NUMERICAL STUDY OF TEMPERATURE STRATIFICATION AND ISOTHERMAL GAS PRESSURE REGULATOR ON ITS BASIS

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Abstract Possibility of increasing efficiency of thermal stratification of turbulent flows up to 3 times using heat pipes analyzed. The scheme of isothermal gas pressure regulator based on gas-dynamic temperature stratification developed. Numerical Study of characteristics of the proposed pressure regulator conducted. This work supported by RFBR grant № 12-08-31091 mol_a «Increasing efficiency of gas-dynamic temperature stratification of a stream using heat pipe» and supported by grants of the President of the Russian Federation № SP-406.2012.1 for young scientists and graduate students engaged in advanced research and development in priority directions of modernization of the Russian economy.

GAS-DYNAMICAL TEMPERATURE STRATIFICATION PIPE AND PRESSURE REGULATOR ON ITS BASIS

The process of gas-dynamic temperature stratification and operation on corresponding pipe carried out due to heat exchange between the gas flows with different Mach numbers, separated by the wall [1]. For supersonic gas flows at Mach 1 and a Prandtl number less than 1, the temperature of the stagnation flow is above the temperature of the walls on the side of supersonic flow. Efficiency of thermal stratification of gas flows is still insufficient for some industries. In this regard, to increase the efficiency of gas-dynamic temperature stratification the following methods are used: technical and technological. Technical methods include design optimization for the pipe of temperature stratification (perforation, fins, etc.). Technological methods alter the properties (the Prandtl number) of the working fluid (hydrogen-xenon, hydrogen-argon and helium-xenon mixtures, two-phase flows), since they determine the temperature of the wall on the side of supersonic flow. However, the mixtures of inert gases are expensive, while the usage of two-phase flows limits the scope of application. Perforation [2] and finning of the surface [3] between subsonic and supersonic flow passages increases the efficiency of temperature stratification. The usage of perforated wall between supersonic and subsonic passages while using the pipe of temperature stratification in technical applications (e.g., for purposes of regulation of gas pressure) is possible, but will require additional research. Usage of a longitudinal fins in devices of temperature stratification is limited by efficiency losses along the fins, and compact dimensions of devices (e.g., for gas pressure regulators). In this regard, the usage of heat pipes, formed as longitudinal fins proposed, to improve efficiency of gas-dynamic temperature stratification (Figure 1).

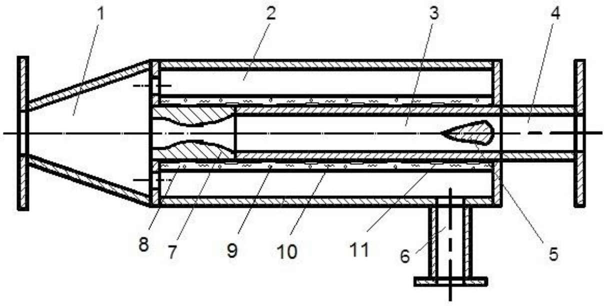

Figure 1. Sketch of tube of temperature stratification with heat pipes: 1 – separation chamber; 2 – subsonic passage; 3 – supersonic passage; 4 – outlet of supersonic passage; 5 – supersonic diffuser; 6 – outlet of subsonic passage; 7 – supersonic nozzle (Laval); 8 – wicked heat pipe formed as longitudinal fin; 9 – evaporation zone of the heat pipe; 10 – wick of the heat pipe, 11 – condensation zone of the heat pipe.

Study of efficiency of heat pipes carried out numerically. The wall temperature on the side of supersonic flow, velocity and temperature profiles in sections of the boundary layer, recovery factor, and heat transfer coefficient calculated by solving the system equations that describe the flow and heat transfer in the boundary layer [4]. Numerical study showed that heat pipes could improve the efficiency of gas-dynamic temperature stratification up to 3 times [4]. Based on the analysis results of the study a construction of natural gas pressure regulator proposed. Its work based on implementation of the process of gas-dynamic temperature stratification. The sketch of the gas pressure regulator shown on Figure 2.

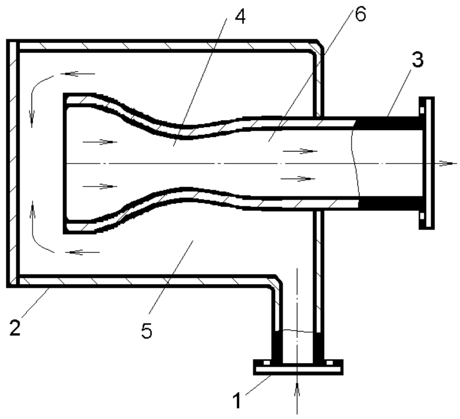

Figure 2. Sketch of the pressure gas regulation setup: 1 – high-pressure gas pipeline; 2 – case; 3 – low-pressure gas pipeline; 4 – Laval nozzle; 5 – subsonic passage; 6 – supersonic passage.

NUMERICAL STUDY OF GAS PRESSURE REGULATOR BASED ON TEMPERATURE STRATIFICATION

To confirm integrity of proposed gas pressure regulator aerodynamic simulation conducted with ANSYS Multiphysics (commercial license holder: Samara State Technical University). Compressible fluid flow analysis conducted for single-part geometry. Advances sizing function on proximity and curvature used with fine relevance center. Pressure-based solver with absolute velocity formulation used for steady state model without gravity effects. Realizable k-epsilon viscous model used with enhanced wall treatment and pressure gradient effects. Inlet defined with constant gauge pressure of 0.3 MPa. Outlet defined with radially distributed atmospheric pressure. Turbulence for both inlet and outlet specified with 10% intensity and inlet hydraulic diameter. Reference temperature of inlet flow set at 300K.

For the first 500 iterations PISO scheme with unit skewness and neighbor corrections used as solution method. First order upwind discretization used for momentum and turbulence. Turbulent under-relaxation factors were set to 0.8. Residuals of continuity and k-epsilon function become relatively steady at 10E-7. Following 200 iterations calculated by coupled scheme with "PRESTO!" discretization. Turbulent under-relaxation factors lowered to 0.4. Result of simulation shown on Figure 3. At critical throat of tube, velocity reached its maximum of 567 m/s.

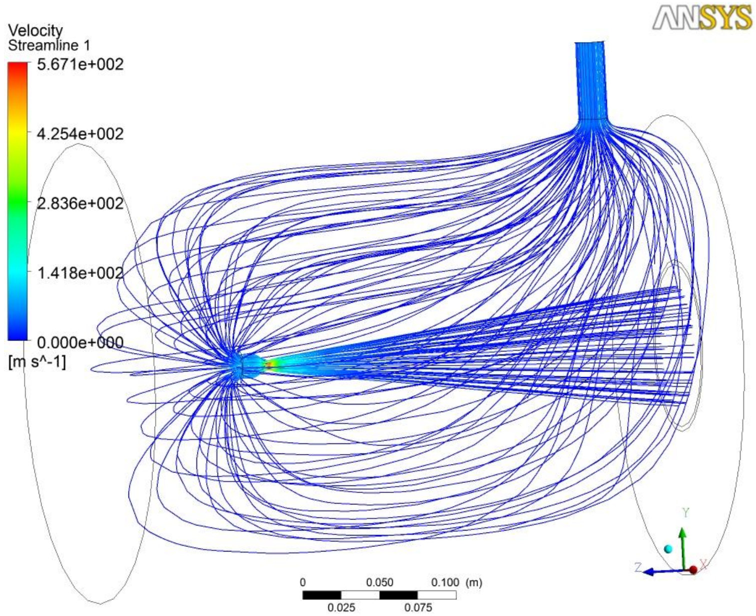

Figure 3. Aerodynamic simulation of gas pressure regulator.

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