The aero-acoustic Hartmann effect: hundred years of research and the current state of the matter

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At the beginning of the last century (1916–1919) Yul. Hartmann discovered an aero-acoustic effect, later named after him. This effect consists in the fact that when a hollow tube is placed in a supersonic jet flowing into the atmosphere at excess or insufficient pressure, the interaction of the jet stream with the obstacle can occur in a nonstationary (self-oscillating) mode and be accompanied by powerful acoustic radiation into the environment. During the last century various researchers repeatedly studied this effect using numerical methods among others, and it has been studying until now. The reason for such interest in this phenomenon is its numerous technical applications. From a purely scientific point of view, the problem is interesting because it is determined by a large number of parameters (at least 10), and not all domains of this multidimensional space of determining parameters have been studied.

This article describes a broad parametric study of the problem in question carried out with the aim of obtaining sufficiently general laws governing the phenomenon under study. Numerical calculations were performed in the formulation of the inviscid gas model (the Euler equation) by the Godunov method. The calculation results were compared with the results of experiments obtained by many authors. As a rule, there was good agreement of the data. The physical picture of the phenomenon is analyzed based on the results of calculations of more than 200 variants. Some areas of the mentioned space of determining parameters not having been previously studied either in physical or in numerical experiments are touched upon. A conclusion is drawn about the various mechanisms of self-oscillation excitation for shallow and deep cavities. The processing of the results for deep cavities (experimental and numerical results obtained by the author and other researches,) allowed making conclusion that there is a universal (with an accuracy of about 10%) dependence of the dimensionless vibration frequency (the Strouhal number) on the depth of the cavity. The experimental result that the switching from the low-frequency oscillation mode to the high-frequency mode occurs when the thickness of the resonator walls changes is confirmed. The process of aerothermoacoustic heating in a Hartmann resonator is considered.

Keywords: *aero-acoustics, Hartmann resonator, self-oscillations, impact jets, numerical simulation, Godunov method*

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