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The Numerical Model of the Onset of Acoustic Oscillation in Pulse Tube Engine

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Abstract : The most of works applied for the pulse tube converters contain the workflow description implemented through the use of mathematical models on stationary modes. However, the study of the thermoacoustic systems unsteady behavior in the start, stop, and acoustic load changes modes is in the particular interest. The aim of the present study was to develop a mathematical thermal excitation model of acoustic oscillations in pulse tube engine (PTE) as a small-scale scheme of pulse tube engine operating at atmospheric air. Unlike some previous works this standing wave configuration is a fully closed system. The improvements over previous mathematical models are the following: the model allows specifying any values of porosity for regenerator, takes into account the piston weight and the friction in the cylinder and piston unit, and determines the operating frequency. The numerical method is based on the relation equations between the pressure and volume velocity variables at the ends of each element of PTE which is recorded through the appropriate transformation matrix. A solution demonstrates that the PTE operation frequency is the complex value, and it depends on the piston mass and the dynamic friction due to its movement in the cylinder. On the basis of the determined frequency thermoacoustically induced heat transport and generation of acoustic power equations were solved for channel with temperature gradient on its ends. The results of numerical simulation demonstrate the features of the initialization process of oscillation and show that that generated acoustic power more than power on the steady mode in a factor of 3…4. But doesn`t mean the possibility of its further continuous utilizing due to its existence only in transient mode which lasts only for a 30-40 sec. The experiments were carried out on small-scale PTE. The results shows that the value of acoustic power is in the range of 0.7..1.05 W for the defined frequency range f = 13..18 Hz and pressure amplitudes 11..12 kPa. These experimental data are satisfactorily correlated with the numerical modeling results. The mathematical model can be straightforwardly applied for the thermoacoustic devices with variable temperatures of thermal reservoirs and variable transduction loads which are expected to occur in practical implementations of portable thermoacoustic engines.

Keywords : nonlinear processes, pulse tube engine, thermal excitation, standing wave
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