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THE FLEXIBILITY OF THE HIGH POWER COMBUSTION ENGINES

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Summary. The purpose of the article was to describe the flexibility of high power combustion engines used in lorries, which can also be very well applied in farm tractors. This parameter (flexibility of engine) proved very important because it depended to a large extent on the torque of the engine. Engines with torque in low rotational speed scope displayed higher flexibility. This publication has been focused on the flexibility of Polish Diesel engines as well as the engines produced by other companies: SCANIA, VOLVO, MAN and DAF.

Key words: combustion engines, flexibility of engine, engine torque, engine power

INTRODUCTION

The engine flexibility is a very significant parameter. It influences traction properties of a vehicle. In case of the flexibility of the lorry engines these properties are of particular importance. Some of these properties have their application as well while considering the farm tractors. The uphill driving capacity or ability to accelerate is of significance at farming works. It is also important to achieve possibly constant torque within the lowest rotational speed range which also affects the engine flexibility.

ENGINE FLEXIBILITY

The *engine flexibility* is an engine's automatic capacity to adapt to the varying loads. This is a product of the torque flexibility (e_{td}) and the flexibility of rpm (rotational speed) (e_n).

$$e = e_{td} \cdot e_n. \tag{1}$$

The *torque flexibility* is the ratio of the maximum torque (M_{max}) to the torque at the engine rated power (M_{eN}).

$$e_{td} = \frac{M_{max}}{M_{eN}}. \tag{2}$$

The *flexibility of the rotational speed (rpm)* is the ratio of the rated rpm (n_N) to the rotational speed of the maximum torque (n_M). This is alternatively referred to as the extent of the rotational speed (rpm).

$$e_n = \frac{n_N}{n_M}. \tag{3}$$

The individual parameters of the engine such as rated rpm, maximum torque rpm and the maximum torque and the torque at the engine rated power can be taken from the engine's external characteristics (Fig. 1).

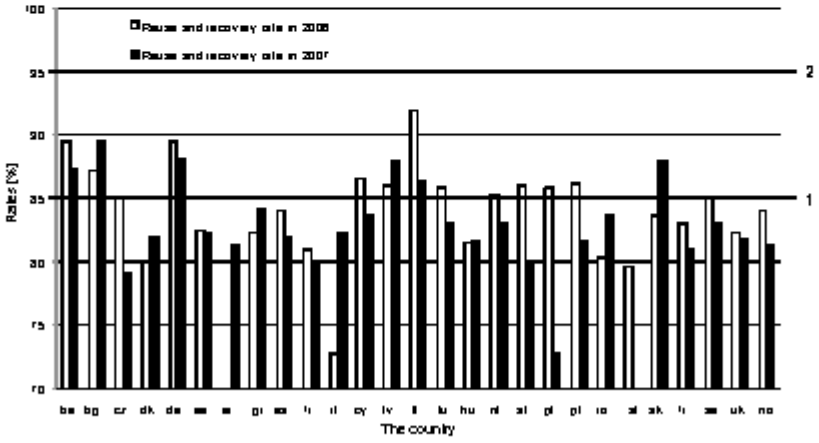

Fig. 1. The external characteristics of an engine (obr/min=rpm)

For the determination of the engine flexibility one needs to calculate the value of the flexibility coefficient. The engine flexibility coefficient takes values in compliance with [1].

THE HIGH POWER COMBUSTION ENGINES

The article presents 5 types of high power engines: home-produced engines as well as engines made by the companies like: SCANIA, VOLVO, MAN and DAF.

The Polish Diesel Engines

The home-produced engines are those manufactured by the 3 companies:

- *The engines of PZL-Mielec make* (SW680/1, SW680/17, SWT11/345 and SWT11/345/1) – six-in-line engines, liquid cooled, with direct injection to the toroidal combustion chamber. The engine displacement for these engines amounts to 11.1 dm^3, and the power – depending on the adjustment from 147 up to 192 kW. Apart from the first of the above-mentioned types, they are all turbocharged.

- *The engines of WEW Andoria make*, four and six cylinder, multipurpose, liquid cooled. The majority of these are engines with the direct injection, except the engines marked

as 4C90 and 4CT90, where the Ricardo Comet Mark VB turbulent chamber has been applied. The power outputs of these engines are within 51.5 up to 125 kW.

- *The engines of FSC Starachowice make*, six-cylinder, liquid cooled and developed basing on the 359 engine, with direct injection to the toroidal chamber in piston bottom, the power of these engines being within 110 up to 133 kW [2].

The flexibility of these engines has been presented in Table 1 and Fig. 2.

Table 1. Flexibility of Polish Diesel engines

Lp.	Engine	eM	en	E
1	SW680/1	1,107	1,571	1,740
2	SW680/17	1,200	1,571	1,885
3	SWT11/345	1,227	1,570	1,926
4	SWT11/345/1	1,205	1,570	1,892
5	4C90	1,233	1,750	2,158
6	4CT90	1,180	1,708	2,015
7	SW266	1,106	1,600	1,770
8	4CT107	1,222	1,625	1,986
9	6C107	1,171	1,733	2,029
10	6CT107-2	1,273	1,733	2,206
11	Star 359	1,128	1,555	1,754
12	R6D	1,114	1,555	1,732
13	T359E	1,318	1,714	2,259
14	T359M	1,198	1,714	2,053
	Average	1,192	1,641	1,958

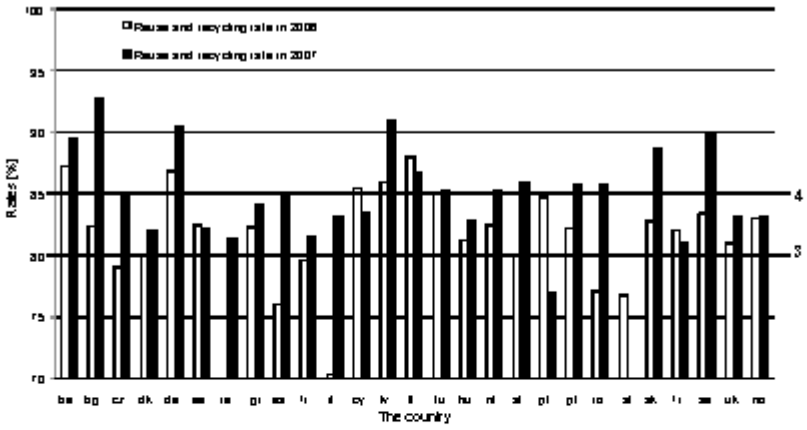

Fig. 2. Flexibility of Polish Diesel Engines

SCANIA Engines

The renown Swedish lorry manufacturer applies in the engines chiefly the direct fuel injection. Generally, they are the in-line engines, liquid cooled, provided with turbocharging and charging air cooling. Owing to the modernisation of the fuel and air supply system, all these engines meet the standards of the exhaust gas emission EURO-2, EURO-3 and EURO-4. The scope of the effective power of these engines amounts from 160 (220) up to 390 kW (530 HP). The values of the flexibility coefficient for these engines are as stated in Table 2 and Fig. 3 [3].

Table 2. Flexibility of SCANIA engines

Lp.	Engine	e_M	e_n	E
1	DSC 14-15	1,177	1,727	2,033
2	DSC 14-13	1,172	1,727	2,024
3	DSC 9-12	1,293	1,538	1,989
4	DSC 11-79	1,263	1,538	1,942
5	DSC 9-11	1,298	1,481	1,922
6	DSC 9-13	1,239	1,538	1,906
7	DSC 12-02	1,249	1,461	1,825
8	DSC 12-01	1,224	1,461	1,788
9	DC 1203	1,352	1,810	2,446
10	DC9 16 230	1,171	1,636	1,915
11	DC9 17 270	1,189	1,636	1,946
12	DT12 12 420	1,352	1,727	2,334
13	DC1104	1,278	1,727	2,208
	Average	1,250	1,616	2,021

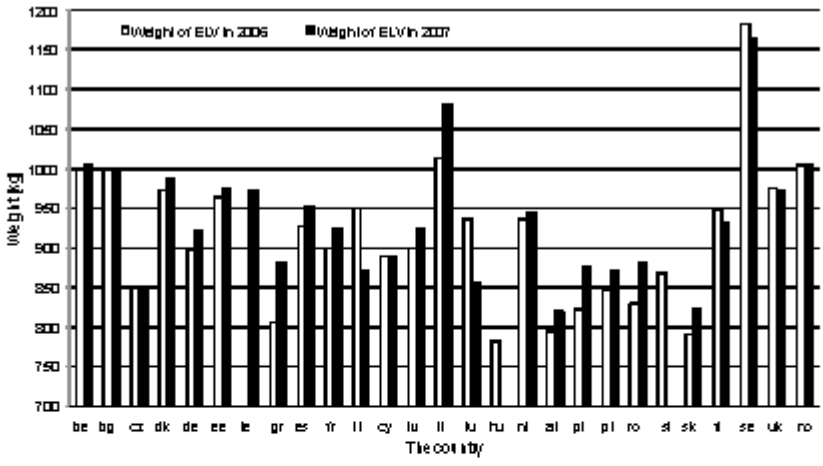

Fig. 3. Flexibility of SCANIA engines

VOLVO Engines

This concern uses for the propulsion of the lorries and buses the four-stroke Diesel engines which are liquid cooled. They are six-in-line engines, with the electronically controlled direct injection, turbocharged with the charging air cooling system. The basic for the Volvo lorries of FH series are the engines of the displacement values: 5.48 dm^3, 9.603 dm^3, 12 dm^3 and 16 dm^3 [3]. FU12 engines have a different injector construction (pump-injector). This is activated by the main camshaft, and the injection pressure is significantly higher than that encountered in the conventional injectors [2].

Further down, Table 3 and Fig. 4 show the data related to the VOLVO engines flexibility. These are all turbocharged engines with the charging air cooling system – apart from TD 61GC engine without charging air cooling.

Table 3. Flexibility of VOLVO engines

Lp.	Engine	e_M	e_n	e
1	TD 61F	1,195	1,75	2,091
2	TD 63E	1,134	1,857	2,106
3	TD 63ES	1,236	1,666	2,059
4	TD 61GC	1,22	1,473	1,797
5	DH 10A	1,22	1,818	2,218
6	DH 10A-285	1,196	1,379	1,649
7	TD 122FH	1,176	1,583	1,862
8	TD 122FL	1,227	1,708	2,096
9	TD 123E	1,214	1,583	1,922
10	TD 123ES	1,224	1,708	2,091
11	D12C	1,152	1,545	1,780
12	D16C610	1,175	1,800	2,115
	Average	1,197	1,656	1,982

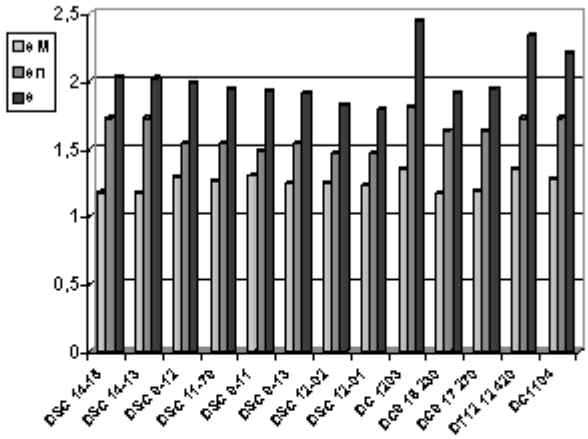

Fig. 4. Flexibility of VOLVO engines

MAN Engines

This factory produces engines with direct injection, in fact its modification known also as M injection system (production of combustible mixture) has been developed and patented by Siegfried Maurer [2]. MAN constructions aim at the development of an engine of the so called "constant power" while they fulfil the requirements related to exhaust gas purity provided for by the standards EURO-2, EURO-3, EURO-4 and EURO-5, accordingly. Further, in Table 4 and Fig. 5, the flexibility of these engines is presented.

Table 4. Flexibility of MAN engines

Lp.	Engine	e_M	e_n	E
1	EURO2 290	1,180	2,000	2,360
2	EURO2 340	1,250	2,000	2,500
3	EURO2 400	1,236	2,000	2,472
4	EURO2 460	1,239	2,000	2,478
5	D 824 LFL 10	1,365	2,000	2,730
6	D 824 LFL 09	1,278	1,500	1,917
7	D 0824 LFL 09	1,300	1,714	2,228
8	D2066 LF04	1,352	1,900	2,569
9	D2066 LF03	1,354	1,900	2,573
10	D2066 LF02	1,317	1,900	2,501
11	D2066 LF01	1,322	1,900	2,511
12	D0836 LFL	1,254	1,917	2,403
13	D2676 LF	1,296	1,727	2,238
14	D2066 LF	1,289	1,900	2,449
Average		1,288	1,883	2,424

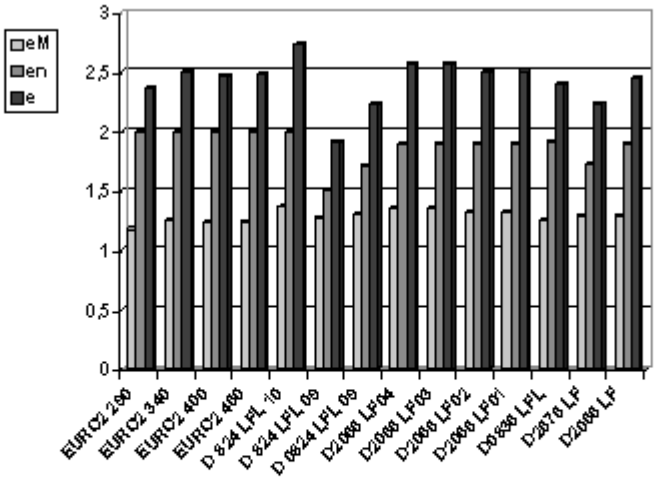

Fig. 5. Flexibility of MAN engines

DAF Engines

Owing to PACCAR MX 12,9.1 engine, utilising the SCR DeNOx technology, the XF105 lorries satisfy the requirements of EURO-4 and EURO-5 standards as far as exhaust gas emission is concerned.

MX engine ensures excellent results and low fuel consumption. The displacement of the engine amounts to 12.9 dm^3. It is available in three versions: XF105.410, XF105.460 and XF105.510 of power ranging from 410 HP (305 kW) up to 510 HP (380 kW), of tremendous torque, 2 000 and 2 500 Nm, adequately. This is a six-cylinder Diesel engine, turbocharged with the charging air cooling system, fitted with 24 valves (4 valves per cylinder) [3].

Table 5 and Fig. 6 demonstrate the flexibility of the modern engines of this factory (XF105 series) as well as their predecessors of 95XF series.

These are six-in-line engines, liquid cooled, turbocharged with the charging air cooling system. Each cylinder is provided with four valves, the displacement amounting to 12.6 dm^3 and the power is varied subject to the charging degree, amounting to 280, 315 and 355 kW, respectively. The good combustion quality has been achieved through the application of very high injection pressure of 125 MPa [2].

Besides the flexibility of the engines series XF95 and XF105 the Table 5 shows also the flexibility of XE280C engine used in the CF 85.380 truck-tractor.

Table 5. Flexibility of DAF engines

Lp.	Engine	e_M	e_n	e
1	DAF XF 280M	1,308	1,818	2,378
2	DAF XF 315M	1,262	1,905	2,404
3	DAF XF 355M	1,208	2,000	2,416
4	DAF XE 390C	1,198	1,727	2,069
5	DAF XE 280 C	1,243	1,267	1,574
6	DAF XF105.410	1,047	1,500	1,570
7	DAF XF105.460	1,062	1,500	1,593
8	DAF XF105.510	1,047	1,500	1,570
	Average	1,172	1,652	1,947

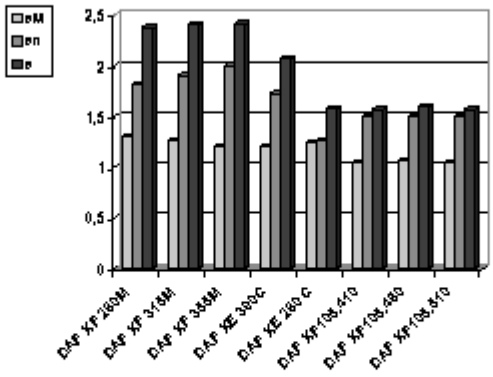

Fig.6. Flexibility of DAF engines

CONCLUSIONS

According to [1] the engines of the Polish make as well as those produced by VOLVO and DAF are low flexibility engines whereas those produced by SCANIA and MAN belong to medium flexible engines. The average flexibility of the engines discussed in this paper amounts to 2.066. The most flexible engines amongst those presented here are the ones made by MAN. Their average flexibility is by 17.3% higher than the average for all engines, and in case of the MAN D 824 LFL 10 engine (E=2.730, en=2) this is as much as 32%. The torque appears within the lower rotational speeds, rpm (good value of en). This is a significant advantage that promotes the application of these engines in lorries as well as in agriculture. This would allow not only for better traction properties, but also quicker reaching of the constant torque, reduction in the fuel consumption by the tractors, less exhaust gas and, in consequence, more economical and environmentally-friendlier performance.

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ELASTYCZNOŚĆ SILNIKÓW SPALINOWYCH DUŻEJ MOCY

Streszczenie. Celem artykułu było przedstawienie elastyczności silników spalinowych dużej mocy wykorzystywanych w samochodach ciężarowych, które z powodzeniem mogłyby zostać zastosowane w ciągnikach rolniczych. Parametr ten (elastyczność silnika) okazał się bardzo istotnym, ponieważ zależał w dużej mierze od momentu obrotowego. Silniki z momentem obrotowym w zakresie niskich prędkości obrotowych cechowały się większą elastycznością. W publikacji zaprezentowano elastyczność silników krajowej produkcji oraz firm: SCANIA, VOLVO, MAN i DAF.

Słowa kluczowe: silniki spalinowe, elastyczność silnika, moment obrotowy, moc