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SIMULATION OF TRACTOR ENGINE OPERATION IN GAS-DIESEL MODE

In modern conditions of fuel use in agriculture, it is necessary to diversify sources and use alternatives to the traditional use of petroleum products. However, there is a pressing issue that is actively being studied regarding the change in power when using a dual-fuel engine power supply system, since there is data on a slight decrease in this indicator, it was also established that the main parameters are preserved, the duty cycle and a significant increase in engine life. The purpose of the study is to simulate the main parameters of the engine in gas-diesel mode. A mathematical model of the duty cycle of the PowerTech 6068HF250 gas-diesel engine of the John Deere 7930 tractor has been created, which makes it possible to establish the operational and technological parameters of its operation. To determine the operating and technological parameters of the tractor engine in gas-diesel mode, for example, determining the LPG gas consumption and the ignition dose of liquid fuel and setting other control points, the thermal calculation of the engine according to the Grynivetsky -Mazing method using the Mathcad environment is informative and relevant. The obtained data were purposefully processed in the Microsoft Excel environment. This method allows to significantly improve the analysis of the operation of diesel engines in gas-diesel mode. When using the mathematical model of the operation of the PowerTech 6068HF250 diesel engine in the Mathcad 14 environment, it was found that the nominal power in the diesel cycle was 3.13% less than the declared engine power by the manufacturer. The obtained data allow us to state the conformity of the model we built. During the next simulation of the engine operation in the gas-diesel cycle, an increase in engine power was detected. An increase in engine power when using a mixture of fuels was also noted. This makes it possible to reduce the dose of consumed gas (LPG) fuel to such an amount that the power was equal to the nominal, which can be observed in the diagrams.

Keywords: *disel engine, the gas-diesel cycle, operational indicators, liquefied petroleum gas, fuel mixture.*

Formulation of the problem. In the modern conditions of fuel use in agriculture, the diversification of sources and the use of alternatives to the traditional use of oil products, which tend to increase in price, are extremely relevant [1,2]. Among the many options for the use of alternative power sources in the design of diesel engines in agriculture, there is a tendency to expand the use of dual-fuel diesel engines in the gas-diesel mode, which is due to their greater economy and reduction of toxic emissions into the environment, in particular nitrogen oxides NOx [3.4].

Analysis of the latest research and publications. However, there is an urgent issue that is being actively studied, regarding the change in power when using a dual-fuel engine power system, since there are data on a slight decrease in this indicator, it is also established that the basic parameters of the operating cycle and a significant extension of the motor resource are maintained [5-8]. The most promising alternative source in the dual-fuel system was the use of liquefied petroleum gas, due to the wide availability of this type of fuel, its economy and the possibility of minimal conversion using gas cylinder equipment up to the 4th generation [9, 10]. Regarding practical recommendations for the use of liquefied petroleum gas, it is justified to switch to a diesel cycle from a dual-fuel cycle when the load is reduced by 30% from the nominal one, the optimal ratio when working in a gas-diesel cycle with diesel fuel is 50% of liquefied petroleum gas [11].

The purpose of the study: simulate the main parameters of the engine functioning in the gas-diesel modeМатеріали та методи

The main results of the study. A mathematical model of the working cycle of the gas-diesel engine PowerTech 6068HF250 of the John Deere 7930 tractor was created, which makes it possible to establish the operational and technological parameters of its operation. The value of the pressure in the cylinder at the characteristic points of the diagram is given in Table 1. From the data in the table, we construct an expansion polytrope.

Table 1

Value of gas pressure in the cylinder at characteristic points

P_r, МПа	P_a, МПа	P_c, МПа	Pz, МПа	P_b, МПа
0,209	0,201	9,688	14,532	0,632

We build a flat coordinate system. On the abscissa axis we put the value of the volume of the cylinder V, on the ordinate axis - the value of the gas pressure P in the cylinder.

V-axis scale:

$$\mu_V = \frac{V_a}{\left[V_a\right]}, \text{ l/mm} \qquad (1).$$

where is the full volume of the cylinder, l,

- the distance on the drawing along the abscissa axis, which reflects the full volume of the cylinder (mm).

The value of the volume of the combustion chamber is determined by formula 2:

$$V_c = \frac{1{,}12}{17-1} = 0{,}07$$

P-axis scale:

$$\mu_p = \frac{P_z}{\left[P_z\right]}, \text{ l/mm} \qquad (2).$$

$\left[P_z\right]$ - the distance on the drawing along the abscissa axis, which reflects the value of the maximum pressure of the cycle in the cylinder (mm).

We draw a vertical line perpendicular to the abscissa axis from the origin at a distance corresponding to the volume of the combustion chamber. This line will correspond to the position of the piston at TDC. The second straight line is placed at a distance from the first, which corresponds to the working volume of the cylinder in scale. This line will correspond to the position of the piston at NMT.

Perpendicular to the ordinate axis, we draw a horizontal straight line from the origin at a distance corresponding to the value of atmospheric pressure P0.First, we build a calculation indicator diagram.To do this, we first set aside the characteristic points of the diagram with the corresponding coordinates: r(Pr;), a(Pa;), c(Pc;), z' (;), b(;).Then we set aside the auxiliary points with the corresponding coordinates: r''(Pa;), z(Pz;), l(;).

To determine the coordinates of point z, we will find the volume. To determine the volume , we use the formula , where , since the point z characterizes the end of the previous expansion and the beginning of the expansion polytrope.

So, substituting the values in formul 1, we determine:

$$V_\rho = \frac{1{,}19}{11{,}807} = 0{,}101 \qquad (3).$$

We start building the diagram from the beginning of the intake. Point r'' is connected to point a with a horizontal straight line, assuming that the pressure remains constant throughout the intake stroke. From point a, we build a compression polytrope. The compression stroke on the diagram is characterized by the as curve, which is a compression polytrope and is described by the formula . In this formula, the relation $\frac{V_a}{V_X}$ change from 1 to and determine the corresponding PX values of the compression polytrope. To calculate the compression polytropy, we will use the tabular method [12]. This makes calculations as easy as possible using Microsoft Excel spreadsheets. From point c, the pressure increases at a constant volume, so we connect points c and z' with a vertical line.

Point z is connected to point z' by a horizontal straight line, which characterizes the supply of heat at constant pressure. Then we construct an expansion polytrope characterized by the zb curve. The expansion polytrope is described by formula 1. In this formula, we change the ratio from 1 to and determine the corresponding PX values of the expansion polytrope.

To construct the exhaust gas exhaust line, connect point l with point r, assuming that the pressure in the cylinder does not change during exhaust.Therefore, the area of he unrounded diagram will be limited by the points rr' 'acz' zblr. As a result, we get the indicator diagram of the PowerTech 6068HF250 engine in the gas-diesel cycle, shown in Figure 1.

The intake process begins at the end of the stroke of the piston to TDC, when the intake valve is opened for purging (point r' on the diagram), after which the pressure after closing the exhaust valve (point), the pressure in the cylinder drops to Ra and remains constant until point a. Therefore, the section of the diagram from point r' to point a is described by a horizontal straight line. Point a' is located at a distance from the origin of coordinates, which in scale corresponds to the volume of the cylinder when the exhaust valve is closed.

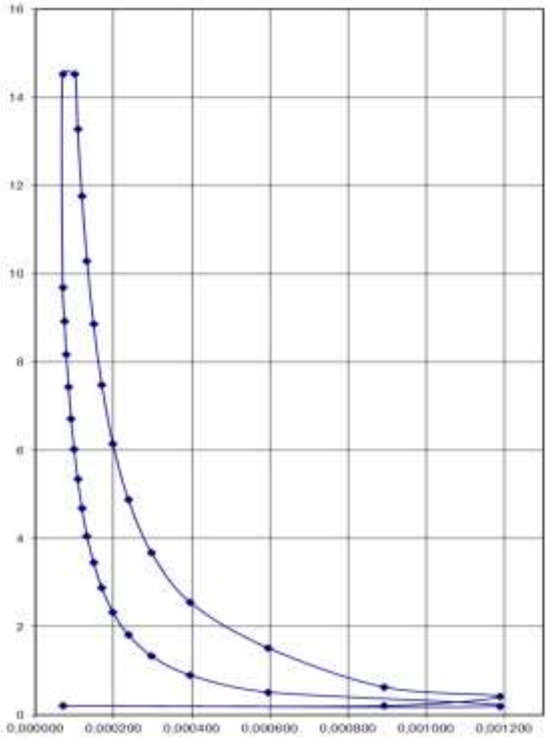

Fig. 1 Engine indicator diagram of the PowerTech 6068HF250 engine in the gas-diesel cycle.

To construct a rounded diagram, write down the coordinates of the rounding points. We connect the points rr' with a smooth curve. We are building an indicator diagram. We unfold the obtained diagram along the angle of rotation of the crankshaft of the engine using the analytical method using Microsoft Excel.To do this, you need to convert the coordinates of the points of the diagram into coordinates. For this, we use a number of formulas relating the volume of the cylinder to the angle of rotation of the crankshaft.Using formula 1, we calculate the volume of the cylinder depending on the angle of rotation of the crankshaft.In this way, we calculate for all positions of the crankshaft, changing from 0 to 720º, taking into account the gas distribution phases. Accordingly, when the crankshaft is turned to a certain angle, the pressure in the cylinder will change by the value of . The value depends on the processes taking place in the engine. At the position of the crankshaft = 0 = .At the position of the crankshaft = , = (closing the exhaust valve). When turning the crankshaft at an angle from to 180 = The value when rotating the crankshaft by an angle from 180º to 360º changes according to formula 1.9 (polytropy of the joint). When the crankshaft position = 360º, will have two values: = and = .

At the position of the crankshaft at = 390.11º, = When rotating the crankshaft from 390.11º to (exhaust valve opening), will change according to formula 1.22 (expansion polytrope).When rotating the crankshaft from up to 540º, the expansion polytrope must be rounded using the indicator chart rounding factor. Thus, further values of the expansion polytrope are multiplied by the rounding factor. When rotating the crankshaft from 540º to (closing the intake valve), it will smoothly fall to and from to 720º = v As a result, we get a diagram of the PowerTech 6068HF250 engine in the diesel cycle, rotated by the angle of rotation of the crankshaft (Fig. 2).

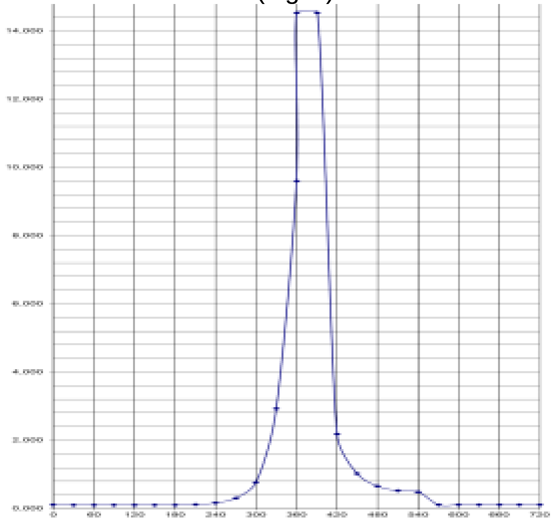

Fig. 2 Indicator diagram of the PowerTech 6068HF250 engine in the gas-diesel cycle

Conclusions. To determine the working and technological parameters of the tractor engine in the gas-diesel mode, for example, determining the consumption of LPG gas and the ignition dose of liquid fuel and setting other control points, the thermal calculation of the engine according to the Hrynivetskyi-Mazing method, using the Mathcad environment, is informative and relevant. The received data was purposefully processed in the Microsoft Excel environment. This tool makes it possible to significantly improve the analysis of the operation of diesel engines in the gas-diesel model.

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МОДЕЛЮВАННЯ РОБОТИ ДВИГУНА ТРАКТОРА В ГАЗОДИЗЕЛЬНОМУ РЕЖИМІ

В сучасних умовах використання палива в сільському господарстві необхідна диверсифікація джерел і використання альтернатив традиційному використанню нафтопродуктів. Проте є актуальне питання, яке активно вивчається, щодо зміни потужності при використанні двопаливної системи живлення двигуна, оскільки є дані про незначне зниження цього показника, також встановлено, що основні параметри зберігається робочий цикл і значне збільшення моторесурсу. Мета дослідження змоделювати основні параметри роботи двигуна в газодизельному режимі. Створено математичну модель робочого циклу газодизельного двигуна PowerTech 6068HF250 трактора John Deere 7930, що дає змогу встановити експлуатаційні та технологічні параметри його роботи. Для визначення робочих і технологічних параметрів двигуна трактора в газодизельному режимі, наприклад, визначення витрати газу LPG і дози запалювання рідкого палива та встановлення інших контрольних точок, тепловий розрахунок двигуна за Гринівецьким -Метод Mazing з використанням середовища Mathcad є інформативним та актуальним. Отримані дані цілеспрямовано оброблялися в середовищі Microsoft Excel. Даний спосіб дозволяє істотно поліпшити аналіз роботи дизельних двигунів в газодизельному режимі. При використанні математичної моделі роботи дизельного двигуна PowerTech 6068HF250 в середовищі Mathcad 14 було встановлено, що номінальна потужність в дизельному циклі була на 3.13% меншою від заявленої потужності двигуна заводом-виробником. Отриманні дані дозволяють стверджувати про відповідність побудованої нами моделі. При наступному моделюванні роботи двигуна в газодизельному циклі, виявлено зростання потжності двигуна. Також відмічено зростання потужності двигуна при використанні суміші палив. Це дає змогу зменшити дозу затраченого газового(LPG) пального до такої кількості, щоб потужність дорівнювала номінальній, що можна спостерігати на діаграмах.

Ключові слова: *дизельний двигун, газодизельний цикл, експлуатаційні показники, скраплений нафтовий газ, паливна суміш.*

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