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The Influence of Cross-profiling of Inlet and Exhaust Pipes on the Gas Exchange Processes in Piston Engines

L.V. Plotnikov*, B.P. Zhilkin, Yu.M. Brodov

Ural Federal University named after the first President of Russia B.N.Yeltsin, ul. Mira, 19, 620002 Ekaterinburg, Russian Federation

Abstract

It is known that more than 80% of global energy is produced by internal combustion engines. Therefore, the improvement of working cycles and modernization of systems and components of the piston and combined internal combustion engines with the aim of improving their technical and economic indicators is one of the urgent tasks in the global energy sector. Research studies in this area were carried out mainly by means of numerical simulations or experimentally under static conditions. Information about gas exchange processes in the unsteady gas dynamic conditions are quite limited and controversial. This work aims at obtaining of the additional clarifying information about the gas dynamics in the air-gas tract of the internal combustion engine and finding ways of improving the processes. The results of experimental studies of gas exchange processes in the intake and exhaust tracts piston engines were presented in the article. Experimental studies were conducted on full-scale models of a single-cylinder engine. The experimental dependencies of change of the instantaneous velocity and pressure of the gas flow in the gas paths from the crank angle were presented in the article. Improvement of gas exchange processes in the intake and exhaust pipes of internal combustion engines due to the transverse profiling of the channels was proposed in the paper.

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Keywords: piston engines; gas exchange processe; gas dynamics; flow characteristics; process improvement.

1. Introduction

The efficiency of internal combustion engines largely depends on the efficiency of processes in the intake and exhaust piping [1-3]. The study of gas-dynamic and heat transfer characteristics of gas flow in the air-gas paths been

* Corresponding author. Tel.: +7-922-291-64-50
E-mail address: leonplot@mail.ru

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given insufficient attention so far. This is due to the fact that the improvement of heat transfer in the cylinder was initially more relevant and effective from the point of view of improving technical and economic performance of piston internal combustion engines (these issues are discussed in a lot of articles in particular [4; 5]). At the moment the engine construction has reached such a level that increasing any parameter of the engine at least a few tenths of a percent is a significant achievement. So now researchers and engineers are looking for new avenues of improving the working cycles of engines. According to the authors one of such directions is the study and improvement of processes in the intake and exhaust pipes of engines in the conditions of gas-dynamic non-stationarity. It is known that the intake and exhaust processes in engines are pulsating, high-frequency and non-stationary. Thus, the study of gas-dynamic and heat transfer characteristics of gas flow in the air-gas paths only in stationary conditions and/or quasi-stationary numerical modeling approaches is not entirely correct. Since, it is known that the parameters of gas flows in the transient conditions may differ from the stationary case in 2-4 times [6-12]. The results of a comprehensive experimental study of gas-dynamic characteristics of gas flows during the intake and exhaust processes in the engine of 8.2/7.1 are presented in this article. Directions of improvement of these processes on the basis of the cross-profiling of piping are also offered in the 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
V_x	local volumetric gas flow rate, m^3/s
d	channel diameter, mm
l_x	linear dimension, mm

2. Experimental setups and measurement equipments

Experimental setup for experimental investigations of gas-dynamics of the inlet and exhaust processes were designed and manufactured. They were full-scale model of single-cylinder engine of 8.2/7.1. The valve control mechanism for the experimental setups is taken from the engine of the car VAZ-OKA. Valve timing and valve lift of the experimental setups consistent with those for this engine. The drive of a crankshaft was carried out by using an asynchronous motor, the rotational speed of which was regulated by the frequency Converter in the range from 600 to 3000 rpm. A detailed description of the experimental facilities is presented in articles [13, 14].

To make the necessary measurements on the basis of the analog-to-digital Converter was created an automated data collection system, which passed the experimental data in the personal computer. To determine the speed of the air flow (w) and local heat transfer coefficient (α_x) was used constant temperature anemometer [15]. Sensor probes in both cases was the nichrome filament diameter of 5 μm and a length of 5 mm. Measuring speed and position of the crankshaft of the engine produced by the tachometer. It included a toothed disk on the crankshaft and an inductive sensor. These data also determined the position of the upper and lower dead points. The pressure sensor (manufacturer WIKA) was used to measure the instantaneous static pressure of the gas flow.

3. Gas dynamic and flow characteristics of the intake process

Traditionally channels with a circular cross-sectional shape are used in the air-gas paths of engine to provide a uniform velocity field. However it is known that in channels deprived of full symmetry have persistent, longitudinal eddy currents [16]. On this basis it has been suggested that they may affect the dynamics and flow characteristics in