EXPERIMENTAL STUDIES OF SUPERSONIC FLOW DECELERATION IN AXISYMMETRIC CHANNELS

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Abstract: The paper considers the results of experimental studies of supersonic gas flows in axisymmetric channels with the formation of a pseudoshock. A series of experiments was carried out to investigate the deceleration process of a supersonic flow in short and long channels ($L/D = 32$ and 64). The data obtained for the short channel are consistent with the data known from the literature. The pseudoshock formation occurs due to an increase in pressure at the outlet of the channel. However, it is shown that in long channels, the pseudoshock formation can occur even in the absence of backpressure at the channel outlet. For both short and long channels, a change in the value of backpressure affects the position of the pseudoshock along the length of the channel.

Keywords: pseudoshock; isolator; supersonic flow

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Figure Captions

Figure 1 Schematic of an aircraft jet engine

Figure 2 Longitudinal static pressure distribution [7]

Figure 3 Schematic of the experimental facility

Figure 4 Typical measurement results

Figure 5 Longitudinal static pressure distribution in a short channel $L/D = 32$, $\mathrm{M_{in}} = 3.95$: (*a*) $\mathrm{Re}_D = 7.4 \cdot 10^5$; and (*b*) $\mathrm{Re}_D = 1.85 \cdot 10^6$

Figure 6 Longitudinal static pressure distribution in a long channel $L/D = 64$; $\mathrm{M_{in}} = 3.95$; $\mathrm{Re}_D = 7.4 \cdot 10^5$

Figure 7 Results of flow measurements at the initial Mach number $\mathrm{M_{in}} = 1.87$ ($\mathrm{Re}_D = 1.45 \cdot 10^5$) (*a*) and 3.0 ($\mathrm{Re}_D = 1.53 \cdot 10^5$) (*b*) for a long channel $L/D = 64$

Figure 8 Results of flow measurements at the initial Mach number $\mathrm{M_{in}} = 3.76$ ($\mathrm{Re}_D = 1.40 \cdot 10^5$) (*a*) and 4.54 ($\mathrm{Re}_D = 1.48 \cdot 10^5$) (*b*) for a long channel $L/D = 64$

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References

1. Zvegintsev, V. I. 2017. Gas-dynamic problems in off-design operation of supersonic inlets (review). *Thermophys. Aeromech.* 24(6):807–834. doi: 10.1134/S0869864317060014.
2. Mazhul, I. I., and Y. P. Gounko. 2018. Numerical simulation of the flow with a pseudo-shock in an axisymmetric expanding duct with a frontal inlet. *Thermophys. Aeromech.* 25(1):31–46. doi: 10.1134/S0869864318010031.
3. Vnuchkov, D. A., V. I. Zvegintsev, D. G. Nalivaychenko, A. Yu. Melnikov, V. I. Smoljaga, and A. V. Stepanov. 2018. Influence of backpressure in the combustion chamber on the characteristics of the supersonics axisymmetric air intake *AIP Conf. Proc.* 2027:040054. 5 p. doi: 10.1063/1.5065328.
4. Melnikov, A. Y., and V. I. Zvegintsev. 2019. Supersonic flow with pseudoshock formation by thermal addiction *AIP Conf. Proc.* 2125:030019. doi: 10.1063/1.5117401.
5. Curran, E. T., W. H. Heiser, and D. T. Pratt. 1996. Fluid phenomena in scramjet combustion systems. *Annu. Rev. Fluid Mech.* 28(1):323–360. doi: 10.1146/ANNUREV.FL.28.010196.001543.
6. Gutov, B. I., V. I. Zvegintsev, and A. Yu. Melnikov. 2017. Vliyanie protivodavleniya na techenie v diffuzore sverkhzvukovogo vozdukhozabornika [Influence of back pressure on the flow in the diffuser of a supersonic air intake]. *Vestnik Permskogo natsional'nogo issledovatel'skogo*

politekhnicheskogo universiteta. Aerokosmicheskaya tekhnika [PNRPU Aerospace Engineering Bulletin]. 49:18–28. doi: 10.15593/2224-9982/2017.49.02.

7. Guskov, O. V., V. I. Kopchenov, I. I. Lipatov, V. N. Ostras, and V. P. Starukhin. 2008. *Protsessy tormozheniya sverkhzvukovykh techeniy v kanalakh* [Deceleration processes of supersonic flows in channels]. Moscow: Fizmatlit. 168 p.
8. Goonko, Yu. P., A. N. Kudryavtsev, I. I. Mazhul, and R. D. Rakhimov. 2001. Nekotorye osobennosti obtekaniya ploskogo i trekhmernogo konvergentnogo vozdukhozabornikov v sisteme giperzvukovogo letatel'nogo apparata [Comparative study of flows over 2D flat and 3D convergent inlets integrated with hypersonic airplanes]. *Thermophys. Aeromech.* 8(1):25–37.
9. Mazhul, I. I. 2018.Supersonic flow in the rectangular duct of an air inlet with the separation-induced interaction of the boundary layer with shock waves *Thermophys. Aeromech.* 27(4):507–518. doi: 10.1134/S0869864320040046.
10. Neumann, E. P., and F. Lustwerk. 1951. High-efficiency supersonic diffusers. *J. Aeronaut. Sci.*18(6):369–374. doi: 10.2514/8.1975.
11. Sullins, G. 1992. Experimental results of shock trains in rectangular ducts. AIAA Paper No. 92-5103.
12. Emami, S., C. A. Trexler, A. H. Auslender, and J. P. Weidner. 1995. Experimental investigation of inlet combustor isolators for a dual-mode scramjet at a Mach number of 4. NASA Technical Paper 3502.
13. Deng, R., Y. Jin, and H. D. Kim. 2017. Optimization study on the isolator length of dual-mode scramjet. *J. Mech. Sci. Technol.* 31(2):697–703. doi: 10.1007/S12206-017-0121-5.
14. Gimranov, E. G., V. G. Mikhaylov, E. I. Onipko, and A. M. Ruska. 2000. Issledovanie techeniy tormozheniya vyazkogo sverkhzvukovogo gaza v kanalakh dvigateley letatel'nykh apparatov [Investigation of deceleration flows of viscous supersonic gas in the channels of aircraft engines]. *Vestnik UGATU*. 1:89–96.
15. Wagner, J., K. Yuceil, A. Valdivia, N. Clemens, and D. Dolling. 2009. experimental investigation of unstart in an inlet/isolator model in Mach 5 flow. *AIAA J.* 47(6):1528–1542. doi: 10.2514/1.40966.
16. Fischer, C., and H. Olivier. 2011. Experimental investigation of the shock train in an isolator of a scramjet inlet. AIAA Paper No. 2011-2220. doi: 10.2514/6.2011-2220.
17. Fotia, M., and J. Driscoll. 2011. Assessment of isolator pseudo-shocks created by combustion with heated flow. AIAA Paper No. 2011-2222.
18. Cui, Tao, Yong Wang, Kai Liu, and Jianren Jin. 2015. Classification of combustor-inlet interactions for air-breathing ramjet propulsion. *AIAA J.* 53(8):2237–2255. doi: 10.2514/1.J053378.

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