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EVALUATION OF SOME OF THE DEVICES FACILITATING STARTING OF DIESEL ENGINES WITH DIRECT INJECTION

Summary: The paper gives evaluation of start-up devices for high-speed diesel engines. Analysis are based on research made over the star-up of mentioned engines, which clearly distinguishes direct-injection engines.. The interferences given by the research made it possible to determine suitability of certain devices for specific type of engine.

Key words: start-up device, direct-injection engine, interference

INTRODUCTION

Starting of a diesel engine is a process consisting in delivering from outside, through the starter, the starting torque to engine's crankshaft and consisting in speeding it up to minimal engine speed, in which the compressed air in the engine's combustion chamber reaches the temperature higher than the temperature of spontaneous ignition of injected diesel oil. As a rule the process proceeds properly in temperature higher than 273 K (0°C) and no problems with starting an engine occur. In lower ambient temperatures some difficulties in executing the starting process occur, which below the starting limiting temperature for a specific engine becomes ineffective unless special treatment and facilitating devices are used [1].

The easy starting of a diesel engine in low ambient temperatures is a factor greatly influencing his operational reliability, which next to labor economics and toxicity of exhaust gases is one of the main criteria for evaluating engine's usefulness. A series of factors influence the starting features of an engine. The factors are:

– the starting dose of the fuel,
– the engine speed essential to obtain the clod start,
– the minimal time of rotating the starter,
– the quality of engine oil,
– the condition of starting installation and the charging of the battery,

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– compression ratio,
– the condition of the devices facilitating starting (spark plug, flame plug, heater);

The start-up time of a diesel engine and the rise of the first ignition, in particular, depend on the temperature in the combustion chamber and on the properties of the fuel connected with the ignition. In the engine the temperatures needed to evoke ignition depend on such factors as: the size of the starting dose, the engine speed, fuel's atomization, time needed for evaporation, mixing, reactions before ignition, pressure and configuration of the combustion chamber. Together with lowering ambient temperatures the conditions facilitating effective starting worsen.

The direct cause of this is the insufficient heating of the air combusted in the working space of the cylinder, caused by the loss of leakiness and of considerable quantity of air, taken by the cold sides of the cylinder and of the combustion chamber. That is why in the further part of the paper the devices facilitating starting, in the case of preparing the air-fuel mixture, that is direct injection, will be discussed.

DEVICES FACILITATING START-UP OF AN ENGINE WITH DIRECT INJECTION

Flame plugs are used to facilitate start-up of engines with direct injection. Those devices, as practice shows, improve engine's starting abilities to a great extent. The process of starting lasts much shorter, and the faster rise of temperature of the combustion space elements' contributes to engine's faster even course reaching, reducing the toxicity of exhaust gases and lowering fuel consumption.

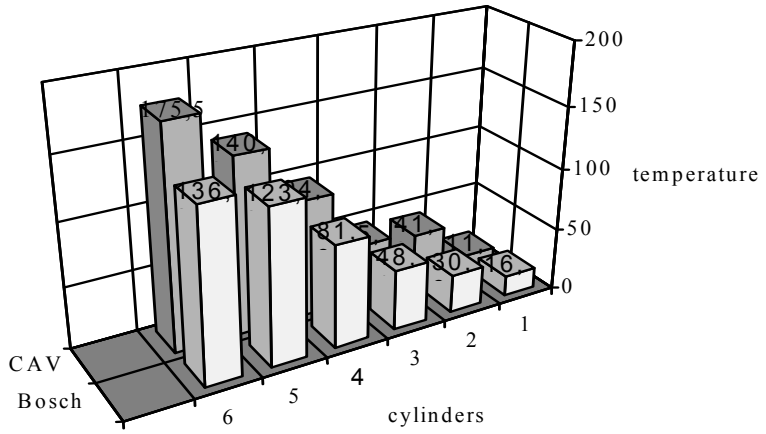

Fig. 1. Temperature of the air sucked into the cylinders with the application of Bosch and CAV-SINTEROM flame plugs

They are completely inefficient in the case of chamber engines because e.g. in the case of the engine 338 (S-530) the starting could not be obtained with the application of CAV 12V plug type NPDES even in the temperature of -10°C.

The way of flame plugs operating consists in creating open flame in the inlet collector from the burnt, specially passed over fuel. The fuel supplied to the flame plug from the injection pump heats up, evaporates and catches fire from its fibre glow. After turning on the starter the engine sucks in the air going through the flame zone and heated from it. The main advantage of this solution is the minor consumption of electric energy with the simultaneous possibility of ensuring great quantity of heat. The disadvantage is the consumption of oxygen from the air cargo supplied to the engine and the contamination of the inlet system with the products of burning. The preliminary research concerned the comparison of the flame plugs' operating effectiveness of two known companies, that is Bosch and CAV-SINTEROM, and the results have been presented on Fig. 1.

It is clearly visible, that the temperature of the air sucked-in to cylinders 6 and 5 greatly surpasses the temperature of the air sucked-in by cylinders 2 and 1, which results from the placing of plugs in the inlet line (in the area of the 6^{th} cylinder) [3]. The proper starting is facilitated by cylinder 6 and 5, what is enough for a multi-cylinder engine to take on independent work and greatly increases its effectiveness.

As it follows from picture 1 the effectiveness of heating the air by the plugs CAV-SINTEROM is much higher and that is why they were chosen for the engines 359 produced by ESC Starachowice. In this case the temperatures were adequately higher by 28.4% in cylinder 6, and by 13.5% in cylinder 5. In the case of CAV flame plugs the temperature of the heated air flowing into the 6^{th} cylinder amounts to 175.5°C, and into the 5^{th} cylinder amounts to 136.7°C. This makes it possible, without any difficulties, to obtain theoretical temperature after compression of air in the cylinder, essential for starting an engine powered by diesel oil, which is 220°C (493 K).

SEARCHING FOR THE START-UP PROPERTIES OF THE 359 ENGINE WITH THE APPLICATION OF CAV–SINTEROM PLUGS

The plug of CAV–SINTEROM Company is a device of simple construction, powered by diesel oil from injection pump. It facilitates starting up to the temperature of -20°C (253 K).

It is activated by the driver through the pressing of appropriate switch**,** directly before the proper starting. The fuel powering the plug is taken from the fall container of 25 cm^3 capacity and the falling height of 10–25 cm. The container supplements automatically with fresh fuel from the feeding system (fuel injection pump).

The plug consists of the glow trunk placed in the frame connected by the thread with the inlet pipe. The sleeve–shaped trunk of the plug is screwed into the engine's inlet commutator. In the trunk there is a heating coil, which warms up with the closure of electric circuit. Fuel from the container is passed through the accelerator pump delivery ball valve directly onto coil, where it undergoes ignition. The heating element of the plug is placed in the perforated metal cover. When the plug is not enclosed, the ball of the valve is hold in the seat through the tappet joined with it and running along the heating coil. After turning on the circuit the coil through heating and lengthening causes the ball of the valve to go away from the seat through the centre bolt of the tappet and the inflow of the fuel follows. The breaking of the plug operating follows after disconnection of the

heating coil electric circuit. The coil is quickly cooled by the stream of air sucked-in and flowing round. It contracts and the supply of the fuel through the ball valve is broken.

In order to turn on the engine, first the flame plug should be turned on for a time of 15-20 seconds, and only then the starter should be turned on. Flame plugs CAV-SINTEROM are designed for operating at the voltage of 12 V or 24 V. Nominal current consumption is 18 A at 12 volt supply or 7.5 A at 24 volt supply.

Engine's 359 starting effectiveness with the application of flame plugs is presented in the table 1 and on Fig. 2.

Table 1. Starting the 359 engine with the application of flame plus [3]

Flame	Ambient	Starting	Engine	Plug heating time		Engine Oil
Plug type	Temperature [°C]	Time [s]	Speed [min^{-1}]	before starting [s]	after starting [s]	Applied
CAV	-10.0	1.5	not specif.	15	20	SAE-10W/30
12VN	-15.0	16.0	110±5	15	24	SAE-10W/30
PDES	-20.0	22.0	112±5	15	35	SAE-5W/20
CAV	-10.0	1.5	not specif.	15	18	SAE-10W/30
12V27	-15.0	2.5	110±5	15	25	SAE-10W/30
PDES	-20.0	8.0	112±5	15	34	SAE-5W/20

The flame plugs presented in the table differed in spiral wire section, N had a circular section and 27 a rectangular section.

The starting time of the 359 engine (direct injection, designed for Star cars and derivatives) with the application of flame plugs decreased form 75 s to 2.5 s, that is thirty times, and it was an immediate starting in the temperature of -15.0 °C, so in the temperature close to the natural starting limiting temperature of this engine. The starting cycle with the application of CAV flame plugs consisted of 15 s plug heating, and then 10 s of rotating the starter.

As it is clearly visible from the upper given examples, flame plugs are an effective means improving starting abilities of the engine with direct injection.

The next problem remained the considerable difference in operating effectiveness of the same flame plug depending on the applied spiral wire section. From the data quoted in table 1 and Fig. 2 it can be clearly seen, that plugs with the rectangular wire section were considerably more effective. It turned out that in the case of circular or rectangular wire the wire's diameter or the dimension of the square's side, the same as diameter, were assumed for the basic dimension. With the same length of the spiral the area which gives away heat to the surrounding is considerably bigger in the case of the rectangular wire. It can be illustrated with a simple example for a wire of nominal dimension 1.5 mm and of 100 mm length.

As you can see from this example in the case of a wire with rectangular section the area which gives away heat to the surrounding (heats up the air in the cylinder) is by 27.3% bigger and hence the higher effectiveness of flame plugs CAV-SINTEROM. The start-up properties are not directly proportional to this structural feature of CAV-SINTEROM flame plugs, because ,as it was mentioned before, the properties depend on

a number of factors, nevertheless it gives some idea about the complexity of the phenomenon.

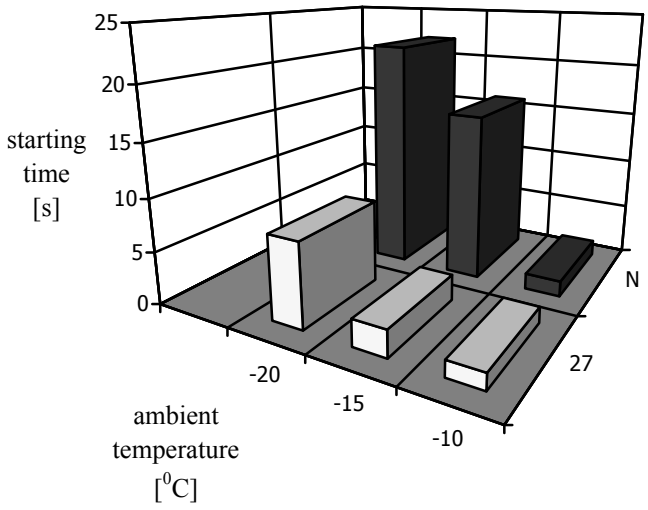

Fig.2. Starting the 359 engine with the application of flame plugs;
NPDES – circular wire 27PDES – rectangular wire

	wire of circular section	wire of rectangular section
section's circumference	$\pi D = 3.14 \cdot 1.5 = 4{,}71$ mm	$4\ D = 4 \cdot 1.5 = 6$ mm
heating area	$P = 4.71 \cdot 100 = 471$ mm^2	$P = 6 \cdot 100 = 600$ mm^2

Therefore, by the selection of a device facilitating starting one should be very careful and bear in mind various implications resulting from the applied solution. The upper mentioned difference of heating area, which equals 27.3%, gives a shortened starting time in the temperature of -20^{0}C by 2.75 times that is by 63.3 %, however in the temperature of -15^{0}C by 6.4 times that is by 84,4%.

CONCLUSION

The upper presented results of research clearly indicate advantages coming from the application of flame plugs in facilitating starting of diesel engines with direct injection, not to mention the environmental side of the issue. It is known that the starting time and the engine's heating up time are the stages most harmful to the environment; therefore their shortening is by all means desired.

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