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The flexibility of compression-ignition engines of scania trucks

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Summary. This paper presents an analysis of the improvement of flexibility coefficient of Scania engines designed for driving heavy goods vehicles. Linear trend was determined for the flexibility coefficient of present-day engines against the older generation ones.

Key words: engine, flexibility.

INTRODUCTION

The steady increase in the number of motor vehicles moving on public roads poses specific threats for the environment surrounding us. It is generally accepted in most discussions that vehicle's engine is the most unfavourable unit in it due to its adverse environmental effects.

The ongoing difficulties with fuels and energy trigger continuous searches for new energy carriers and entail attempts to reduce energy consumption [7,8,9].

The requirements set for present-day engines are frequently antagonistic, which is clearly visible when the ever-increasing number of motor cars and traffic difficulties connected with this, and on the other hand the necessity of reducing the quantity of consumed fuel and exhaust gases being expelled into environment, are taken into account. However, to ensure adequate truck dynamics requires larger and larger flexibility of their engines and application of appropriate drive train ratios [1]. The improvement of engine flexibility itself can bring significant results, the evidence of which should be considerations being quoted above. It is apparent that the method of feeding air and fuel to an engine may help improve engine flexibility The results presented below refer basically to the improvement of air feeding to engines [3].

FLEXIBILITY EVALUATION OF SCANIA ENGINES

Total flexibility of combustion engine is a product of torque flexibility and rotational speed flexibility (rotational speed range) according to the formula presented below.

A numeric expression of engine flexibility is flexibility coefficient. It may be determined, among others, on the basis of engine's external characteristics [1,6,10] in a manner given below:

$$E = e_M e_n = \frac{M_{o\max}}{M_N} \frac{n_N}{n_{Mo\max}}, \qquad (1)$$

where: e_M – torque range (torque flexibility),
e_n – rotational speed range,
M_{omax} – maximum engine torque,
M_N – torque corresponding to rated power,
n_{Momax} – rotational speed of maximum torque,
n_N -– rated rotational speed.

The first part of the above product presents torque range (torque flexibility) and it depends on the course of engine's torque curve. This course depends on a number of factors, such as characteristic parameters of intake system, timing gear characteristics and feed system characteristics. By changing these parameters, the course of torque curve may be altered towards a user-desired direction so that the engine would be well adapted to performed tasks. The manner in which the flexibility and torque improvement is being implemented depends on performance abilities and profitability analysis of a given solution in case of specific engine.

When it comes to the possibilities of changing the second part of the above product, they are closely related to modification of its first part, consisting in the shift of torque curve maximum position. The range of rotational speed depends on the position of this maximum and it is possible to control effectively the engine flexibility by changing it.

Analysis of the flexibility of engines of Scania trucks [4] over the last 10 years was carried out dividing these engines into 5-year-long periods of their operation, starting with the 90s of the last century. Comparison of the flexibility of the oldest engines is presented in Table 1.

Table 1. Flexibility of older generation Scania engines [1,4,6]

No.	Engine	e_M	e_n	E
1.	Scania D 8	1.158	1.600	1.852
2.	Scania DS 8 tb	1.143	1.600	1.828
3.	Scania D 11	1.172	1.833	2.148
4.	Scania DS 11 tb	1.004	1.571	1.577
5.	Scania 112	1.154	1.600	1.846
6.	Scania 112 M Tb	1.192	1.600	1.907
7.	Scania 142 M Tb	1.110	1.520	1.687
	Average	1.133	1.617	1.832

Explanations: tb – turbocharged engines

It clearly appears from the analysis of Table 1 that Scania turbocharged engines have worse dynamic properties when compared to unsupercharged engines. Average value of the flexibility coefficient of turbocharged engines amounted to 1.749, with 1.948 for unsupercharged engines, and was lower by 11.5%. This was the time of common introduction of turbo-supercharging which was not brought to perfection as it is at present. Next stage of the improvement of dynamic properties in Scania Company was common introduction of turbo-charging in the engines designed for driving heavy goods vehicles. This was primarily determined by economic reasons but simultaneously turbo-supercharging system was improved so that dynamic properties of engines increased in the manner being presented in Table 2 below.

Table 2. Flexibility of newer generation Scania engines [6,13]

No.	Engine	e_M	e_n	E
1.	Scania DSC 9 - 11	1.298	1.481	1.922
2.	Scania DSC 9 - 12	1.293	1.538	1.988
3.	Scania DSC 9 - 13	1.239	1.538	1.905
4.	Scania DSC 11 - 79	1.263	1.538	1.942
5.	Scania DSC 12 - 01	1.224	1.461	1.788
6.	Scania DSC 12 - 02	1.249	1.461	1.824
7.	Scania DSC 14 - 13	1.172	1.727	2.024
8.	Scania DSC 14 - 15	1.177	1.727	2.033
	Average	1.239	1.558	1.928

All the engines being described in Table 2 are turbocharged. Increase in the flexibility coefficient by 5% was mainly obtained through the increase of torque flexibility by 9.3%, i.e. by improving the charging system since the torque range coefficient decreased by 3.6% in relation to the engines being described in Table 1. This shows a clear-cut consistency of manufacturer in improving the applied method of engine charging, which greatly diverged [5,11].

Next Scania engines had much higher flexibility coefficients, which is presented in Table 3.

As in Table 2, all the engines described in Table 3 are turbocharged.

As far as flexibility is concerned, an increase was obtained from 1.835 (Tab. 1) to 2.253 (Tab. 3), i.e. by 22.9 %. This was obtained by increasing the torque flexibility and expanding rotational speed range (rotational speed flexibility). The flexibility of rotational speed increased by 7.2% in relation to the engines being described in Table 1, whereas the torque flexibility by 15.2.

Table 3. Flexibility of the latest generation Scania engines [13]

No.	Engine	e_M	e_n	E
1.	Scania TD 06 470	1.268	1.727	2.190
2.	Scania DC 11 D1 340	1.281	1.636	2.096
3.	Scania D12 D 279	1.300	1.817	2.363
4.	Scania D12 D 309	1.299	1.818	2.362
5.	Scania D12 D 338	1.291	1.636	2.113
6.	Scania D12 D 368	1.399	1.727	2.417
7.	Scania TD 12 12 420	1.347	1.794	2.327
8.	Scania DC 16 18 560	1.303	1.727	2.251
9.	Scania DC 16 21 620	1.308	1.727	2.260
10.	Scania DC 17 19 620	1.308	1.727	2.260
	Average	1.305	1.733	2.253

Comparison of the flexibility changes during twelve years is presented in Figure 1 [2,12].

Sequence numbers on the X axis correspond to engine numbers in respective tables, whereas symbols El1, El2, El3 represent respective tables.

Analysis of the trend line (linear trend, marked with a thick straight line) in Fig. 1 clearly indicates a downward trend for the first group of engines (decrease from 1.9 to 1.7), which resulted from their construction properties and rather poorly developed turbo-supercharging system. The improvement of this charging system resulted in an upward trend (trend line El2 in Figure 1, with an increase from 1.9 to 1.95). A small decrease may be noticed in

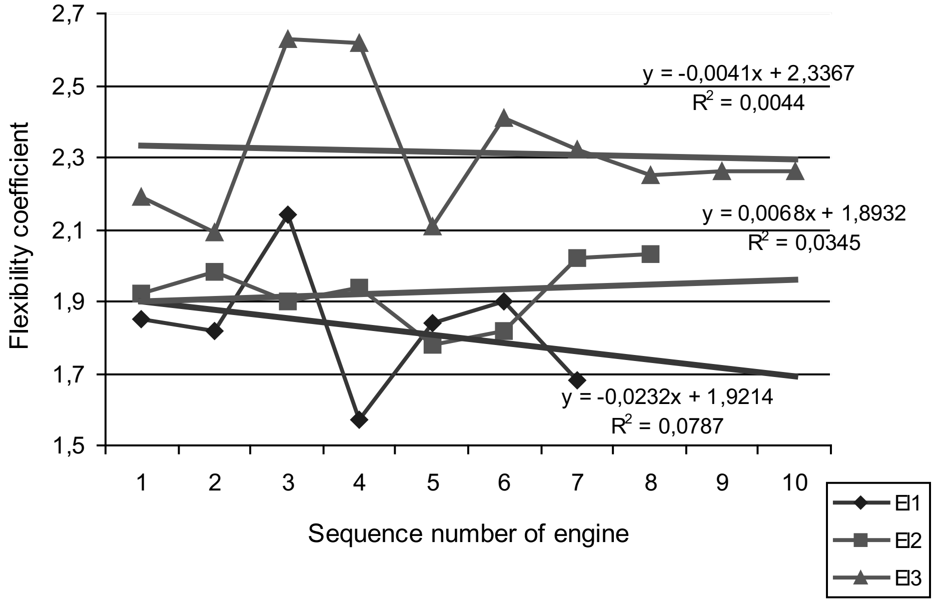

Fig. 1. Comparison of the flexibility of Scania engines under discussion

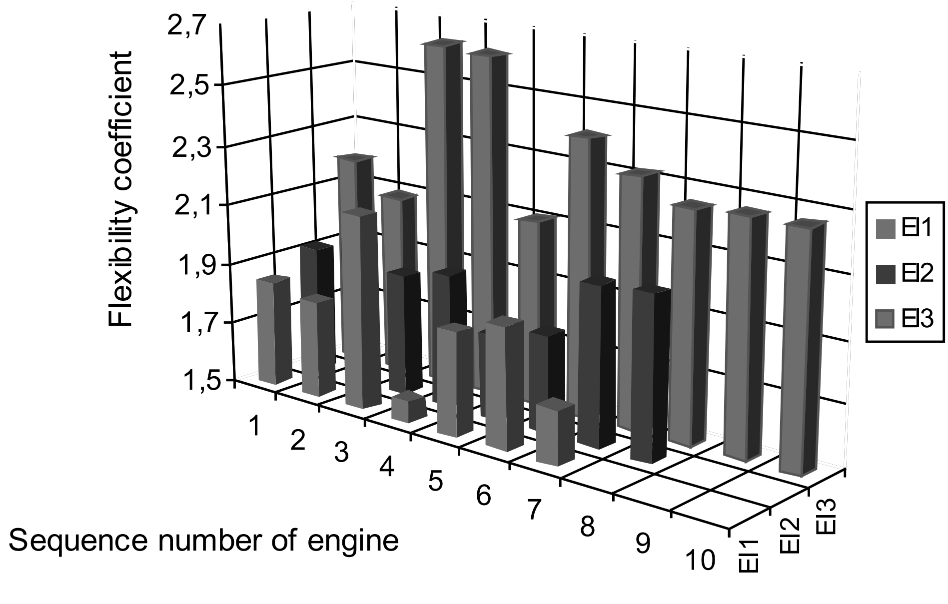

Fig. 2. Comparison of the flexibility coefficients of Scania engines as 3D column graph

flexibility in present-day engines (from 2.32 to 2.3) but the obtained flexibility values are higher by 18% to 26% than in case of the older generation engines. These results are more readable in the column graph presented in Figure 2.

CONCLUSIONS

The discussion presented in this paper allows for seeing how refinement of the feed systems and carburation in compression-ignition engines with tangential intake duct may affect the improvement of engine dynamic properties [11]. Similar trends will probably occur in engines with swirl intake duct (drallkanal) but their effects should be examined in the same way.

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ELASTYCZNOŚĆ SILNIKÓW O ZAPŁONIE SAMOCZYNNYM SAMOCHODÓW SCANIA

S t r e s z c z e n i e . W pracy przedstawiono analizę poprawy współczynnika elastyczności silników Scania przeznaczonych do napędu samochodów ciężarowych o dużej ładowności. Wyznaczono trend liniowy dla współczynnika elastyczności współczesnych silników na tle silników starszej generacji.

S ł o w a k l u c z o w e : Silnik, elastyczność.