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OPTIMISATION OF JOINT OPERATION OF PRESSURE WAVES COMPRESSORS OF TYPE COMPREX WITH DIESEL ENGINES

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Abstract: *Optimisation of the joint operation of Comprex unit with Diesel engine can be achieved by driving the compressor with a variable speed independent of engine's one. In this paper we present some of the results obtained from experimental research of a Diesel engine supercharged with a Comprex unit driven by an electric motor. For each of the Diesel engine's operating modes (speed and load), with Comprex being driven sequentially with 4-5 speeds, the optimum driving speed was determined for Comprex so that Diesel engine will provide an appropriate behavior regarding environmental and energy aspects, the evaluation criteria being, in this case, the specific fuel consumption and the smoke emission.*

Key words: *Comprex, supercharger, optimisation, fuel consumption, pollution.*

1. Introduction

This paper, taking into account the current concerns of manufacturers of internal combustion engines for automotives which simultaneously target: improved ecological parameters and improved performance while maintaining the torque and power performances, aims, in this context, to identify experimentally the optimal conditions of the joint operation of the engine with the supercharge unit.

Given that the sensitive point of Diesel engine research and development is the improvement of processes of forming and burning the mixture in the cylinder, considerable efforts have been made in the new generation of Diesel engines to improve the injection systems, using electronic management - simple or combined - of some of its characteristic parameters. Achieving this goal was made possible by the use of flexible systems, capable to generate the optimal injection rate at any operating point on the engine's cartogram, with an appropriate advance and multiple injections, making it possible to obtain a good compromise between ecological parameters and fuel consumption [1].

As increasing the flexibility of fuel injection system, by modulating the injection, has brought important energy and environmental benefits, we appreciate that the increase of the supercharge system's flexibility degree, through continuous variation of the filling coefficient according with the engine's operating mode (speed and load), will also lead to improved energy and ecological parameters of Diesel engines.

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Thus, we consider that both supercharge and injection systems should be developed interconnected and in parallel, in order to continue to ensure a permanent improvement of environmental and energy performance of the new generations of Diesel engines.

2. Description of the Supercharge System

An accessible way, and of interest, to increase the flexibility of the supercharge system, in order to obtain a continuous variation of the filling factor for achieving an appropriate value for it in any operating point on the Diesel engine's cartogram, is the supercharge with the help of pressure waves compressors of type Comprex (Figure 1). This efficient method of supercharging, besides being suited by its specificity to this tendency to increase the flexibility degree of the supercharge process, also presents a great potential for development.

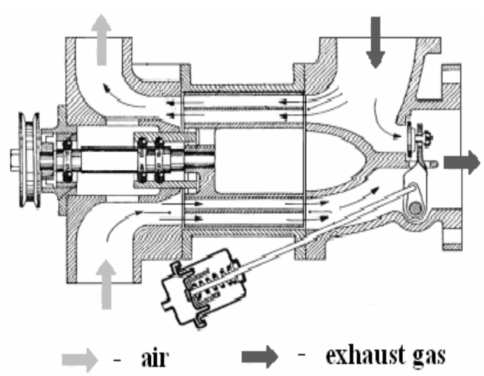

Fig. 1. *Compressor with pressure waves of type Comprex* [5]

In this type of supercharge, the compression of fresh air is achieved through exhaust gases, the operating principle being based on phenomena that occur when two fluids with different pressures (exhaust and intake air) make direct contact, the pressure equalization of the two fluids taking place in a shorter amount of time than the one needed by their mixture [2], [4] (Figure 2).

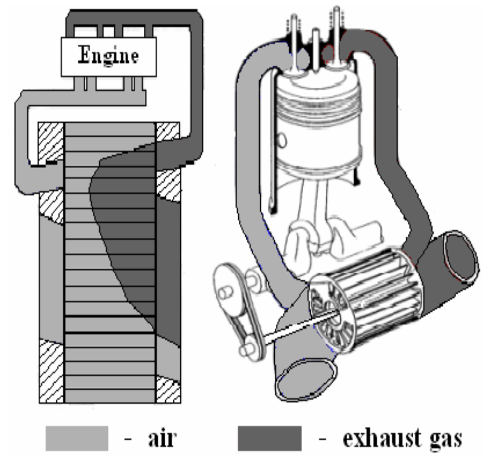

Fig. 2. *Operating principle of compressor with pressure waves of type Comprex* [8]

Because the driving of the pressure wave supercharge unit is made by the crankshaft through a belt, meaning that the unit of type Comprex is driven with a speed proportional with the engine's one, this supercharge system presents a major drawback that consists in the difficulty of its adjustment with the Diesel engine's operating conditions. To optimise the operation of Comprex with Diesel engine on its entire range of speed and load, the supercharge aggregate requires auxiliary equipments to provide an effective control over the dynamic phenomena within the rotor [3], [6], [7].

In this context, the adopted solution is to drive Comprex with a variable speed, independent of the supercharged engine's own speed, through an electric motor, solution that provides a very good flexibility and control over the supercharging aggregate's speed at any Diesel engine's speed and load, thus realising the adjustment of the filling factor at each operating mode (speed and load).

3. Aspects of Experimental Research

The experimental research on the test bench, held in the Engine Testing Laboratory of the Faculty of Mechanical Engineering, *Transilvania* University of Braşov, was made using the Romanian-made engine 392 L4 DT (Table 1) with direct injection, equipped with the turbocharger option offered by manufacturer.

Table 1

General characteristics of the turbosupercharged engine 392 L4 DT

Stroke number	4	
Number of cylinders	4, in line, vertical	
Stroke	S = 120	[mm]
Bore	B = 102	[mm]
S/B	1.17	[–]
Compression ratio	17.5	[–]
Engine capacity	3922	[cm^3]
Maximum power/speed	80/2600	[kW/rpm]
Maximum torque/speed	325/1600	[Nm/rpm]
Minimum specific consumption/speed	212/2000	[g/kWh]/[rpm]
Type injector	KBEL-BOSCH	
Sections of injection	4	

The whole system under experimental investigation was properly instrumented with sensors, transducers and equipments specific to the testing stand, ensuring the required precision, of finesse, of experimental research.

As shown in Figures 3 and 4, the 392 L4 DT engine had the turbocharger replaced by an aggregate of type Comprex, driven by a three-phase electric motor acted by a frequency converter that allowed the adjustment of the driving speed in order to identify the adequate value for each experimentally investigated operation mode.

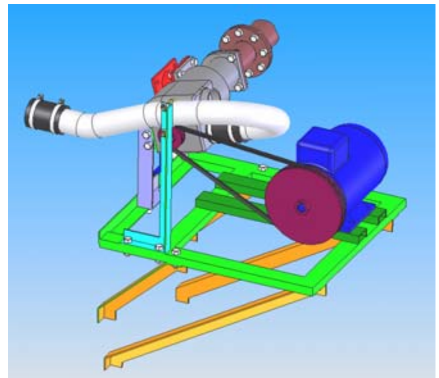

Fig. 3. *The adaptation and training system of Comprex with 392 L4 DT engine*

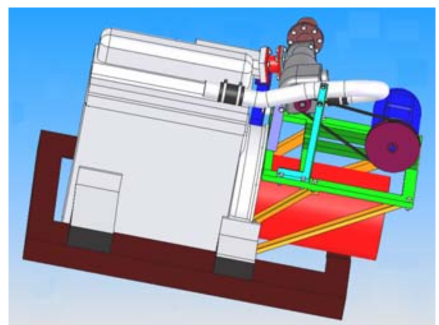

Fig. 4. *Placement of the adaptation and training system of Comprex on the engine's 392 L4 DT*

The DF-51 frequency converter (Figure 5) undertook the task of converting data and commands received from the user to corresponding operation sequences of the three-phased engine.

Fig. 5. *The DF-51 frequency converter*

This driving solution for Comprex unit was adopted because it presents similar results with the only driving option functioning on automotives (with DC electric motor), but at much lower manufacturing costs.

Experimental investigations on the testing stand of 392 L4 DT engine, supercharged with aggregate of type Comprex driven with variable speed independent of Diesel engine, (Figure 6) consisted in detecting the speed values at which Comprex must be driven so that the engine will have an appropriate behaviour regarding environmental and energy aspects, evaluation criteria being, in this case, the specific fuel consumption and smoke emission. In each experimentally investigated operating regime (speed; load) of the 392 L4 DT engine, Comprex was sequentially acted with 4-5 driving speeds, thus resulting about 100 measurement series of the parameters of interest.

Fig. 6. *Engine 392 L4 DT equipped with aggregate of type Comprex, mounted on the test bench*

As an example, for several operating modes (speed and load) which were experimentally investigated, the evolution of the two parameters mentioned above was represented graphically in Figures 7a-f, depending on the driving speed of Comprex. In these figures, the braking load applied to Diesel engine by the testing stand's brake was noted with *F*.

The analysis of Figures 7a-f shows that with increasing of Comprex's speed, the specific fuel consumption is - in general - on a descending trend, regime except examined in Figure 7e, where evolution is oscillating. This evolution is a direct consequence of driving the speed's Comprex whose value is not optimized operating regimes (speed; load) of 392 L4 DT engine. In the case emission of smoke, this is not substantially influenced by it, noting, however, a tendency of decrease with the Comprex speed's increase.

In operating modes for which the minimum values of the above mentioned parameters do not correspond to the same value of Comprex's driving speed, the optimum speed is considered the one for which the most impressive reduction of one of the parameters is obtained.

Another aspect of interest in Diesel engine's supercharging field is the power consumption or, more precisely, the drop of energy performance of the engine caused by the driving of supercharging aggregate. For this reason, during the experimental investigation of the 392 L4 DT engine, supercharged with the Comprex unit driven with a speed independent of engine's one, the power consumed for Comprex's driving was measured and its value was, throughout the whole experimental investigation, at an average of 2.04% of the engine's own power, which is a frequently accepted value for such type of supercharge.

The value of power consumed for Comprex's driving was found to be inversely proportional to the value of engine's load, due to the windows within Comprex's stators which are oriented in such a way as to give a positive moment to rotor, thus reducing the power consumption for its own driving, based on the quantity of air/exhaust gas processed by aggregate.

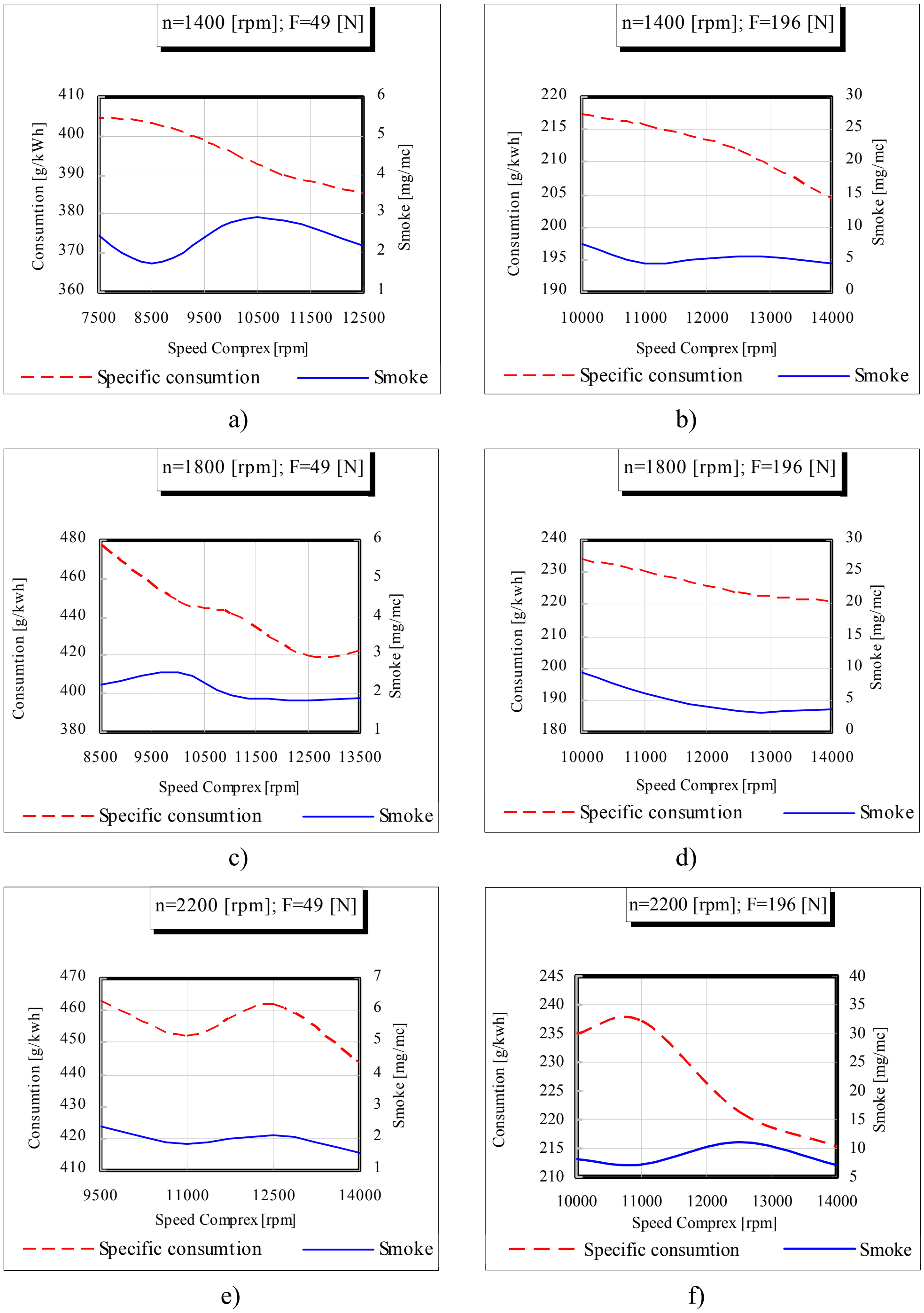

Fig. 7. *Evolution of the values of specific consumption and smoke emission, depending on Comprex's speed, during different operating regimes (speed* - n; *load* - F) *of 392 L4 DT Diesel engine*

4. Conclusions

The paper presented a simplified algorithm of experimental research conducted to optimise the joint functioning of the aggregates of type Comprex with Diesel engines. Practically, using this research algorithm for developing supercharging systems with aggregates of type Comprex, in order to improve environmental and energy performance of supercharged Diesel engines, it will be necessary, for identification of the suitable driving speeds of the Comprex unit, to take into account, as evaluation criteria, a broader range of environmental and energy parameters of the supercharged engine.

Also, it can be concluded that the best option for tuning Diesel engine with the aggregate of type Comprex consists in driving the latter one with a variable speed independent of the engine's one.

The main disadvantage of this driving type for the Comprex consists in the additional costs brought by its own speed management system.

Finally, based on the obtained results, we strongly assert that the development of supercharge systems with pressure waves will certainly result in improved ecological and energy performance of Diesel engines supercharged in this manner.

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