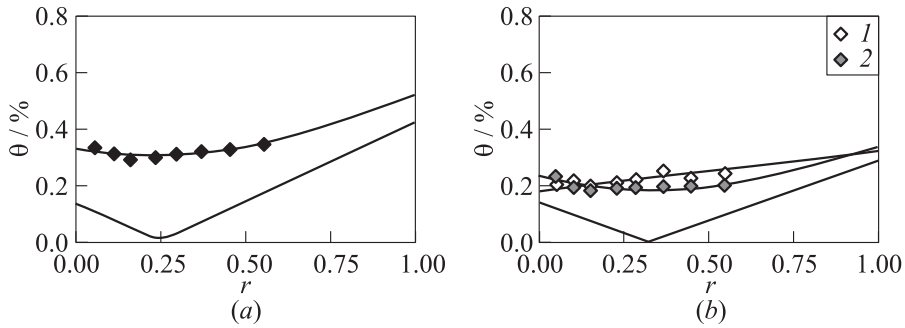

Figure 7 The broad (0–25 kHz) (*a*) and narrow (*1* — 0–1 kHz; and *2* — 1–25 kHz) frequency FDs (*b*) obtained at M = 0.7, $\mathrm{Re}_1 = 41.0 \cdot 10^6$ 1/m, and $T_0 = 150$ K

Table 3 Mass flow, temperature fluctuations, and correlation coefficients at M = 0.7 and $T_0 = 150$ K

Frequency range	$\mathrm{Re}_1/10^6$, 1/m	$\langle m \rangle$, %	R_{mT_0}	$\langle T_0 \rangle$, %	$r_{\min}$
Broad	41	0.56	0.41	0.33	0.24
	103	0.58	0.21	0.24	0.09
0–1 kHz	41	0.13	−1	0.19	−1.39
	103	0.12	−1	0.16	−1.31
1–24 kHz	41	0.43	0.60	0.23	0.33
	103	0.55	0.53	0.17	0.16

For instance, relative values of mass flow fluctuation $\langle m \rangle$ were not changed, while total temperature $\langle T_0 \rangle$ values were a bit lowered.

The variation of mass flow fluctuations $\langle m \rangle$ in respect of unit Reynolds number Re_1 at fixed freestream Mach number is shown in Fig. 8*a* (left part). The control of Re_1 was mainly provided by means of changing the total temperature of the flow and sometimes by changing the stagnation pressure. As it can be seen, the dependence of fluctuations $\langle m \rangle$ on Re_1 is nonmontonic with some maximum for each Mach number curve. The complete distribution of $\langle m \rangle$ over Re_1 is given in the right part of Fig. 8*a*. It can be seen some weak upward trend of mass flow fluctuations with unit Renolds number increasing.

In Fig. 8*b*, the distributions of total temperature fluctuations over unit Reynolds number are presented. The distributions of $\langle T_0 \rangle$ plotted at fixed Mach numbers are looking similarly as $\langle m \rangle$ ones in Fig. 8*a*. However, the appropriate complete distribution of $\langle T_0 \rangle$ given in the right part of Fig. 8*b* demonstrates almost constant level of total temperature fluctuations over Re_1.

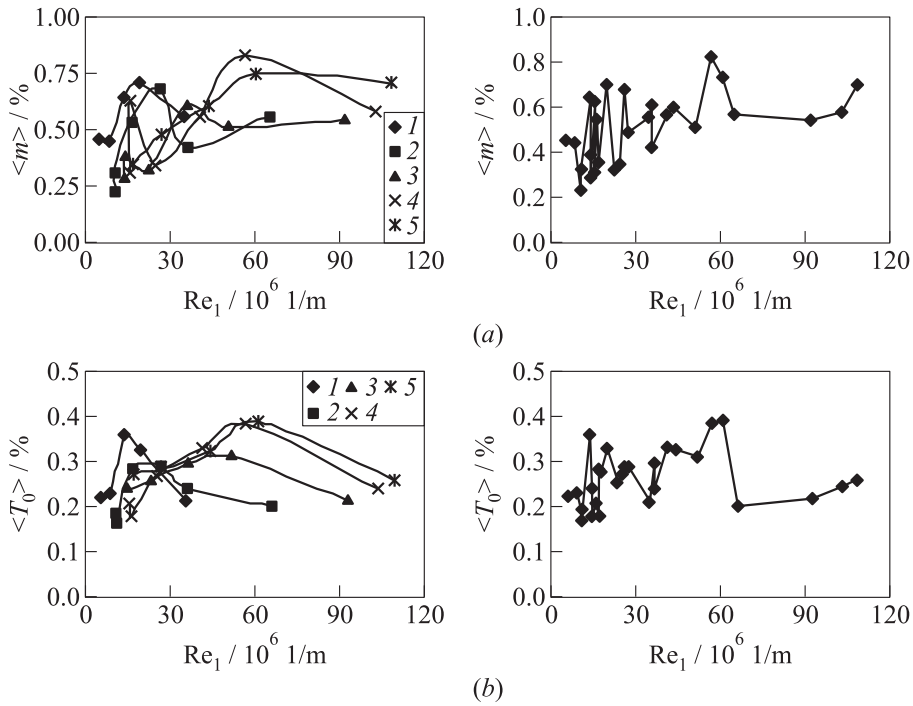

Figure 8 Mass flow (a) and total temperature (b) fluctuations over unit Reynolds number (for selected M — left and total — right): *1* — M – 0.2; *2* — 0.4; *3* — 0.6; *4* — 0.7; and *5* — M = 0.8

4 CONCLUDING REMARKS

Investigation of fluctuation structure in the test section of transonic wind tunnel at convenient and cryogenic temperatures of the flow was performed by means of hot-wire anemometer.

1. It was shown the complete applicability of the hot-wire technique, including method of fluctuation diagram, at cryogenic conditions without some particular limitations.

2. The hot-wire measurements allowed to find out that the typical frequency spectrum of flow fluctuations consists of bell-shaped low-frequency and uniform distributed high-frequency parts. There is a marked maximum at frequencies 2–8 Hz within the low-frequency part of the spectrum.

3. It was discovered that mostly, the fluctuation diagrams corresponded to the low-frequency part of the spectrum have straight line form while the

diagrams reconstructed from the high-frequency part of the spectrum are looking like hyperbolas.

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REFERENCES

1. Kovásznay, L. S. G. 1950. The hot-wire anemometer in supersonic flow. *J. Aeronautical Sci.* 17(9):565–72.
2. Kovásznay, L. S. G. 1953. Turbulence in supersonic flow. *J. Aeronautical Sci.* 20(10):657–82.
3. Spangenberg, W. G. 1955. Heat loss characteristics of hot-wire Anemometers at various densities in transonic and supersonic flows. NACA-TN-3381.
4. Morkovin, M. 1956. Fluctuations and hot-wire anemometry in compressible flows. *AGARDograph*, 24.
5. Horstman, C., and W. Rose. 1977. Hot-wire anemometry in transonic flow. *AIAA J.* 15(3):395–401.
6. Rose, W., and E. McDaid. 1977. Turbulence measurements in transonic flows. *AIAA J.* 15(9):1368–70.
7. Stainback, P. C., C. B. Johnson, and C. B. Basnett. 1983. Preliminary measurements of velocity, density and total temperature fluctuations in compressible subsonic flow. AIAA Paper No. 83-0384. 18 p.
8. Stainback, P. C., and D. E. Fuller. 1980. Flow quality measurement in transonic wind tunnel and planned calibration of the national transonic facility. NASA CP 2183.
9. Johnson, C. B., and P. C. Stainback. 1984. A study of dynamic measurements made in the settling chamer of the Langley 0.3-meter transonic cryogenic tunnel. AIAA Paper No. 84-0596.
10. Bruce, W. E., and B. N. Gloss. 1989. The US National Transonic Facility (NTF). AGARD R No. 774. Special Course on Advances in Cryogenic Wind Tunnel Technology. 3.1–3.27.
11. Bois, X. 1989. The European Transonic Wind Tunnel (ETW). AGARD R No. 774. Special Course on Advances in Cryogenic Wind Tunnel Technology. 6.1–6.16.
12. Archambaud, J.-P. 1989. The cryogenic induction wind tunnel T2 at Toulouse. AGARD R No. 774. Special Course on Advances in Cryogenic Wind Tunnel Technolog. 7.1–7.12.

13. Quest, J. 2000. ETW — high quality test performance in cryogenic environment. AIAA Paper No. 2000-2206. 11 p.
14. Lebiga, V. A., A. Yu. Pak, and V. N. Zinoviev. 2008. Remote control constant current anemometer. *Conference (International) on Methods of Aerophysical Research 2008*. Section I. Novosibirsk, Russia. 35.1–35.5.
15. Lebiga, V. A., and V. N. Zinoviev. 1999. Applications of hot-wire for acoustic measurements in gas flows. AIAA Paper No. 99-1867.
16. Lebiga, V. A., V. N. Zinoviev, and A. Yu. Pak. 2003. Hot-wire anemometry in compressible flows. Characteristics of hot-wire probes. *J. Aeromechanics Gas Dynamics* 4:53–69.