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Contributions on modeling the intake and compression processes of the spark ignition engine

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Abstract

Because of the the complexity of the phenomena and different operating modes of the spark ignition engine, used in vehicle propulsion, it was prepared a simulation, in order to optimise its co-operation with the vehicle, using a theoretical model, developed by the authors. The proposed model addresses to the intake and compression processes, considered to have a major importance, influencing the evolution of the engine operating cycle and implicitly, the overall performance. This paper, through the developed model, leads to the achievement of functions that emphasise the variation of the pressure and temperature of the fresh load at the end of the intake process, together with the engine load modification, at different engine speed values in the operating range. The calculation expressions of the pressure and temperature at the end of the intake process are also developed, depending on the engine load. The main results obtained derive from the performed simulation on the modification of the parameters that characterize the intake and compression processes for the spark ignition engine.

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Keywords: fuel-air mixture; temperature of the mixture; filling coefficient; volumetric efficiency; residual gases coefficient; compression polytropic coefficient.

1. Introduction

Considering the complexity of the phenomena and the multitude of the operating modes of the spark ignition engines, used in the propulsion of the motor vehicles, in order to optimize its co-operation with the vehicle, a

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simulation was carried out, based on a theoretical model, developed by the authors of this paper, considering the major importance processes in the engine operating cycle, such as the intake and compression. This model takes into account the fact that till now, the technical literature does not reveal a unitary treatment of the propulsion engine behavior at different regimes, with a clear indication of the evolution and modification of characteristics energy parameters, such as effective power, torque and fuel consumption.

2. Analysis and modeling of the spark ignition engine intake process

The pressure at the end of the intake stroke, currently denoted with p_a, influences the cylinder filling and thereby the performances of the engine itself [1].

Currently, according to the technical literature, the pressure p_a, depending on the environmental pressure p_0, varies between the following references limits:

$$p_a = (0{,}81 \div 0{,}96) \cdot p_0 \quad (1)$$

The pressure p_a *[bar]* values vary when the defined operating mode is modified, as already known, mainly through the engine load and speed. For the spark ignition engine, the load setting is obtained by changing the shutter position, representing a quantitative setting.

In turn, the filling coefficient or the degree of filling, often referred by many authors yield of filling or volumetric yield, is defined, according to the technical literature, as the ratio of the amount of fresh load actually retained in the engine cylinder, under the condition of a filling with gas-dynamic and thermal losses. This represents the quantity that fills the volume V_s, having the parameters $p_a < p_0$ and $T_a > T_0$, denoted with G_a and G_0, representing the quantity of the fresh load which can be retained in the engine cylinder, under conditions of an optimal filling, for example if the volume V_s will be filled, having the parameters p_0 and T_0. The parameter T_a represents the temperature of the fresh load at the end of the intake process [2].

The filling coefficient it's an important indicator of quantitative appreciation of the admission process efficiency. In order to analytically estimate of the degree of filling, there are, as already known, several expressions, recommended by various authors, but more often the simple form is preffered:

$$\eta_v = \frac{1}{\varepsilon - 1} \cdot \frac{p_a}{p_0} \cdot \left(\varepsilon - \frac{p_r}{p_a}\right) \quad (2)$$

In this expression, ε represents the engine compression volumetric ratio, mostly denoted as compression ratio, defined, as known, as the ratio between the maximum volume of the cylinder, corresponding by the volume delimited by the piston position on BDC (bottom dead center) and the combustion chamber volume, delimited by the pyston position on TDC (top dead center). The value of the compression ratio ε depends on the engine type and influences its efficiency and its performance [3].

Pressure p_r signifies the pressure of the residual gases, The residual gases represents the amount of burned gases which cannot be discharged from the cylinder at the end of the exhaust process, obviously affecting the intake process in several paths. It was experimentally proved that in case of the spark ignition engines, pressure p_r varies between the following limits, defined according to pressure p_0 *[bar]*:

$$p_r = (1{,}20 \div 1{,}25) \cdot p_0 \quad (3)$$

As can be seen from the expression (2), for a defined constructive-energetic formula of a propulsion engine, the filling coefficient is influenced by the intake pressure p_a and and the pressure of the residual gases, p_r *[bar]*.

Thus, in this paper, for a constructive formula, characterised by a compression ratio of ε=10.2, which corresponds to many current spark ignition engines construction, some different influences on the intake process were analysed.

In a first step, it was emphasised the influence of pressure p_a, accepting a variation of the pressure p_a = (0,81÷0,96)$\cdot$ p_0, p_r being mantained constant. Lower intake pressure values correspond to high engine speed values.