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The Influence of Piston Internal Combustion Engines Intake and Exhaust Systems Configuration on Local Heat Transfer

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Abstract

The improvement of work processes of piston engines to boost the technical and economic parameters is the main objective in the field of power engineering. The improvement of the gas exchange processes (intake and exhaust processes) quality is one of the possible profiles to improve the efficiency and reliability of piston internal combustion engines. The study of the instantaneous local heat transfer at flow unsteadiness is one of the objectives of the experimental studies of the thermomechanical processes in the intake and exhaust systems of the engines. The influence of configuration of the intake and exhaust pipes on the heat transfer intensity is a relevant engineering problem. The local heat transfer intensity data serves as the basis to determine the basis for determination of heating of the air (at intake), cooling exhaust gas (at exhaust), calculation of thermal stresses in the nodes and details of intake and exhaust systems. The article presents the results of the experimental investigation of the instantaneous local heat transfer (taking into account the hydrodynamic nonstationarity) in the intake and exhaust pipes of different configurations for piston internal combustion engines. It is established that the cross profiling of the intake and exhaust pipes of piston engines leads to 5-20% decrease in the local heat transfer intensity depending on the crankshaft speed.

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Keywords: piston engines; gas exchange processes; intake and exhaust pipes; cross profiling; local heat transfer; process improvement.

1. Introduction

The improvement of work processes of piston engines with the aim of improving technical and economic indicators is an important task in the field of engine and energy. The improvement of the quality of gas exchange processes (intake and exhaust processes) is one of the possible directions of increase of efficiency and reliability of

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piston internal combustion engines. In particular, the limited amount of information in the Russian and foreign literature can be found about the studies of heat transfer in the intake and exhaust pipes. Apparently, this can be explained by the fact that the gas exchange processes in piston internal combustion engines are unsteady and high-frequency processes, this greatly complicates scientific approaches to their study. Data about intensity of the instantaneous heat transfer are the basis for determination of heating of the air (at intake), cooling exhaust gas (at exhaust), calculation of thermal stresses in the nodes and details of intake and exhaust systems. However, data on instantaneous heat transfer is practically absent, so engineering calculations are performed on the basis of data on stationary flows. It is known that the heat transfer coefficient in unsteady conditions may differ from the stationary case in 2-4 times [1-6].

Results of experimental investigation of the instantaneous local heat transfer (taking into account the hydrodynamic nonstationarity) in the intake and exhaust pipes of different configurations for piston internal combustion engines are presented in this article.

Nomenclature

ICE	internal combustion engine
TDC	top dead center
BDC	bottom dead center
φ	crank angle, degrees
n	engine crankshaft rotation frequency, rpm
w_x	local speed of gas flow, m/s
α_x	local heat transfer coefficient, W/(m^2·K)
p_b	pressure at the end of exhaust process, bar
d	channel diameter, mm
d_e	equivalent hydraulic diameter, mm
l_x	linear dimension, mm

2. Experimental setups and measurement equipments

The experimental setups for the experimental investigation of local heat transfer in the intake and exhaust pipes were designed and manufactured. They were a full-scale model single-cylinder engine of 8.2/7.1 dimension. The valve timing mechanism for experimental setups was used from the VAZ-OKA engine. The periods of valve timing and valve lift for setups were in accordance with the one for this engine. An induction motor drives the rotation of the crankshaft of the experimental setups. The frequency Converter regulates the rotation speed of the crankshaft in the range from 600 to 3000 rpm. Detailed description of the experimental setups presented in [7].

Automated system for the collection and processing of experimental data was developed on the basis of the analog-to-digital Converter. This system was sending experimental data to the computer for processing. The constant temperature anemometer [8] was used to determine the flow rate of air (w_x) and the local heat transfer coefficient (α_x). The sensitive element of the anemometer sensor was nichrome filament which had a diameter of 5 μm and length of 5 mm. Measurement of rotation frequency and the position of the engine crankshaft is produced by the tachometer. The position of the piston at the top and bottom dead points is determined on the basis of this data.

3. The instantaneous local heat transfer in the intake pipe

It is known [9-12], that one of the ways to improve gas dynamics in intake and exhaust pipes is a cross profiling of the channels. Cross profiling of the channels leads to a significant change in gas dynamic parameters of the flow in the piping, this could also affect a change in the local heat transfer coefficient.

The studied configuration of the intake system and location of sensors are presented in Fig. 1.