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FUEL ECONOMY OF OLDER DESIGN TRACTORS DIESEL ENGINES IN RELATION TO NEW ONES

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INTRODUCTION

On a global scale, environment concern, energy saving and cleaning up of air pollution is one of the most important subjects. One of the characteristics feature of our time is a common viewpoint is charred by the public community that our society is very irrational user of energy. Total consumption of all forms of energy is very high at present time [1] and that is increasing simultaneity (Fig.1) due to the growth of world's population and the great changes in human activities.

It follows from this that human activities must be geared towards minimum energy use in order to help protect energy resources and minimize ecological and economic disadvantages.

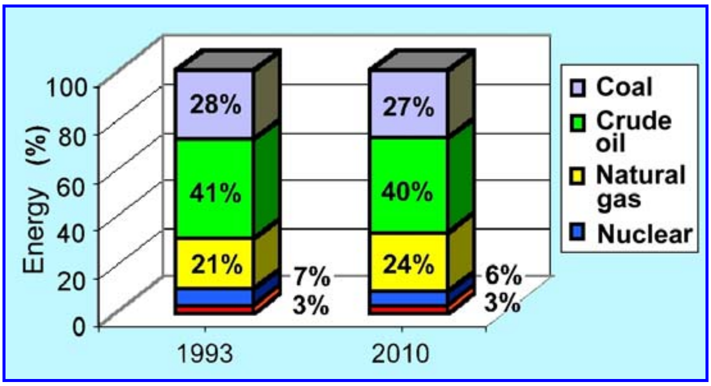


Figure 1: *World primary energy demand*

Transport sector is one of the highest consumers of energy obtained from fossil fuels (Fig.2) [2]. The transport sector accounted for about two-thirds of the total mineral oil consumed. On the other hand the fuel consumption of gasoline and heavy-duty diesel engines is of great important, since it account for up 30% of operating costs.

It is absolutely clear that the reduction of energy consumption and the protection of environment – exhaust emission reduction, i.e. cleaner air, will be one of the main tasks of automotive industry in the first decades of the 21st century. The improvement of fuel economy means the reduction of CO_2 emissions.

Due to globalization of national economies, very significant growth will take place in the transportation sector, which is going to be the most important consumer of energy.

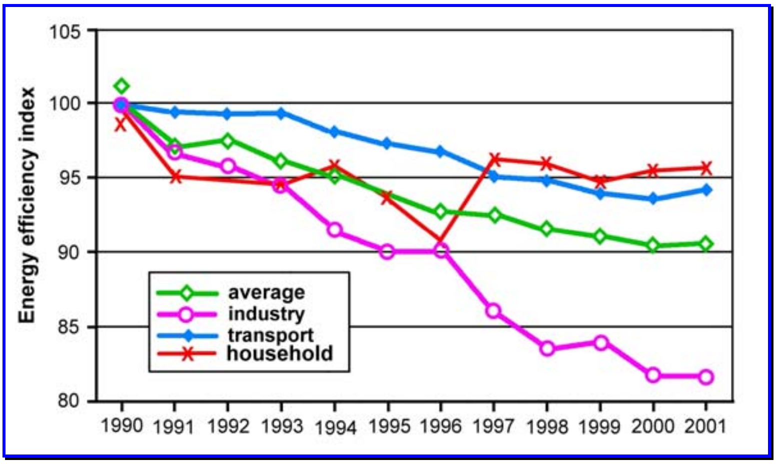


Figure 2: *Energy efficiency index for main consumers in EU related 1990*

For example, in 2004 Emus diesel and gasoline consumption amounted to 270 mil.tons, compared to 180 mil.tons in 1985, and it is forecast to reach 325 millions in 2020.

Efficiency is generally defined as the ratio of benefit to cost, of output to input.

Rising fuel costs and the need to conserve fossil fuel led to an increased interest in the role of lubricants in improving fuel economy.

Lubricant formulation can have a beneficial reduction of engine friction, this improving fuel economy. For example, friction losses in a car engine may account for more than 10% of the total fuel energy [3].

Due to, in Japan, by the Year 2010, the fuel consumption of automobiles must be reduced by an average of 22, 8% compared to 1995 [4]. This trend to improve fuel economy has led to the introduction of lower oil viscosity grades such as 5W30 and 10W30 grades that are now commonplace in the heavy-duty engines.

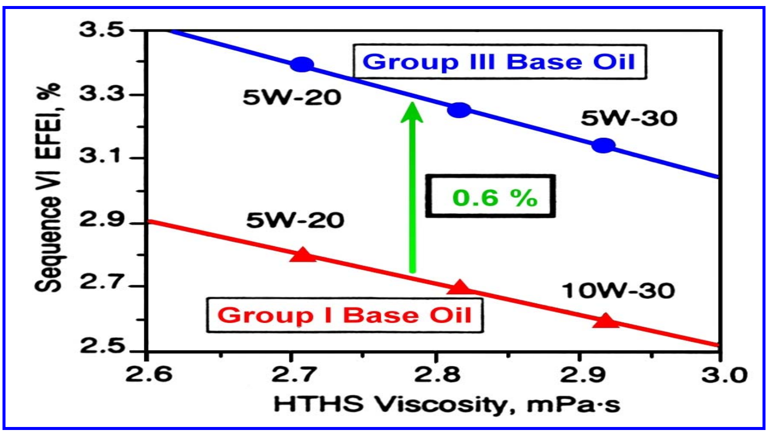


Figure 3: *Fuel economy benefits obtained from VHVI Group III base oil*

Figure 3 shows fuel economy benefits as result of the lower elastohydrodynamic lubrication (EHL) friction of the very high viscosity index (VHVI) Group III in compare with Group I base lubricant oils [5].

Typically, PAO based engine oils have a fuel consumption benefit of up to 3.4% relative to comparable mineral oils. In automotive transmissions the benefit is of the order of 10% of the power transmitted through the unit resulting in a fuel economy benefit of up to 2% in the driveline of a vehicle. This results in on overall benefit of up to 5.4% in a vehicle [6]. In industrial transmissions, it is a possible to achieve a 10% reduction in energy consumption by replacing mineral oil with equiviscous PAO based oils [4, 7].

Pressure to improve the fuel economy of motor vehicles is getting stronger due to necessity of preventing global atmospheric warming, and on the other hand, saving energy.

Commercial vehicles and tractors are invariably powered by the diesel engines because of its superior thermal efficiency and 30% lower fuel consumption than the gasoline engines and high CO_2 reduction effects. For that reason, the diesel engine is at least in Europe, seen as the best solution for reducing fuel consumption and these reducing CO_2 emissions.

It is estimated that diesel engines could emit 28% fewer green house gasses in the total energy cycle including refining and vehicles use.

This testing has been performed from that point of view, energy efficiency of four-cylinder tractors engines older design and diesel engines of newer design.

EXPERIMENTAL

Testing of fuel efficiency has been performed on four cylinders tractors engines with indirect fuel injection (Perkins 4.203 –M 34/T) and direct fuel injection (Perkins D4.203 - DM 34/T).

These engines are older design -production technology. The criterion for choice of these engines was theirs large production as well as representative in exploitation in Serbia and wide area of Balkan’s peninsula.

These engines are compared to equally of European engines, which are newer design.

The criterion for choice of representative European tractor’s engines (W4 and E4) was theirs market share, the same class as domestic representative engines and as the first theirs performance (power, torque) and fulfillness of European provisions with regard to the emissions of pollutants by the engine.

The technical characteristics of engines, older and newer design show the table 1.

It can be seen from the table 1 that European modern tractor diesel engines, W4 and E4, have 10÷15% higher compression ratio, ~33% higher injection pressure, 4-12% lower specific fuel consumption, larger piston diameter and smaller stroke, 9-12% lower swept volume and considerable higher, 9÷20%, volume power related to M34/T and DM34/T older design diesel engines.

Moreover, there are significant differences in injection equipment. Modern European’s engines have fuel pump for every cylinder while older design engines have rotational high-pressure pump.

Specific fuel consumption measuring has been performed on a test stand using direct method [8].

Specific effective fuel consumption is presented by diagram as:

1) brake performances and 2) over universal diagram, finding economical point, i.e minimum fuel consumption pole.

Table 1: *Characteristics of tested engines*

Item	Data \ Engines	M34/T	DM34/T	W4	E4
1	Fuel injection system	IDI	DI	DI	DI
2	Total swept volume V(lit)	3,33	3,33	2,97	3,11
3	No. of cylinder in line	4	4	4	4
4	Compresion ratio ε	17,4:1	16,5:1	18:1	19:1
5	Bore D (mm)	91,4	91,4	94	94
6	Stroke S (mm)	127	127	100	112
7	Rated power ISO 2288 (KW)	41,4	46,2	50	47
8	Rated speed n (o/min)	2250	2250	2650	2800
9	Max. torque M(o/min) (Nm)	194,5/1400	210,8/1470	210/1450	190/1600
10	Injection pump	Rotational	Rotational	Unit	Unit
11	Volume power (KW/lit)	12,43	13,872	16,83	15,11
12	Start of injection (before TDC)	20	20		
13	Injection pressure (bar)	118	200	230	
14	Spec.fuel consump.–ge(g/kWh)	257	244	235	218

RESULTS

Comparative results of testing brake performances on four-cylinder tractor's diesel engines, M34/T and DM34/T, older design, shows Figure 4.

It can be seen that the direct injection engines -DM34/T, related to indirect injection engines- M34/T have larger power approx. 12%, and lower specific fuel consumption approx. 6% from the same engine displacement. These differences are result in design of these two engines. Namely, engine M34/T has indirect fuel injection in a swirl chamber in a cylinder head. Nozzle has two holes; the injection pressure is relatively low compared to modern tractor's diesel engines.

The engine DM34/T has direct fuel injection in cylinders at considerably higher fuel pressure (45%), thus better energy efficiency.

The nozzles have four holes (0, 28 mm) that the fuel spray makes better mixture with rotating air. The figure 5a/b shows universal specific effective fuel consumption of M34/T and DM34/T diesel engines.

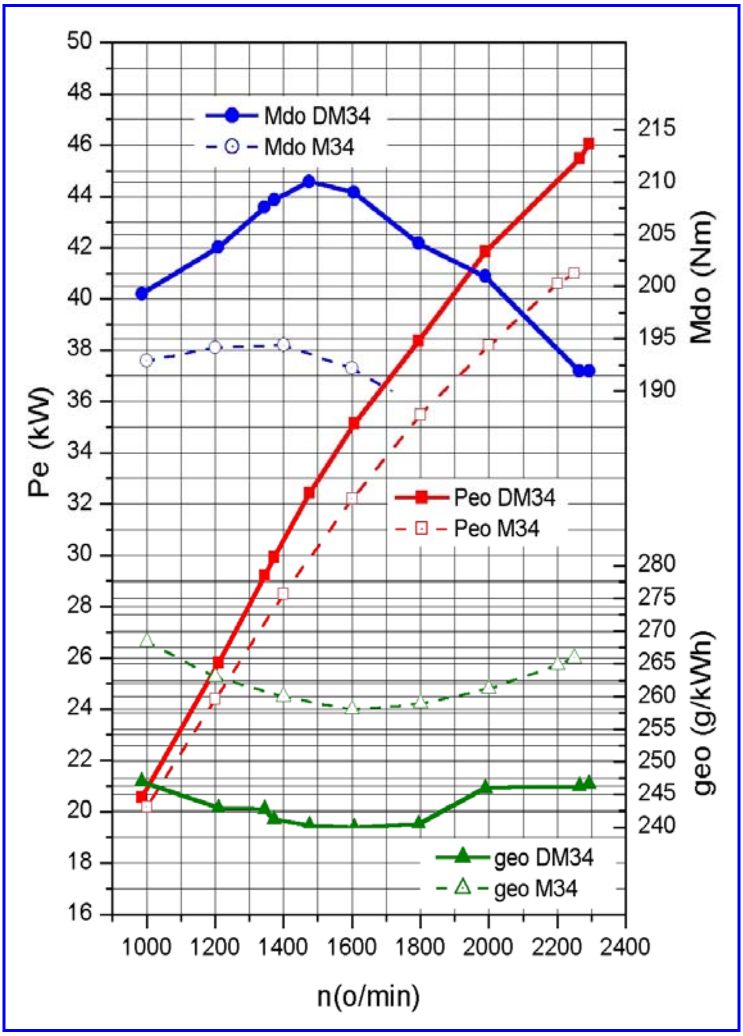


Figure 4: *Brake performances of M34/T and DM 34/T engine*

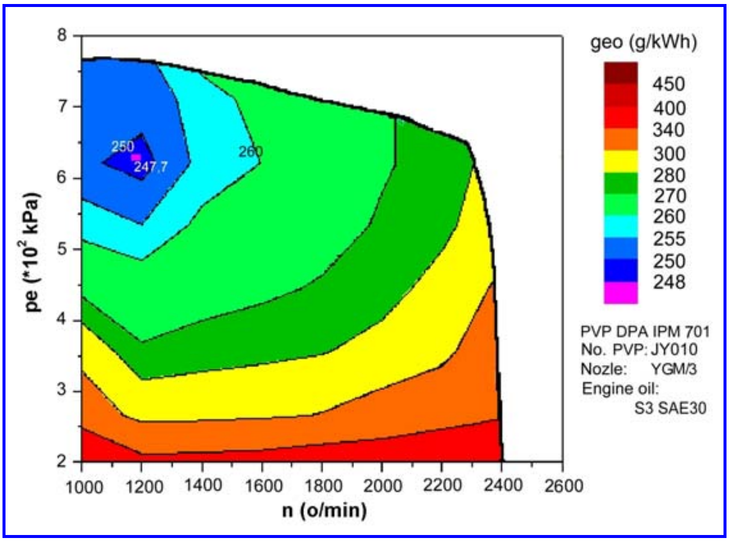
It can be seen from Fig. 5ab, that the minimum fuel consumption poles these two engines - M34/T and DM34/T- are differ, namely they include different section of working regime.

They are 247,7g/kWh and 233 g/kWh, respectively, i.e. the difference is approx. 6%.

The minimum specific fuel consumption pole of DM34/T engine (233g/kWh), related to one of M34/T engine (247,7g/kWh) is slightly shifted to right and down, thus it is approx. 450 rev/min right of max. torque and at approx. 80% of full load.

Relatively low position of minimum fuel consumption pole of DM34/T engine shows that if it would be readjusted to declared power of M34/T engine 41,4 kW at 2250 rev/min, instead of 46.2 kW at 2250 rev/min (table 1), the minimum fuel consumption pole will be again inside the working area of engine.

Practically it means that the adjusted engine will have approx. 6% lower fuel consumption. However, the smoke emission and NOx emission will not be decreased.



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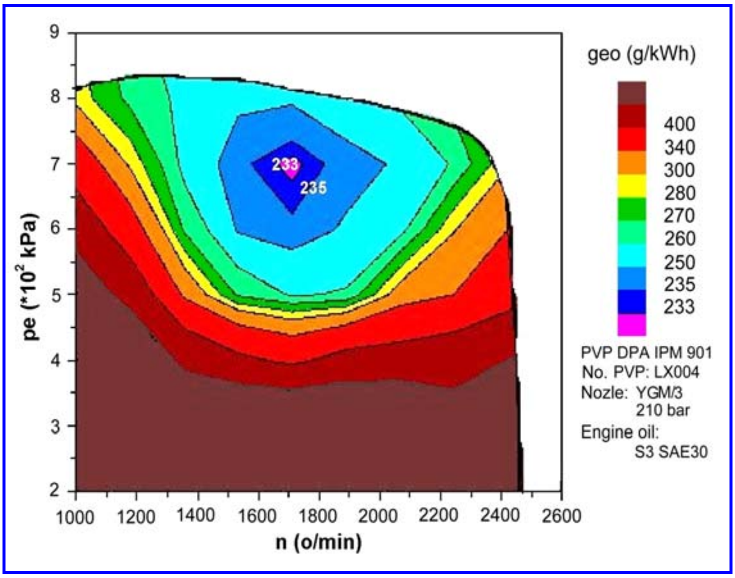

b

***Figure 5**: a, b. Universal specific effective fuel consumption diagrams of M34/T and DM34/T engine*

Comparative brake performances of examined older design four cylinders tractor engines (M34/T and DM34/T, made in Serbia) and equivalent European diesel engines newer design are presented in Figure 6.

Figure 6 shows that modern European engine W4 vs. DM34/T has 9% higher max. power, about 12% smaller swept volume and larger power per unit displacement of 20%, and at the same time better torque back-up. Second European engine of modern design E4 vs. DM34/T has 6% approx. higher max. power, smaller swept volume of 9%, and larger power per unit displacement of 9%, and at the same time better torque back-up .at the same time better torque back-up.

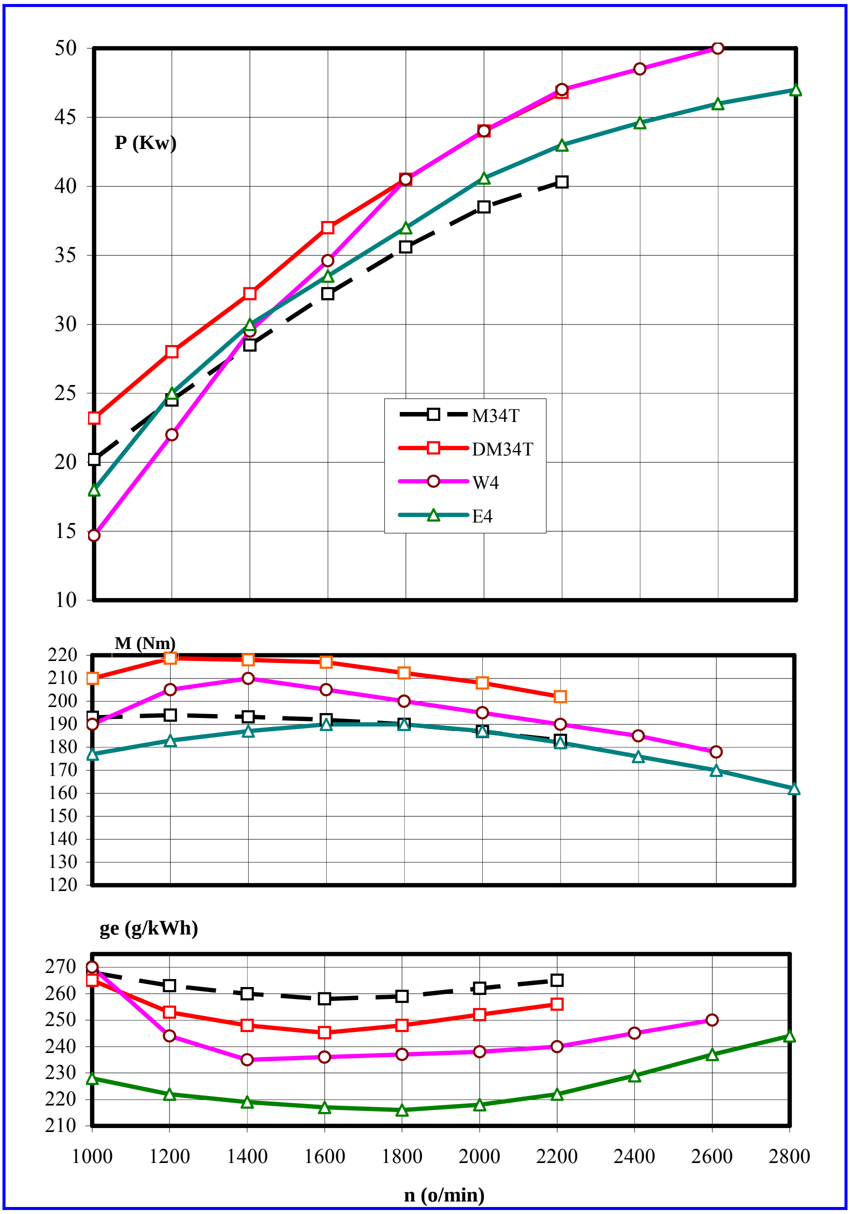

***Figure 6:** Comparative brake performances of four cylinders tractor engines older and newer design*

Fuel consumption of four cylinder tractors diesel engines of older and newer design shows figure 7.

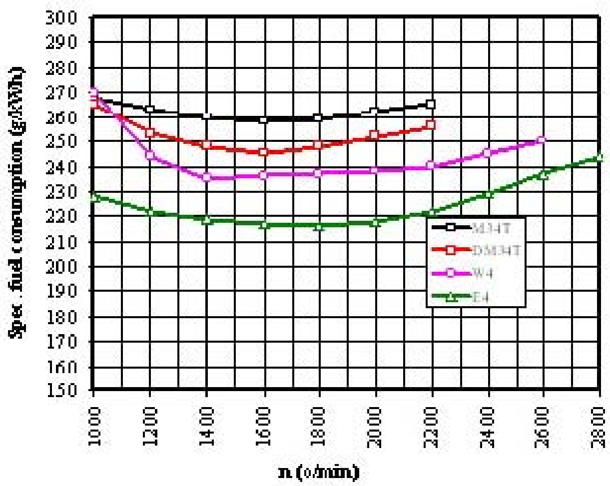

Figure 7: *Specific fuel consumption of four-cylinder tractors diesel engines older and newer design*

From figure 7 it can be noted that the engine M34/T with indirect injection (older design) has approx. 6% higher fuel consumption vs. DM34/T direct injection engine also older design. However if considering load regimes adapted to the minimum fuel consumption pole (Fig.5a/b) it can be seen that the disposition and size of pole of DI engines fit much better to engine exploitation condition as important tendency of modern designed tractor diesel engines. That means, in condition of engine exploitation i.e. tractor, during the basic works, the disposition of point of min. fuel consumption can influence to absolute i.e. fuel consumption per hour which can be considerably lower comparing to one or more discrete points calculated during the laboratory testing.

It is well known that tractor diesel engines in most working operations required operating regime of 1400 rev/min to 1600 rev/min and load of 65% to 80% as it is at the same time the region of min. DI fuel consumption.

Analyzing the fuel consumption in that manner, the savings can be higher, to 15%.

Related to modern design engines (W4 and E4) the fuel consumption of M34/T engine is considerably larger for approx. 9% and 18% respectively.

Comparing direct injection engines older (DM34/T) and newer design (W4 and E 4) it can be seen that engine W4 has approx. 4% lower specific fuel consumption while engine E4 has approx. 12% lower specific effective fuel consumption related to DM34/T engine. These differences are mainly results of different injection equipment, injection pressure, distribution systems, compression ratio etc. This point out that on the tractor diesel engines of older design must be applied design solutions, which will improve the efficiency related to national long-term interests as well as necessity to fulfill Europeans fuel consumption and emission regulations.

Must be emphasized, but it not shown on figure 7, that the modern design engines, W4 and E4, have considerably higher power per unit displacement related to older design engines,

thus pointing out to development of modern designed engines – increasing power per unit displacement and at the same time decreasing the specific fuel consumption.

CONCLUSIONS

Based on obtained results the following conclusions may by make:

1. Older designed tractor's direct injected diesel engines -DM 34/T have approx. 6% lower specific fuel consumption related indirect injected engines M34/T.
2. Modern European tractor's diesel engines W4 and E4 have approx. 4% and 12% respectively,lower specific fuel consumption related to DM34/T older designed engine.
3. Modern European tractor's diesel engines W4 have approx. 9% higher max. power, approx. 12% smaller swept volume, approx. 10% higher compression ratio, approx. 33% higher injection pressure and approx. 20% higher power per unit displacement related to DM34/T older designed engines.
4. Modern European tractor's diesel engines E4 have approx. 6% max. power, approx. 9% smaller swept volume, approx. 15% higher compression ratio, and approx. 9% higher power per unit displacement related to DM34/T older designed engine.
5. Approaching European's fuel consumption regulations it is necessary to apply technological solutions on older designed engines in order to improve theirs energy efficiency.

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