, $\overline{P^2(f)}$ - spectral density, f - frequency, $P_0 = 2 \cdot 10^{-5}$ Pa - a zero level) and distributions of spectral capacities of pulsations with the help of the analyzer of a spectrum were measured. For an opportunity of comparison of the given tests on various installations, except for dimensionless parameter P^I .The value $\left(\overline{\overline{P^2}}\right)^{0,5} \Big/ q$ describing the attitude of root-mean-square value of pulsations of pressure to a high-speed pressure was used. At data processing tests on pulsations of pressure on the cylinder the size was used $P' = \left(\overline{\overline{P^2}}\right)^{0,5} \Big/ \left(\overline{\overline{P^2}}\right)^{0,5}_\infty$, where $\left(\overline{\overline{P^2}}\right)^{0,5}$ and - $\left(\overline{\overline{P^2}}\right)^{0,5}_\infty$ - root-mean-square values of pulsations the pressure measured on a lateral surface and in a forward point of the cylinder accordingly.

At small speed of an undisturbed flow (M = 0.44) there are two fields of the increased pulsations: at $\varphi = 40 - 60^0$ and $\varphi = 110 - 130^0$. Two extreme on the diagram of distribution specify formation initial separated areas on a lateral face with a separation of a boundary layer and the subsequent connection. One of the reasons of formation of high levels of pulsations in points separated and connections is oscillatory character of moving of these points and the pulsing change of average pressure connected to it.

Increases of speed of an undisturbed flow levels distribution of pulsations a little (M = 0.54, Fig. 1)) , and at M = 0.68 pulsations in area of a lateral point begin to grow ($\varphi = 90^0$), which reach the maximal value at M = 0.88. Powerful pulsations of pressure upon surfaces of the cylinder at subsonic speed of a flow are connected to fluctuations of closing shockwave for shockwave behind local supersonic zones. Reduction of pulsations of pressure in process of growth of speed of a subsonic stream, before formation of local supersonic zones on lateral surfaces, is caused by increase of stability average flow. Distribution, upwards on a stream, area of supersonic flow on a lateral surface, in process of growth of number of Mach in a range of critical numbers of the Mach, results, on the one hand, in decrease of influence of a near trace on a forward part of a body, and with another - to increase intensity closing this area shockwave and accordingly to a secondary separation and connected with it pulsations in separated zone and, especially, in a point of connection. For a wide class of bodies the greatest amplitudes of pulsations arise at subsonic and small supersonic speeds of an external flow. The combination of intensive fluctuations of pressure and rather high-speed pressure in this range of speeds may result in significant dynamic loadings, and sharp reorganization of character of a flow changes aerodynamic characteristics. Increase of pulsations in area rear critical point depends on influence of a return jet. If to consider dependence P^I = f (M), it is visible, that at growth speeds of a subsonic flow from M = 0.44 up to M = 0.68 pulsations are reduced on all surface of the cylinder. Exception represents point with φ = 90^0, where sharp increase of P^I is observed at the approach to sound speed.

On spectra of pulsations the approached values of numbers Strouhal are determined $Sh = fD/u_\infty$, *where* f - frequency, D - diameter цилиндра, u_∞ - speed of the undisturbed flow, appropriate area of the maximal capacities of a spectrum on a corner φ. We shall consider change of numbers Sh, describing distribution of group frequencies of pulsations on a surface of the cylinder. At spreading a stream from a forward point speed is increased, that is accompanied by decrease of frequencies of pulsations. In a range of small subsonic speeds (M = 0.44) decrease of numbers Sh is observed at values of angle φ =40 - 60^0. At M = 0.54 (Fig. 2) frequencies rise up to φ =140, then are a little bit reduced, and at M = 0.88 the increase of frequencies up to a back point of the cylinder is observed.

As spectra of pulsations in a forward point reflect "background" of the installation, it is possible to assume, that rises on low frequencies at subsonic speeds are caused by vortex formation at a flow of elements in the closed aerodynamic contour of installation. Prevalence of a high-frequency part over spectral structure of turbulent noise is caused by a turbulent boundary layer on walls of a wind tunnel.

Fluctuations of base pressure can be caused by a number of interconnected factors. In particular, realization of quasistationary regimes with relaxation oscillations, flow-rate variations of fluid in the stagnant zone, instability of the reversed stream, shifting of separation and joining points of the flow, acoustic oscillations In the resonance volume and also by large scale eddying and turbulence. In the spectra of pulsations of base pressure of relatively low-frequency oscillations are explained in the base region as a whole and involve change in the quantity of fluid, which circulates in the stagnant zone.

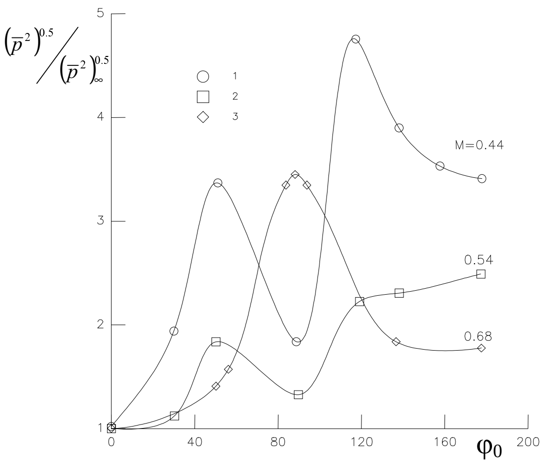

FIG. 1

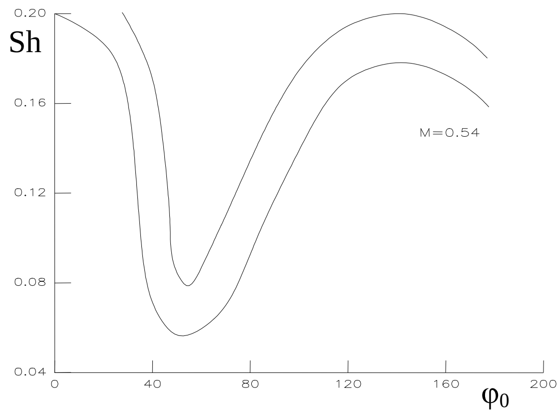

FIG. 2

CONCLUSIONS

The distribution of root-mean-square values and spectral characteristics of pulsations of pressure at a cross flow of the cylinder in a subsonic stream of gas (M = 0.3 - 0.8) are investigated. As a result of measurements of pulsations of pressure on cross-section streamline cylinder it is established: at small subsonic speed (M = 0.44) there are two field of the increased root-mean-square value of pulsations of pressure (φ =50 - 120^0) owing to initial and rear separates a boundary layer, at big subsonic speed (M = 0.9) - on a field φ =90^0- owing to formation of a local supersonic zone with closing shockwave. At spreading a stream from a forward point speed is increased, that is accompanied by decrease of frequencies of pulsations. In a range of small subsonic speeds decrease of numbers Sh is observed at values of angle φ =40 - 60^0. At M = 0.54 frequencies rise up to φ =120, then are a little bit reduced, and at M = 0.9 the increase of frequencies up to a back point of the cylinder is observed.

References

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