

Research Article

Checking the Mechanisms of Internal Combustion Engines for the Presence of Parasitic Forces Using a New Methodology

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Abstract

This article presents the results of a study of internal combustion engines equipped with a crank mechanism according to the efficiency criterion using a new method for determining the operating efficiency of machines and engines. The study revealed the presence of parasitic forces in internal combustion engines equipped with a crank mechanism. The occurrence of parasitic forces present in internal combustion engines and the law of their dependence on the movement of the piston have been studied. As well as the negative impact of parasitic forces on engine efficiency. This article presents the main results of the study. As a result of the research, it was revealed that when converting the thermal energy generated in the combustion chamber of internal combustion engines equipped with a crank mechanism into mechanical work, more than 30% of the energy of the pressure force is spent on parasitic forces. The influence of the mechanical friction force (friction of the plain bearings) with the crankshaft on the effective torque was also studied. Thus, the inefficiency of internal combustion engines equipped with a crank mechanism has been theoretically and practically proven. Finally, recommendations are given for eliminating parasitic forces when designing new internal combustion engines. It is proposed to equip new internal combustion engines with mechanisms without parasitic forces. Equipping internal combustion engines with a mechanism that does not contain parasitic forces (that is, equipping them with more efficient mechanisms) significantly increases the possibility of efficient use of the thermal energy of the fuel introduced into the combustion chamber in internal combustion engines. Consequently, this increases the engine efficiency by 130% or more. For internal combustion engines, a new mechanism is recommended that eliminates the loss of force and allows the use of rolling bearings. This feature of the new mechanism makes it possible to increase the efficiency of internal combustion engines by another 4-6%. From previous studies it is known that the efficiency of a rolling bearing relative to a plain bearing is more than 2-3 times.

Keywords

Machinery, Engine, Internal Combustion Engine, Crank Mechanism, Mechanism Efficiency, Parasitic Forces, Torque, Mechanical Work, Energy

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1. Introduction

As everyone knows, the United Nations Economic Commission for Europe will raise the problem of Europe's ecology, namely the increase in greenhouse gas emissions from vehicles into the atmosphere of the city.

Research has shown that the amount of greenhouse gas emissions from vehicles is more than 70%. In this regard, United Nations Economic Commission for Europe has set a target for vehicle manufacturers to increase the efficiency of internal combustion engines by 10% over the next five years.

On May 28–30, 2008, transport ministers met at the International Transport Forum in Leipzig, Germany, to discuss transport sector challenges related to energy and climate change, especially global warming and greenhouse gas emissions. Transport ministers reviewed the need to reduce CO₂ emissions and improve fuel efficiency in the transport sector, mainly through the use of innovative elements. One of them:

- “Innovative engine technologies, advanced engine management systems and efficient vehicle transmissions” [1]

This information motivated a group of scientists from our university to conduct scientific research on internal combustion engines. To solve this problem, theoretical and practical studies have been conducted and certain results have been obtained.

In the first scientific approach, the main shortcomings of modern Internal Combustion Engine with a crank mechanism are as follows:

Low efficiency;

The main part of the gas pressure force that occurs during the combustion of gas in the combustion chamber tends to destroy the piston, connecting rod, and crankshaft.

The complexity of the design of the internal combustion engine with a crank mechanism and the high cost of production;

The design features of the crankshaft do not allow the use of rolling bearings in the crank mechanism, which would significantly reduce the energy costs of friction forces between parts of the mechanism [2].

The efficiency of the four-stroke gas internal combustion engine, built by the German inventor N. Otto in 1878, was 22%. It's been 150 years since the invention. Since then, despite the efforts of scientists, the efficiency of four-stroke engines with Crank Mechanism has increased by only 5-6%.

This is because the crank mechanism has not yet been considered as a parasitic mechanism. The methodology for evaluating the engine performance was simple.

Scientists attribute more than 70% of the energy losses in engines to the traditional mechanism with frictional forces in the mechanism and exhaust gases [3, 4].

2. Research Methodology

The purpose of the theoretical study is to determine the magnitude of parasitic forces and their influence on the effi-

ciency of an internal combustion engine with a crank-slider mechanism.

To achieve this goal, the following main questions were posed: (Figure 1):

1). To what forces are the gas pressures acting on the piston distributed?

2). How much energy does the crank mechanism lose when converting the gas pressure force into M-e torque?

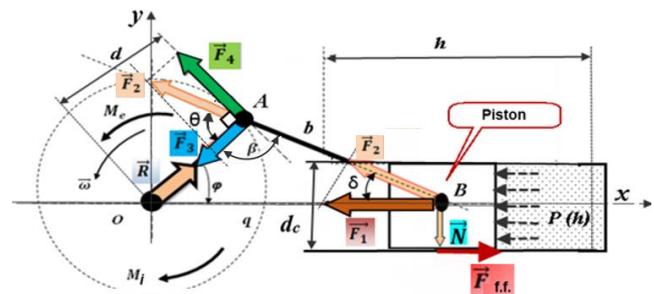


Figure 1. Distribution of the force created by the gas pressure in the working chamber over the piston and the crank mechanism.

In Figure 1, the following notations are applied.

$\overrightarrow{P(h)}$ is the gas pressure in the working cylinder.

$\overrightarrow{F_1}$ is the main dynamic force acting from the piston to the connecting rod, the value of which is determined using Equation (1).

$\overrightarrow{F_2}$ where is the force acting on the connecting rod.

\overrightarrow{N} where is the lateral force acting on the cylinder wall.

$\overrightarrow{F_3}$ where is the force acting along the crank axis.

$\overrightarrow{F_4}$ where is the force applied to create an effective torque on the crankshaft.

$\overrightarrow{F_{f.f.}}$ is the friction force between the piston and cylinder wall.

\overrightarrow{R} where is the reaction force of the crankshaft acting along the knee axis.

$\overrightarrow{M_e}$ where is the effective torque on the crankshaft.

M_i where, denotes the moment of inertia.

h is the piston stroke.

δ is the angle between the axes of the connecting rod and the x -axis.

β is the angle between the axes of the connecting rod and the crank.

ϕ is the angle between the crank axes and the x -axis.

d is the crank length.

d_c is the cylinder diameter;

b represents the length of the connecting rod.

The investigation of crank mechanism according to the technique described in reference revealed several parasitic forces, such as forces \overrightarrow{N} , $\overrightarrow{F_3}$, $\overrightarrow{F_{f.f.}}$ and \overrightarrow{R} (see Figure 1). They occur during the operation of the mechanism but do not perform useful work [5].

From figure 1, one can see the following.

- 1) The force \vec{F}_1 at point (B) is divided into lateral forces \vec{N} and \vec{F}_2 .
- 2) The force \vec{F}_2 at point (A) is divided into forces \vec{F}_3 and \vec{F}_4 .
- 3) Only the force \vec{F}_4 at angle $\theta = \pi/2$ creates an effective torque - M_e .

The value of the force \vec{F}_1 depending on the stroke position can be determined using Eq. (1):

$$|\vec{F}_1| = P(h) \cdot S_p \tag{1}$$

where: S_p is the piston head area. At one time, the force \vec{F}_1 at point (B) is divided into two components

$$\vec{F}_1 = \vec{F}_2 + \vec{N} \tag{2}$$

The force \vec{F}_2 at point A is divided into two components

$$\vec{F}_2 = \vec{F}_3 + \vec{F}_4 \tag{3}$$

The main condition for the stability of a dynamic system is given by Equation (4). Considering expressions (1) – (3), we constructed a system of vector equations, projections of dynamic forces on the coordinate axes [6, 7], and a system of moments relative to point (0) based on the system of equations

$$\begin{cases} \sum_i^n F_i^x = 0 \\ \sum_i^n F_i^y = 0 \\ \sum_i^n M_i = 0 \end{cases} \tag{4}$$

3. Results and Discussions

Using a mathematical simulation model, we can observe changes in the magnitude of the forces that arise in the dynamics of the system [8, 9].

NOTE: For the theoretical study and simulation model of the efficiency of an internal combustion engine with a crank mechanism, the characteristics of the Mercedes 601.912 internal combustion engine were used according to the new method [10-12].

Figures 2 and 3 show graphs of the changes in the dynamic forces depending on the piston stroke. The results were obtained using a mathematical simulation model.

Figure 4 shows a graph describing the torque behavior as a function of the piston stroke. The expressions $M_1 = f(h)$ represent the torque function when the gas pressure force is directly converted into torque, and $M_2 = g(h)$ is the torque function when the gas pressure force is converted into torque by the crank mechanism.

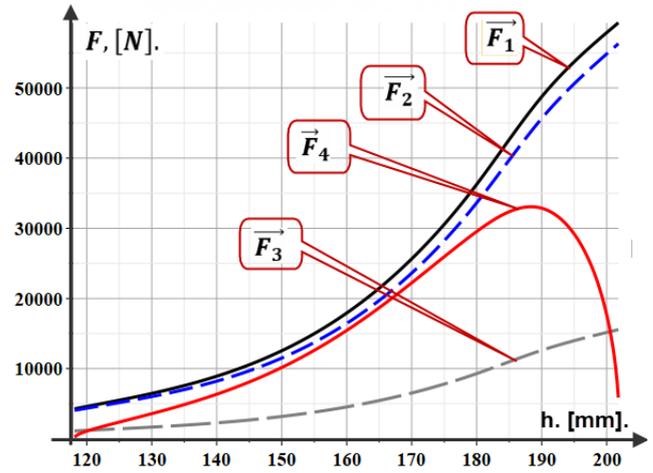


Figure 2. Graphs of changes in dynamic forces depending on the piston stroke. The results were obtained using a mathematical simulation model.

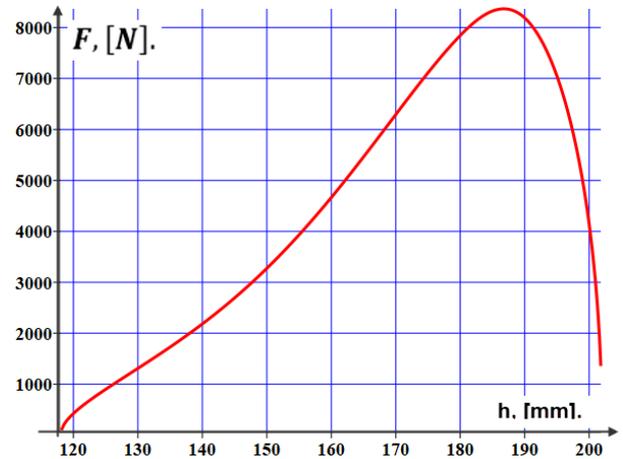


Figure 3. Graphs of the change in the lateral force N acting on the cylinder walls.

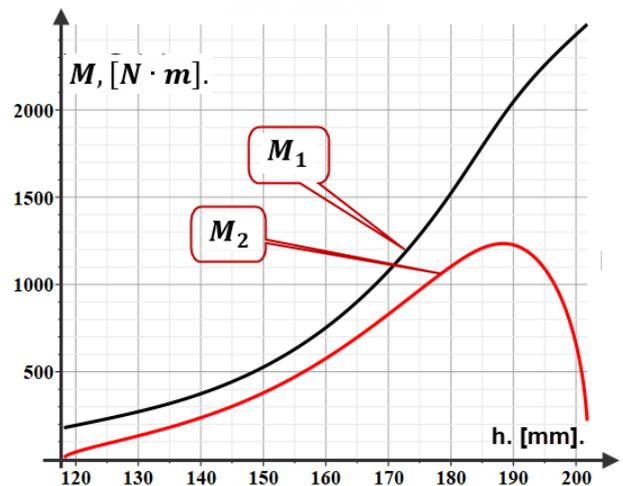


Figure 4. Demonstration of the torque graph M1 obtained by converting the gas pressure force directly into torque and the torque graph M2 obtained by converting the gas pressure force directly into torque crank mechanism.

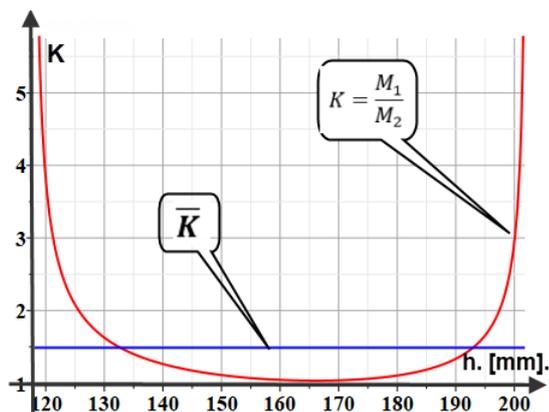


Figure 5. K is a graphical representation of the ratio of moments. \bar{K} is the overall average.

Figure 5 shows a graph of the torque ratio $K = \frac{M_1}{M_2}$ and the average value of the \bar{K} ratio.

The main characteristic of an internal combustion engine is the effective torque M_e .

According to theoretical mechanics, the most effective torque on a lever can be achieved by applying a force at a 90-degree angle to convert the impact force into torque (Figure 5) [13].

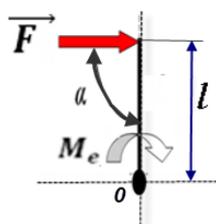


Figure 6. M is torque, F is the rotational force relative O point, l is the shoulder, α is the angle between the direction of the force and shoulder.

A project was developed to develop highly efficient internal combustion engines. The engineering solution of the project was modeled in engineering and mathematical programs, and is being worked out in the laboratories of the university.

Table 1. Mechanical work is carried out by F_1 and F_4 forces.

Acting forces, in [N].	Piston stroke, in [mm].	Mechanical work done by forces, in [J].
F_1	84	1986.1
F_4	84	1502.7
Difference $\frac{F_1}{F_4} \cdot 100\%$	-	132%

In laboratory studies, high results have been obtained in improving the efficiency of internal combustion engines, exceeding the tasks set by the UNECE. This means that the efficiency of the new internal combustion engine is more than 40%, while the efficiency of existing crank mechanism engines is less than 28% [14-16].

4. Conclusion

Based on the results of the above studies, we conclude that in an engine with a crank mechanism, more than 30% of the gas pressure force is exerted on parasitic forces.

Therefore, by changing the design of the internal combustion engine mechanism, the engine efficiency can be significantly improved.

In our research, we theoretically proved that the crank mechanism is parasitic.

According to the results of research using the method presented in [1], we have invented new designs of engine mechanisms that allow us to increase the efficiency of the engine by at least 1.3 times (by 130% or more). A patent for the invention IAP 06141 dated January 30, 2020, for this type of engine was received [17, 18].

We believe that the results of our study on crankshaft engines will be useful for scientists involved in research on low-fuel consumption engines, as well as for internal combustion engine companies.

Abbreviations

UNECE: The United Nations Economic Commission for Europe

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We are grateful to all of those with whom we have had the pleasure to work during this and other related projects.

Conflicts of Interest

The authors declare no conflicts of interest.

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