EFFECTS OF LUBRICATING OIL CHARACTERISTICS ON VALVE TRAIN SYSTEM FRICTION LOSSES

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Abstract: *Modern requirements imposed in modern and actual agriculture-related goals of improve the technologically processes efficiency. Efficiency of specific work processes to agriculture is directly related to energy sources efficiency, energy sources used agricultural machinery and equipment. Importance is given by the contemporary massive growth of the degree of mechanization and automation of agricultural equipment. Energy sources (IC engines) efficiency is defined in general by the quality of transforming the fuels energy into useful heat energy and by the value of mechanical losses due to friction between the mechanisms relative moving. Using adequate lubrication oils can reduce friction losses. Rheological characteristics of lubricating oil directly influence the friction losses due to mechanical friction of IC engines internal mechanisms (piston group, valve train, fuel pump, crankshaft, bearings and seals etc.). The paper aims to determine by computer simulation process (numerical investigation) the influence of the different classes lubricating oils characteristics on lubricating process of the friction losses in valve train system. The friction losses due to camshaft bearing hydrodynamics, between cams and cam followers, due to oscillating valve train hydrodynamics and due to oscillating mixed valve train lubrication was considered. Valve train system has a poor lubrication during cold startup process of an IC diesel engine and thus is necessary a proper lubricating oil to full fit the complex demands of all engine components and subassemblies. The results were obtained according to consideration of constructive parameters and design particularities of tractor diesel engine D-110 type, and were compared with data obtained by experimental measurements. The difference between the total friction losses in valve train system using a SAE10 class lubricating oil and a SAE40 class lubricating oil is 0.16 kW(-7.3 %). Considering these results, is worth to note that if will use a higher SAE viscosity class (e.g. SAE40), is a greatly reduce the friction of the valve train system, but this may negatively influence the engine crankshaft lubrication. High viscosity oil poses to achieve a proper lubrication system, especially at low temperatures engine start process. There are different trends of variation of mechanical losses in components of valve train system for changing the SAE viscosity class of lubricating oil, trends that must be taken into account in the redesign and optimization of the valve train system components.*

Key words**:** *lubrication, oil, friction, losses, valve train, simulation.*

INTRODUCTION

A modern agriculture must increase mechanical efficiency performance of tractors, agricultural machines and aggregates used in agricultural specific technology processes. An immediate way to increase the mechanical efficiency is to reduce mechanical and hydraulic friction taking place between different relative moving components. Since ancient times (Leonardo da Vinci, 1452-1519) and until today, there are many experimental and theoretical studies and researches that had as aim to study physico-chemical phenomena related to friction and wear.

Friction losses, wear and lubrication process were considered to have a major impact on worldwide economy due to the negative effect on the efficiency and lifetime of machinery in industry and agriculture [6, 14, 20].

The internal combustion (IC) engine is the major source of energy for machinery and equipment use in agriculture, energy obtained through the transformation of fuel's chemical energy into mechanical energy.

Unfortunately, due to structural and functional principles of IC engines is not possible to transform all the chemical energy contained in the molecular structure of fuel into useful mechanical energy.

According to [4, 5, 7] the fuel energy is dissipated trough the following:

- 30-37% goes to exhaust gases (lost thermal energy);
- 25-33% goes to cooling system;
- 33-40% is only converted in mechanical power.

The part of the fuel energy devoted to mechanical power related to overcome friction is about 33-35%, and can be divided in (Fig.1):

- Friction between tire and road contact;
- Friction of engine systems moving parts;
- Friction in the transmission system;
- Friction consume by brake action.

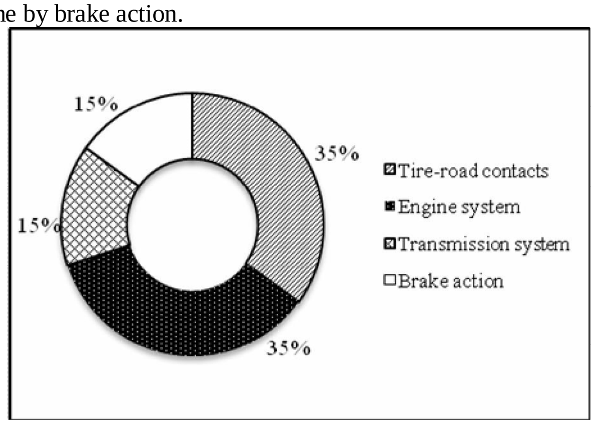

Figure 1. The overcome friction of tractor system

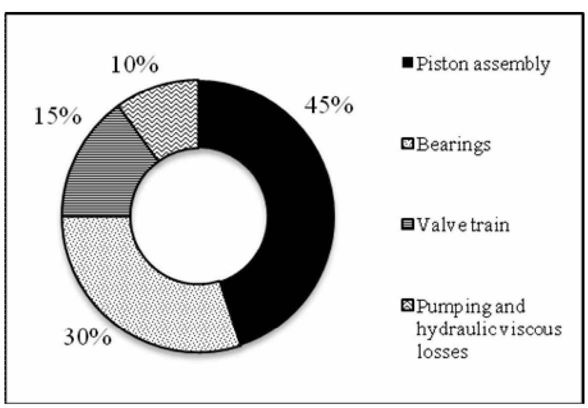

Figure 2. Distribution of mechanical energy consumed in engine system

As we presented previously, the group of the engine systems friction is major, and also the mechanical consumption can be divided in four big classes (Fig.2):

- Consumed in the piston assembly;
- Consumed in bearings and seals;
- Consumed in valve train system;
- Consumed by pumping and hydraulic viscous losses.

Reduce friction losses can be achieved by methods agreed by researchers worldwide and certificates by their use in practice [3, 10, 12, 19]:

- Low friction coatings on mechanical components;
- Improving the surface topography and texturing;
- Improving rheological characteristics of lubricants;
- Improving the engine's cold start process.

Note that methods to reduce friction losses include rheological quality and properties of lubricating oil. Lubricating oils must ensure lubrication of engine parts both in operation at low to heavy loads as well, in a field to the fullest extent of ambient temperatures.From the point of view of engine's components lubrication process, the dominant characteristic of lubrication is hydrodynamic (HD) for bearings and seals and mixed lubrication (ML) for valve train system. For the piston group a mixture of HD and ML lubrication can be find but also it is present the elasto-hydrodynamic lubrication in sliding contacts (EHD).

Considering that the friction losses in the distribution system are relatively high (15%), the paper aims to study the intensity of friction losses depending on lubricating oil viscosity grade. Lubricating oils were analyzed in class SAE10, 20, 30, 40W by computer simulation. The ambient temperature was considered to be 25^{o}C.

MATERIAL AND METHODS

Computer simulation is one of the modern and contemporary methods widely used by researchers to solve a technical problem. Lately, the development of mathematical models allowed a better correspondence between the physical models and numerical models and led to the use of computer simulation in specific processes of tractors and agricultural machinery [2, 8, 9].For the computer simulation process, in order to determine the friction losses for engine function at different ambient temperature, we used simulation software package Cruise, developed by AVL GmbH [1].

Cruise computer simulation package is easy to use trough it's interface, that allows total or partial construction of components, subassemblies and assemblies models that constituting a vehicle and set operating parameters and conditions thereof. The Cruise friction model had the advantages of taking into account the engine design variables such bore, stroke, number of valves and also the engine-operating conditions (engine speed, load, oil temperature). The values of friction losses coefficients are calculated by model considering the above presented engine design and operating conditions variables. In terms of mathematical models used to account the effect of ambient temperature on functional parameters and emissions of internal combustion engines (spark ignition or compression ignition) for determining friction losses in the motor mechanisms using SLM model proposed and developed by [10, 16-18]. The effect of oil viscosity changes is taken into account by scaling the instantaneous friction losses (Eq.1) to values for fully warmed up conditions [11, 15].

$$\frac{Fmep_{Toil}}{Fmep_{Toil@90^{o}C}} = \left(\frac{\upsilon_{Toil}}{\upsilon_{Toil@90^{0}C}} \right)^{0.24} \qquad (1)$$

As seen from Eq.1, this model takes into account the important parameter of lubrication process quality (viscosity), the physical parameter that varies in case of different ambient temperature.

The model used in simulation and created using CRUISE software is based on D 110 diesel engine that equip the Romanian U650 agricultural 2 WD tractor, and is shown in Fig. 3. Engine general technical characteristics need to be considered as input parameters of computer simulation are presented in the Table 1. The model is used also to determine the functional and dynamic performances of tractor, for specific agricultural works.

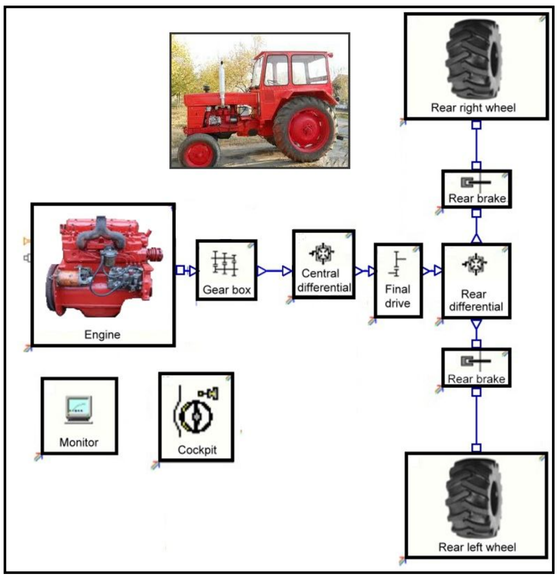

Figure 3. The Cruise D-110 engine simulation model

Table 1

D-110 engine's technical data

Properties	Value
Engine type	D110, diesel, direct injection, 4 cylinders in line, water cooling system
Displacement	4750 cm^3
Bore	108 mm
Stroke	130 mm
Power	47.8/65 [kW/HP] at 1800 min^{-1}
Torque	289 Nm at 1250 min^{-1}
Compression ratio	17:1

RESULTS AND DISCUSSIONS

After computer simulation, using as primary data input lubricating oil viscosity according to SAE viscosity class; results were obtained for instantaneous frictional losses in the distribution mechanism and are presented in Figures 4-8.

In terms of friction losses variation it can see that there are two specific particularities. Whilst friction losses due to camshaft bearing hydrodynamics and friction losses due to oscillating valve train hydrodynamics is an increase with increasing grade of SAE Viscosity (Fig. 4 and 6), for friction losses between cams and cam followers and friction losses due to oscillating mixed valve train lubrication, opposite phenomena happens (Fig. 5 and 7).

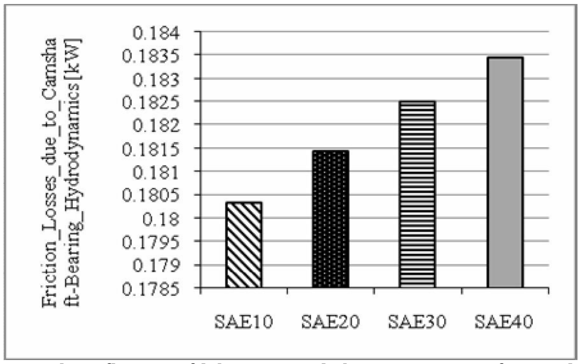

Figure 4. The influence of lubricating oil characteristics on friction losses due to camshaft bearing hydrodynamics

Considering the nominal values obtained from computer simulation, the values obtained for the friction losses between cams and cam followers and friction losses due to oscillating mixed valve train lubrication are one order of magnitude higher than other considered friction losses, showing their global influence of lubricating oil characteristics on the total engine friction losses.

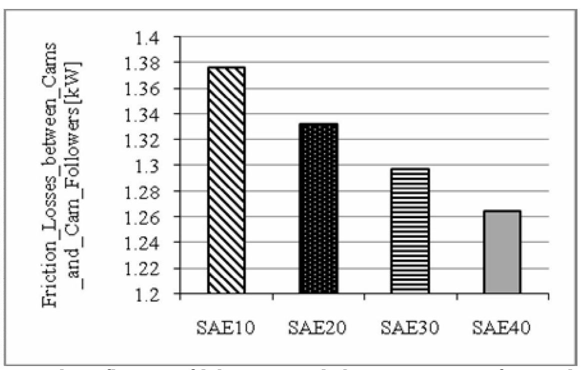

Figure 5. The influence of lubricating oil characteristics on friction losses between cams and cam followers

The difference between the total friction losses in valve train system using a SAE10 class lubricating oil and a SAE40 class lubricating oil is 0.16 kW(-7.3 %). Considering these results, is worth to note that if will use a higher SAE viscosity class (e.g. SAE40), is a greatly reduce the friction of the valve train system, but this may negatively influence the engine crankshaft lubrication. High viscosity oil poses to achieve a proper lubrication system, especially at low temperatures engine start process [3, 13].

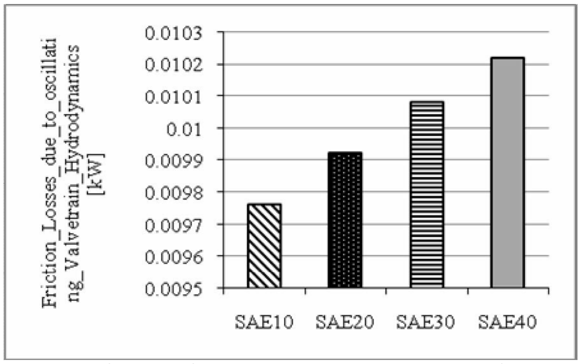

Figure 6. The influence of lubricating oil characteristics on friction losses due to oscillating valve train hydrodynamics

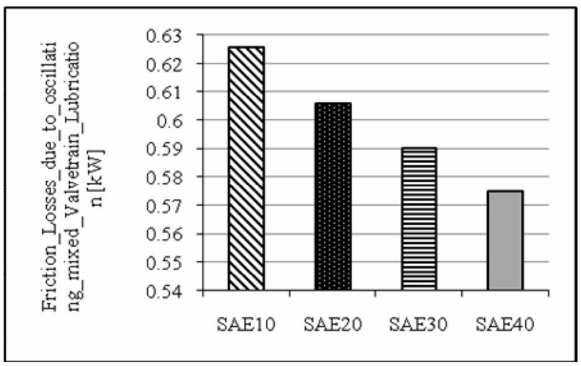

Figure 7. The influence of lubricating oil characteristics on friction losses due to oscillating mixed valve train lubrication

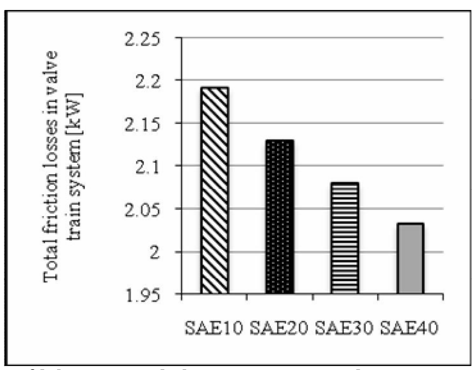

Figure 8. The influence of lubricating oil characteristics on valve train system total friction losses

However, all the friction losses through the study are important in the current context that is increasingly obvious increase engine performance in terms of fuel consumption and pollutant emissions that can be achieved by redesigning all subassemblies distribution system.

The reduction of valve train system friction losses can be achieved by adopting methods that change the viscosity of lubricating oil for limited time, especially during the engine cold start process.

CONCLUSIONS

Computer modeling and simulation process shows its immediate benefits in identifying ways and opportunities to improve the overall efficiency of internal combustion engine (mechanical efficiency in this case).

For the mechanism of distribution of a tractor diesel engine D-110, is found that the total friction losses of valve train system can reach a value of 4.6-4.2% (comparative with 8% obtained by experiments conducted by [6]) of actual total power developed by engine (47.8 kW), a value that can not be neglected in the contemporary context of demands in continuous modernization and optimization of energy sources used in agriculture.

There are different trends of variation of mechanical losses in components of valve train system for changing the SAE viscosity class of lubricating oil, trends that must be taken into account in the redesign and optimization of the valve train system components.

Also it must to be develops new processes and / or technologies that allow changing lubricating oil viscosity briefly (for the specific engine cold start process, when the lubricating oil viscosity is a critical characteristics), and with no degradation of the rheological requirements characteristics of lubricating oils, to compensate the differences in lubrication in valve train and auxiliary equipment systems comparative with the engine crankshaft.

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