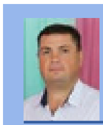
STUDIES ABOUTS THE ENERGY AND ECONOMIC PERFORMANCES OF THE DC4 11.0/12.5 BIODIESEL COMBUSTION ENGINE

STUDIU PRIVIND PERFORMANȚELE ENERGETICE ȘI ECONOMICE A MOTORULUI CU ARDERE INTERNĂ DC4 11.0/12.5 ALIMENTAT CU BIODIESEL

REZUMAT: *Această lucrare prezintă rezultatele unui studiu experimental al performanțelor energetice și economice ale motorului cu aprindere prin comprimare (DC4 11.0/12.5) alimentat cu motorină, amestec format din motorină-biodiesel B20, B50 și biodiesel B100. Amestecurile combustibile B20, B50 au fost formate prin adaos în motorină a biodieselului trans esterificat din ulei de rapiță. Concentrația biodieselului s-a determinat ca raport procentual al maselor de amestec. Rezultatele obținute în acest studiu indică faptul că majorarea proporției biodieselului în amestec combustibil de la 20% până 100% determină diminuarea puterii nominale a motorului. De exemplu, la alimentarea motorului DC4 11.0/12.5 cu biodiesel B100 și cu amestecuri B50, B20 puterea nominală a motorului s-a micșorat cu aproximativ 8,7% în raport cu cazul alimentării cu motorină din cauză că puterea calorifică a biodieselului (37,7 MJ/kg) și a derivatelor acestuia este inferioară puterii calorifice a motorinei (42,5 MJ/kg). Ulterior valoarea momentului efectiv al motorului crește pe ramura regulatorului deoarece acesta cu majorarea sarcinii modifică poziția cremalierei pompei de injecție și majorează debitul ciclic de combustibil. Consumul orar al motorului alimentat cu biodiesel și amestecuri biocombustibile a crescut în raport cu motorina la majorarea sarcinii motorului până la puterea nominală, ceea ce se explică prin valorile mai mici ale puterii calorifice pentru biocombustibili și, drept urmare, mărirea debitului ciclic de combustibil.*

Keywords: Biofuel, diesel fuel, vegetable oil, rapeseed oil, blend diesel – biodiesel, tractors



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1. INTRODUCTION

Because energy demands are increasing and that fossil fuel reserves are being depleted, and the polluting effects of their use on the ecosystem are catastrophic, it has become imperative to find new ways of producing energy from alternative sources that replace these classic fuels [1]. This necessity is even more current for countries that do not have their own fossil energy sources, the Republic of Moldova belongs to the latter. That is why the need to develop, produce, and use renewable energy sources becomes more and more current [3]. Particular attention is paid to renewable energy sources, namely alternative fuels of vegetable origin that ensure a balance in the conservation of greenhouse gases, as well as meet the requirements of the energy, economic and ecological performance of compression ignition engines [4]. One of them is biodiesel – a fuel that can be produced directly from vegetable oils and animal fats. Biodiesel produced from vegetable oil only emits into the atmosphere what the plants from which it originates have accumulated from nature. This is the fundamental principle on which the policy to promote the use of biodiesel in the economy is supported. This product, according to its physico-chemical properties, is similar to diesel fuel, therefore it can easily be used as a liquid fuel [2].

Several factors simultaneously influences the performance of the internal combustion engine, but the joint influence of these factors is practically very difficult to identify. Therefore, IC engine stand research is carried out under mono-factorial conditions, when one operating parameter is variable and others are constant (engine crankshaft speed n=const, invariable position of the injection pump rack, etc.). The performance of the diesel engine was assessed depending on operating regimes (crankshaft speed n, effective power Ne) or the composition of fuels (diesel, biodiesel B100, diesel-biodiesel mixtures B20, B50). The estimation of the stand parameters served as a basis for establishing the effective values of the operating regimes of the biofuel-fueled engine.

The purpose of the bench research was to obtain the performance characteristics of the biofuel-powered engines and to establish the optimal operating regimes of the given engines.

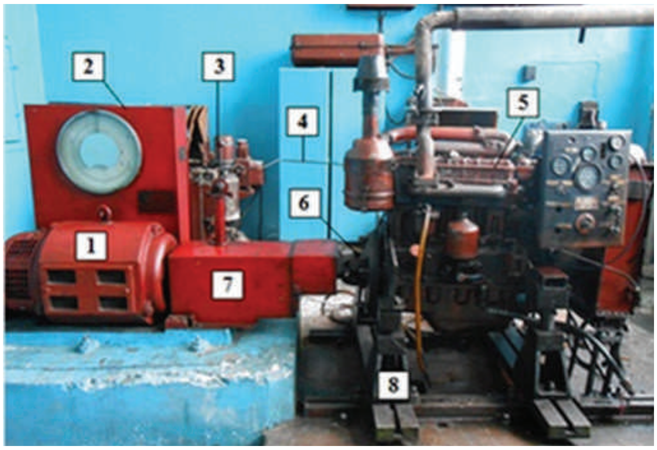

Fig. 1. Experimental engine test facility
1 – the electric swinging machine; 2 – information panel of the load mechanism; 3 – fuel flow control lever; 4 – lever rod; 5 – compression ignition engine; 6 – cardan shaft; 7 – protective casing; 8 – base.
The methyl ester from rapeseed oil B100 was obtained using the M8-КПБ-01 facility, developed and manufactured at the „Alimentarmaș" Joint Stock Company, Chisinau [5,6]. Fuel mixtures were prepared from a single batch of diesel and biodiesel, obtaining the following ratios (% by mass): 20% biodiesel + 80% diesel (B20); 50% biodiesel + 50% diesel (B50) and biodiesel B100

2. MATERIALS AND METHODS

The experimental research was carried out on a DC4 11,0/12,5 type compression ignition engine (compression ratio $\varepsilon = 16$) fuelled with diesel fuel, a mixture consisting of diesel-biodiesel B20, B50 and biodiesel B100, with which equipped with machinery and equipment from agriculture and other branches of the national economy (forestry, food industry, construction). It should be mentioned that the DC4 11,0/12,5 engines are installed on agricultural tractors (Belarus brand) which occupy about 50% of their total in agriculture in the Republic of Moldova. The research was carried out on a stand model KI 13638 GOSNITI (according to GOST 18509-88 and GOST 17.2.02-98) with direct current electric machine, which works in generator mode during braking.

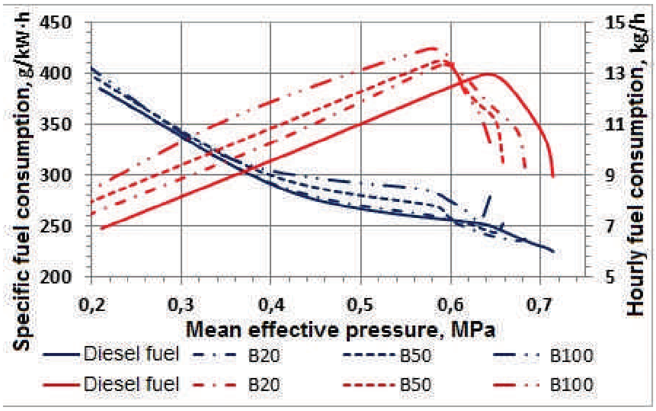

Fig. 2. . Load characteristic of DC4 11,0/12,5 motor at speed n = 2100 min^{-1} Hourly Ga consumption is marked with red lines, Effective specific consumption ge – with blue lines

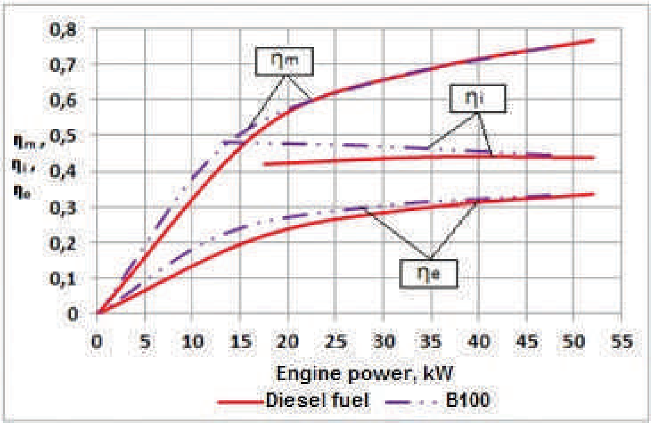

Fig. 4. Change in the mechanical efficiency η_m, indicated η_i and effective η_e during the operation of the DC4 11,0/12,5 engine fueled with diesel and biodiesel depending on the load

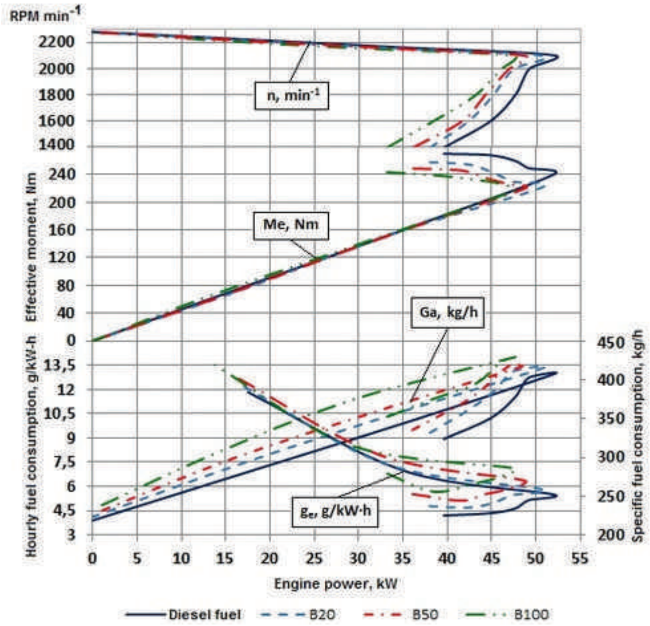

Fig. 3. Governor characteristic of DC4 11,0/12,5 engine fueled with diesel, biodiesel and fuel blends

3. RESULTS AND DISCUSSION

The influence of the composition of the fuel mixture, considering the added amount of biodiesel in the diesel, on the MAC performance was evaluated, also using load characteristics.

Figure 2 shows the load characteristic of the DC4 11,0/12,5 engine fueled with diesel, biodiesel (B100) and biodiesel blends (B20, B50) at constant speed. In order to maintain constant crankshaft speed n, the resistive moment applied to the engine (brake adjustment) was changed at each change in fuel flow.

The analysis of the effective parameters (figure 2) demonstrates that in the case of feeding the DC4 11,0/12,5 engine with biodiesel B100 and with fuel mixtures B20, B50, the hourly fuel consumption Ga has higher values in relation to diesel over the entire variation range of charge P_e (G_a^{bio}>G_a^{mot}). This phenomenon occurs because when the injection pump control lever is moved, due to the lower value of the calorific value of the biofuel, the cyclic flow rate of this fuel increases.

Up to a load of approximately 70÷75% N_e (P_e = 0,5 MPa), the dependence $G_a = f(P_e)$ practically has a linear character. For example, at diesel engine operation with nominal load (P_e = 0,21 MPa) the hourly consumption of biofuel is higher in relation to diesel (G_a = 6,9 kg/h): for biodiesel B100 by 14,5% (G_a = 7,9 kg/h), for mixtures B20 and B50 - by 7,2% (G_a = 7,4 kg/h) and by 11,6% (G_a = 7,7 kg/h), respectively. In the case of load P_e = 0,5 MPa, the same hourly consumption ratios between diesel and biofuels B100, B50, B20 are maintained.

The effective specific fuel consumption $g_e = G_a/P_e$ presents a complex parameter, which simultaneously includes economic and energetic performance, therefore the value of ge is important in the assessment of engine operation. The results of the stand research (figure 2) demonstrate that the specific consumption values of biodiesel B100 and B20, B50 mixtures are higher compared to diesel, but the difference between g_e^{bio} and g_e^{mot} values varies depending on the engine load. In the range of effective average pressure values 0,2-0,4 MPa the difference (g_e^{bio} - g_e^{mot}) is small and does not exceed 4%. At higher loads in the limit P_e = 0,4-0,6 MPa, the mentioned difference increases up to 7%. The minimum values of the specific consumption g_e are identified at different loads: in the case of supplying diesel engine with biodiesel B100 g_e^{min} = 255,2 g/kW·h at P_e = 0,64 MPa, and for mixtures of biodiesel and diesel, the specific consumption made up g_e^{min} = 235,5 g/kW·h for B20 (P_e = 0,67 MPa) and for B50 case g_e^{min} = 244,2 g/kW·h (P_e = 0,65 MPa), respectively. The minimum value of the specific consumption of diesel is equal to g_e^{min} = 225,6 g/kW·h (P_e = 0,71 MPa).

The increase in the 4-7% limit of the effective specific consumption ge and the hourly G_a of fuel can be explained by the lower value of the heat of combustion of biodiesel B100 and B50, B20 mixtures compared to that of pure diesel. The minimum value of the specific fuel consumption is obtained when supplying the diesel engine with diesel and biofuel in the range of low loads, respectively, of the average effective pressure of P_e = 0,64-0,71 MPa (figure 2). In the case of fueling the engine with twin diesel, it is at P_e = 0,71 MPa, and when fueling with pure biodiesel and with biodiesel-diesel mixture, the minimum specific consumption values correspond to the load P_e = 0,64 MPa (B100) and for the B20 case and B50 g_e^{min} stood out at load P_e = 0,67 MPa and at load P_e = 0,65 MPa, respectively. It is obvious that the addition of biodiesel to diesel modifies the character of the formation process of the combustion mixture and, consequently, the characteristics of the combustion process.

The exploitation of agricultural technical means in the process of carrying out various technological operations often requires the operation of their engines on the regulator branch of the full or partial characteristic, when the crankshaft speed is close to the nominal one. In connection with this, the regulator characteristics of the DC4 11,0/12,5 engine fueled with diesel, biodiesel B100 and with biodiesel-diesel mixture B20, B50 were raised. The above-mentioned characteristics provide a general representation of the technical state of the engine and the trends of changes in the main parameters when using B100 biodiesel and B20, B50 blends in diesel engine. As can be seen from figure 3 when feeding the DC4 11,0/12,5 engine with biodiesel and fuel mixtures, no significant changes were found on the regulator branch of the characteristic, and on the activity branch of the corrector it was established a decrease in effective power Ne by 6,4 kW for biodiesel B100, and for the case of B20, B50 - by 1,6 kW and 3,5 kW, respectively, in relation to diesel fuel at crankshaft speed n = 1400 min^{-1}.

The value of the effective moment M_e of the engine increases on the regulator branch because it, with the increase in load, changes the position of the injection pump rack and increases the cyclic fuel flow (figure 3). Increasing the effective moment of the engine on the activity branch of the corrector is achieved due to its operation, which provides the opportunity to increase the cyclic flow of fuel. Lower values of the effective moment M_e on the corrector branch are generally caused by the worsening of the process of formation of the combustion mixture and the increase of heat losses during fuel combustion.

At the same time, it was determined that the increase in the fraction of biodiesel in the fuel mixture from 20% to 100% is the cause of the decrease in the nominal power N_e of the engine. For example, when fueling the DC4 11,0/12,5 engine with B100 biodiesel and B50, B20 blends, the rated power N_e of the engine decreased by about 8,7% compared to diesel because the calorific value of biodiesel (37,7 MJ/kg) and its derivatives is lower compared to the calorific value of diesel (42,5 MJ/kg).

The hourly G_a consumption of biodiesel and biofuel blends increased compared to diesel when increasing the engine load up to the rated power (figure 3), which is explained by the lower values of calorific value for biofuels and, as a result, the increase in the cyclic flow of fuel (the regulator moves the injection pump rack in the direction of increasing fuel flow). The decrease in the hourly fuel consumption G_a on the corrector branch of the characteristic obtained due to the sudden decrease in the crankshaft speed and the decrease in the fuel flow in the combustion chamber of the engine cylinder.

At the same time, on the regulator branch at low loads, an increase in the specific ge consumption of biofuel was established in relation to diesel by 53,2 g/kW·h for biodiesel B100, by 12,4 g/kW·h and 27,6 g/kW·h for case B20 and B50, respectively. And at loads, the ge increase was up to 33 g/kW·h for biodiesel B100, for fuel mixtures - by 7 g/kW·h (B20) and 18 g/kW·h (B50), respectively (figure 3).

Our research carried out on the stand demonstrates that the specific ge consumption values of all studied fuels tend to decrease substantially (from 400 to 250-280 g/kW·h) on the regulator branch (figure 3) with increasing engine load from 16,5 to 55 kW.

One of the causes of this extremely positive phenomenon in the real operation of the diesel engine is the increase in the mechanical efficiency η_m under these conditions (figure 4). Another cause of the decrease in g_e in the area of the speed characteristic with engine loading from minimum to nominal loads (figure 3) is the delayed start of the cyclic fuel flow corrector. As a result, the fuel injected into the cylinder chamber burns practically completely, with a slight increase in the efficiency indicated η_i observed (figure 4).

The overall efficiency of the combustion process is characterized by the effective efficiency η_e of the engine. The values of this integral indicator (figure 4) demonstrate that when feeding the DC4 11,0/12,5 engine with pure biodiesel B100, the effective efficiency η_e has higher values by up to 20% compared to diesel in the engine power range from 5 to at 35 kW. In the marginal sectors of the dependence $\eta_e = f(P_e)$ the effective yield values coincide for both cases: fueling with B100 and diesel. The highlighted phenomenon demonstrates the more complete and efficient combustion of biodiesel and its derivatives compared to diesel.

4. CONCLUSION

The results of the experimental research carried out in order to use biodiesel and mixtures formed from biodiesel and diesel were the basis for the formulation of some conclusions as follows:

- it has been established, that in relation to diesel, fueling with biodiesel and B20, B50 blends practically do not change the performance of the DC4 11,0/12,5 engine and does not require additional adjustment of the fuel supply system. Increasing the fraction of biodiesel mixed with diesel decreases the nominal power N_e of the engine. For example, when feeding the DC4 11,0/12,5 engine with biodiesel B100, the power N_e decreased by approx. 8,7% compared to diesel because the calorific value of biodiesel (37,7 MJ/kg) is lower by 12,7% in relation to the calorific value of diesel (42,5 MJ/kg).
- it was demonstrated that the values of the specific consumption ge of all the fuels studied have a substantial decreased tendency (from 400 to 250-280 g/kW·h) on the regulator branch with the increase of the engine load from 16,5 to 55 kW. One of the causes of this extremely positive phenomenon in the real operation of the diesel engine is the increase in the mechanical efficiency η_m under these conditions. Another cause of the decrease in g_e in the area of the speed characteristic with engine load from minimum to nominal loads is the delayed start of the cyclic fuel flow corrector. As a result, the fuel injected into the cylinder chamber burns practically completely, with a slight increase in the efficiency indicated η_i observed.
- it was identified that the effective efficiency η_e of the DC4 11,0/12,5 engine increases by 20% in the case of fueling with B100 biodiesel compared to diesel, which demonstrates the more complete combustion of biodiesel and its derivatives.

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