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Performance Evaluation of Compression-to-Combustion Transition Process in Diesel Engine Cylinder

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Abstract

Thermal-mechanical loading of components, the vibration of individual elements, noise performance and the toxicity of diesel exhaust gases depend on the pressure build-up dynamics. The dynamic is defined by the gas maximum pressure, the maximum of pressure rise rate, the conditions and patterns of the process of transition from the compression to the combustion, and the temperature of the working gas in the cylinder. The gas pressure rise depends on several factors, including the features of the working fluid compression processes, combustion and subsequent burning of fuel. Typical links between the pressure raise intensity during the compression and the fuel burning features in the cylinder of a diesel engine are established by the theoretical analysis of these processes.

The basic parameters of the compression process include the compression ratio, the dependence between the character of change of the cylinder volume and the crank angle and heat transfer characteristics. Features of the combustion process in the cylinder are estimated by timeliness, the pattern, and duration, as well as the rate of fuel burn. The analytical assessment of the natureof the compression to combustion transition process allows identifying the ways of reducing the thermo-mechanical loading and vibro-acoustic activity of a diesel engine.

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Keywords: diesel engine; pressure build-up in the cylinder; the maximum of pressure rise rate; duration of the transition process from the compression to the combustion; acceleration of the transition process; mechanical loading; vibration; noise

Introduction

Among the indicators of the pressure growth dynamics in the cylinder of a diesel engine it's important to consider conditions and pattern of the transition from compression to combustion, which are determined by

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analyzing the indicator-diagram. By linking gas pressure changes pattern to the heat generation pattern during the fuel burnup, the differential equation of the combustion process allows to obtain analytical expressions for the assessment of the pattern of transition from compression to burn. Using heat patterns in the theoretical analysis, identified reserves to limit the pressure dynamics indicators, which allows to identify the main ways to reduce mechanical loading, vibration and noise of the diesel engine due to the influence on the pattern and duration of the transition process from compression to burn.

1. Review

The transition process from compression to the combustion in the cylinder is characterized by change in pressure rise rate within a certain range of time – which is acceleration of pressure rise. The interval from the start of combustion θ to a maximum rate of pressure rise is called the length of the transition process from the compression to the combustion t_w (sec) or in the angle of crank rotation φ_w (deg).

Amplitude of vibration depends on the length of the transition process from the compression to the combustion. The closer the maximum rate of pressure rise to the start of combustion, the larger the double amplitude of the cylinder cover mounting studs vibration in diesel engine [1].

In the engine, in which the working cycle of the diesel and gasoline engine alternately carried out, with equal maximum cycle pressure, level of the high-frequency noise is higher, the greater the acceleration of pressure rise. At full load, the noise reduction by 5 to 10 dB in the range of 1000 to 5000 Hz frequency is due to the increased length of the transition process from compression to burn at a constant maximum rate of pressure rise [2, 3].

For this reason, the change amplitude of the vibration and the noise level is convenient to estimate by one physical quantity - the acceleration of pressure rise. The duration of the transition process from the compression to the combustion is a factor which had not previously taken into account in the evaluation process.

It was established by special researches, that a decisive influence on the combustion noise has not the first $v_p = dp/dt$, but the second time derivative d^2p/dt^2 [4]. Note, the process to ensure a smooth transition from compression to combustion, accompanied by a decrease d^2p/dt^2, excludes the impact changes in the gaps of various joints of the crank mechanism.

According to [1, 5-7] rate of pressure rise determines the value of the vibration amplitude of the crank mechanism parts, which can be regarded as a dynamic component of the part's total deformation. Changing the dynamic deformation rate is determined by the pressure rise acceleration.

However, this does not exhaust the appropriateness of accounting duration of transition process from compression to burn in the evaluation of this process. It is known that the natural oscillations of the parts of the crank mechanism, such as connecting-rod shank, are damped. The greatest amplitude of natural oscillations occur at the beginning of the oscillation process. Under the influence of gas pressure in the cylinder the rod vibrations become forced, the amplitude of the oscillation process will be determined by the degree of frequencies compliance of the exciting and natural oscillations. Frequency range of exciting oscillations, generated by changing the gas pressure, determined by the pattern of the pressure rise in the cylinder of a diesel engine [8]. For diesel vehicles the frequency of the exciting oscillation lie near the frequency of natural oscillations of the crank mechanism parts, while not ruled out the resonance case. There is a ratio of the frequency range of exciting vibrations to the natural frequency equal to 0,6-1,2, beyond which you can not take into account the effect of the increase rate to the dynamic and vibro-acoustic performance diesel engine parts. Determination of the exciting oscillation frequency is very important for future comparison it with natural oscillation of engine parts. Typically, the frequency of the exciting oscillation of the cycle is determined by considering the pattern of the pressure rise from the start of combustion. Knowing the length of the transition process from the compression to combustion give information on the location of the maximum rate of pressure rise in the indicator diagram of a diesel engine, which indicates of the nature and frequency of vibrations, caused by the gas pressure change.