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ANALYSIS OF DAMAGE OF SELECTED ELEMENTS OF THE INJECTION SYSTEM OF MARINE DIESEL ENGINES

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Abstract

The injection system of a marine diesel engine is one of the most important functional systems, but it also belongs to the most failure prone. This article presents chosen damage of main elements of the injection equipment. The causes of their failures and characteristic effects connected with their wear have been discussed. Problems encountered by ship crews in reference to injection system failures have been considered.

Keywords: *fuel injection system, injector, fuel injection pump, marine diesel engine*

1. Introduction

In the case of marine diesel engines there are tendencies to turning to residual fuels of worse and worse quality, with a high content of impurities. Impurities are one of the main factors influencing states of decreased reliability of injection equipment, causing the wear of its elements and in consequence, they decide on its durability and longevity.

Studies show, that failures of injection equipment are also to a great extent caused by worse quality atomizers and "non-original" spare parts for injecting pumps or injectors (longevity of these elements is almost by half shorter than it is the case for the original ones). However, the most important is bad quality fuel, which is the main cause of maintenance problems at operation of injection pumps, injectors and fuel filters.

2. Chosen failures of the injection system

During the studies carried out by the author of this paper, faulty operation of brand new atomizers occurred (after the ship owner had changed its spare part supplier) which was caused by a badly made atomizer well. It can consequently lead to a change of pressure under the needle and damage the atomizer itself (Fig.1).

Another example of atomizer damage, very dangerous to the engine, which the author of this paper encountered, is breakaway of a whole part of the atomizer body – the needle guide (Fig. 2). It is an example of using very bad quality fuel.

a) b)

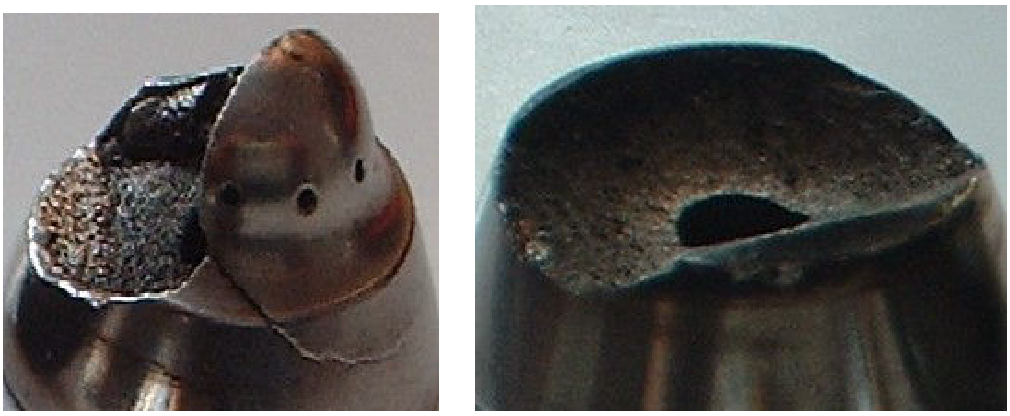

Fig. 1. Partial (fig. a) and total (fig. b) breakaway of the atomizer nipple

Change of thermal conditions of atomizer operation, caused damage in the structure of the atomizer body material and as a result its cracking. At first the effect of this failure is usually damage of piston crown (Fig. 3), and later the damage of the whole piston – rod - crank system together with the engine body. Using improper quality of fuel (with too high viscosity) together with the wear of the seat - atomizer needle cone system causing a change of pressure under the needle lead to a failure of an atomizer of one of the engines manufactured by Caterpillar (Fig. 4)

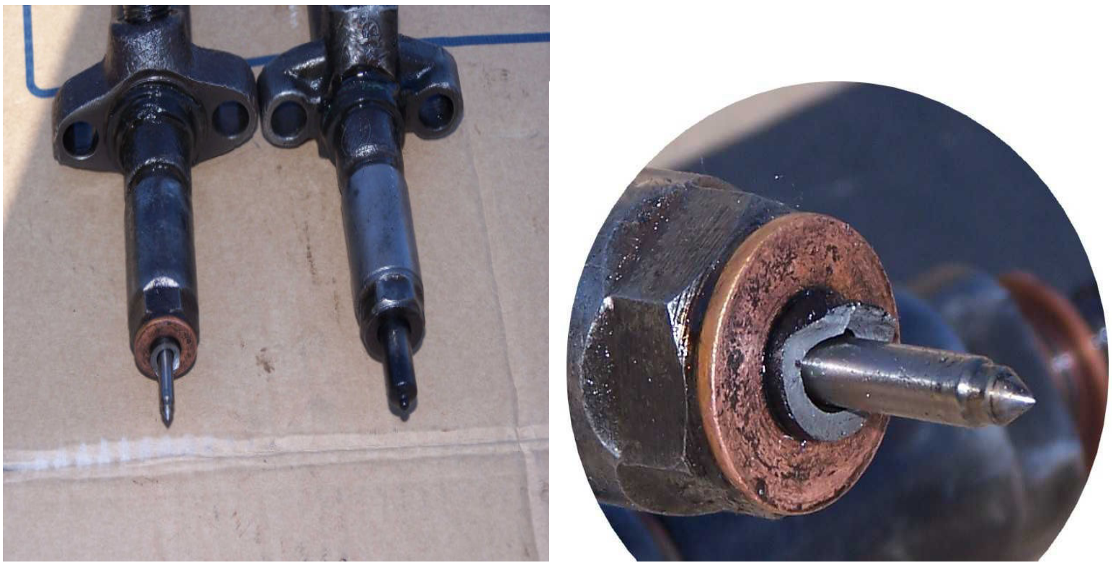

Fig. 2. An example of damage (breakaway) of a part of the atomizer body caused by the improper quality of fuel

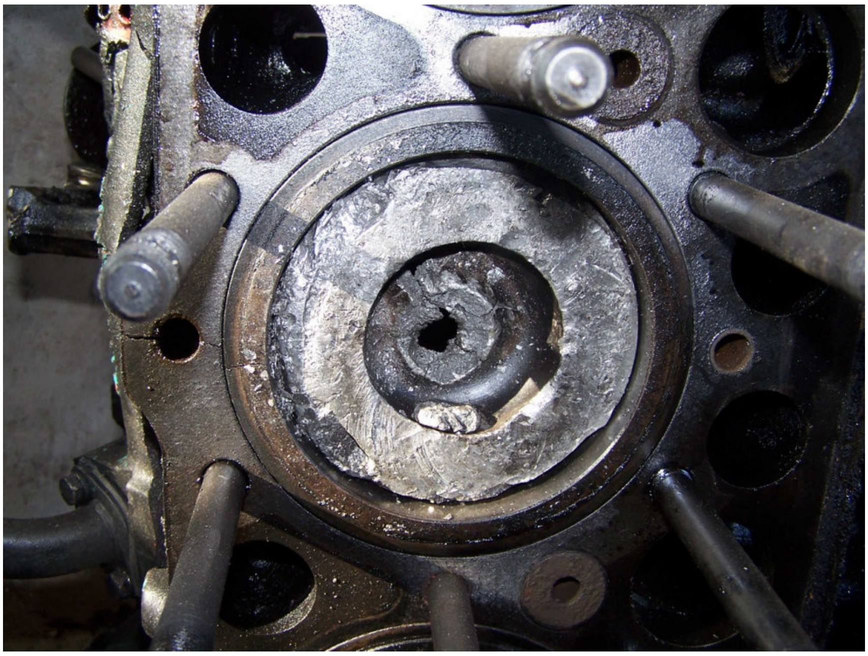

Fig. 3. Damage of the piston and engine body being the result of the breakaway of the lower part of the atomizer body (from Fig. 2)

Fig. 4. A view of the damaged atomizer in a an injector pump of the Caterpillar engine

Interesting wear which the author had a chance to consider was the damage of directional multi-hole fuel atomizers of the Sulzer RTA 58 engine. After a relatively short period of injector operation, atomizers of one of the systems suffered from wear visible in Fig. 6. The ship owner decided to replace the atomizer with new ones, made by renowned manufacturers, which did not, however, bring expected results.

Fig. 6. Erosion-cavity formation damage together with local overheating (scorching) of the atomizer in a Sulzer RTA 58 engine

Analysing the kind of wear and the engine operation and maintenance manual the author of this paper came to a conclusion that when fuel flows from the injector, gas turbulence appears in the combustion chamber causing erosion- cavity wear on the opposite site of the holes. Also, local overheating of the atomizer takes place. The cause of this lies in the too pronounced wear of a part of the head (fig. 7). In practice a similar effect could occur due to the crew error in the case of a too deep milling of the injector seat in the head during cleaning. It causes deeper seating of the injector and its more pronounced protruding form the combustion chamber. It is the main cause of turbulence appearance which is responsible for the cavity erosion on the surface of the atomizer.

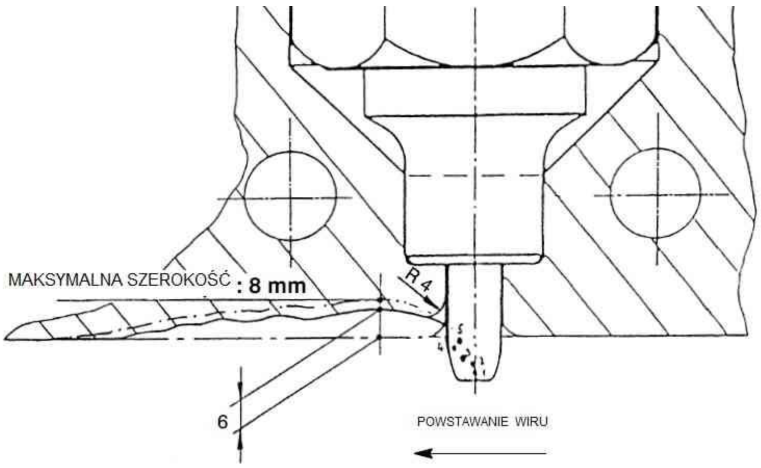

Fig. 7. A view showing the wear (scorching) of the inside part of the head of the Sultzer RTA 58 engine which causes the "cavity turbulelence" and atomizer damage as shown in Fig. 6

In the Sulzer RTA engines, very close to the lower part of the head (from the combustion chamber side) there is also a cooling duct. A decreased distance (because of the needle material scorching) between the cooling area and the combustion chamber causes much lower heat reception also from the atomizer tip itself.. In the studied case two phenomena interfered and they both lead to the studied kind of wear; cavity erosion and local overheating.

Similar overheating may also appear in the case of incorrect setting of the fuel injection commencement timing. When fuel injection comes too early (it is most often caused by an inappropriate setting of the injection pump for example after shipyard overhauls), it leads to the so-called knock combustion. Its effect is also a higher than normal maximum pressure of the combustion process.

In the case of new atomizers, the quality of fuel jet mainly depends on compression pressure (counter pressure in the combustion chamber) and the pressure under the needle in the injector. In one of the engines (Wartsila SW 280) a problem of incorrect combustion with high emissions of smoke occurred. For the crew the problem was so important that earlier they had replaced precision pairs of injection pumps with new ones, also they replaced atomizers together with the spring and they checked the supercharging pressure and all other parameters which could lead to increased emission of smoke. After preparing a developed indicator graph, it was observed that the maximum pressure had a "dual character" – there was an increase, a decrease and then another increase of pressure, this time main in character, until its maximum value was reached (Fig. 8) It is the case when an incorrectly sprayed fuel jet reached the hot surface of the cylinder barrel, initial fuel combustion took place, after which the main combustion process occurred. As it was mentioned before this effect is influenced by compression pressure and by the fuel pressure under the needle (with faultless atomizer holes). Accordingly, it was suggested that if the compression pressure was correct, just as other parameters, then probably "smoke emission" and "dual effect of the maximum pressure of the combustion process" could probably be ascribed to a faultily manufactured injector well. In fact, it turned out that the company supplying atomizers had changed its sub-supplier and thus a batch of **new** atomizers delivered onto the ship was faulty. The problem of brand new faultily manufactured parts is unfortunately becoming more frequent.

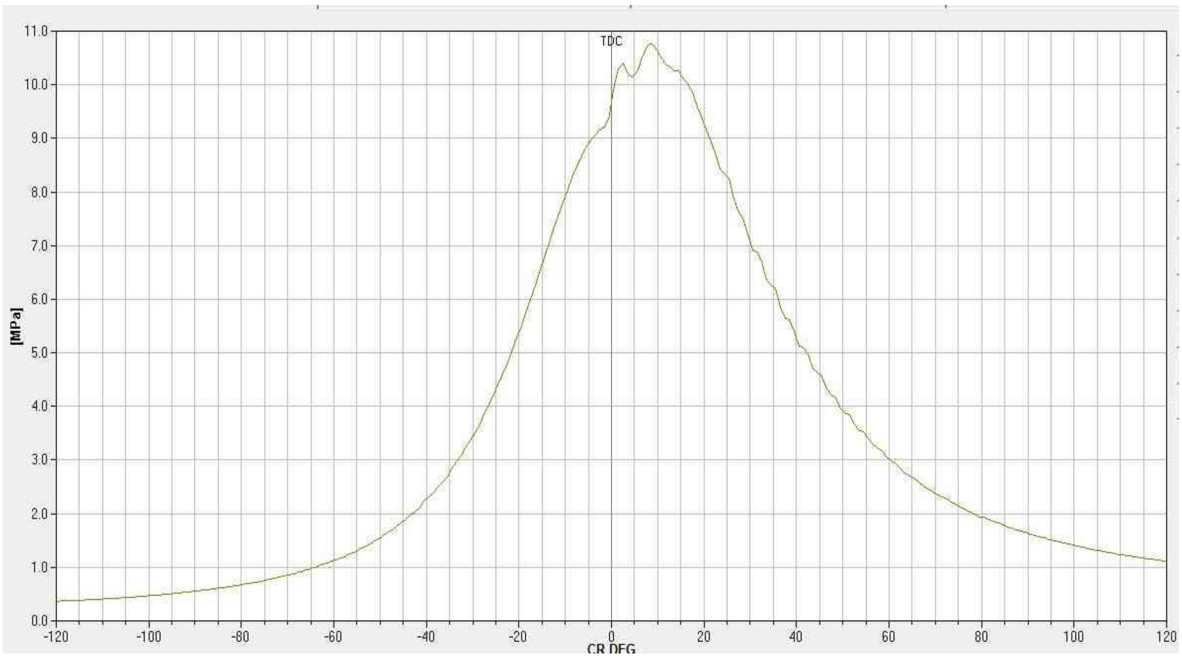

Fig. 8. A developed graph of an injection process run for a faultily manufactured atomizer well which changes the quality of fuel jet (description in the text).

Getting a correct atomization in the whole volume of the combustion chamber is possible when all the atomizer holes have equal ability of fuel flow capacity. Foul atomizer holes are the cause of far worse fuel atomization, decrease in engine power, and increase in unitary fuel consumption. The unburned fuel and carbon deposit increase the friction effects of the piston/ring in the barrel, as particles of fuel sediment on the piston and cylinder barrel, they also “wash out” the cylinder oil layer, while the coked particles of fuel directly increase the wear between the piston and the cylinder barrel. It can be concluded from the author’s own studies that the problem of equal “flow capacity” of all atomizer holes is not only the result of atomizer wear. The problem is often valid for brand new atomizers delivered onto the ship (not to mention the repaired or regenerated atomizers).

Engine smoke emission caused by the change of fuel jet was observed when performing diagnostic measurements of a marine diesel engine of the MAN D2848 type. This engine belongs to the group of the so-called “difficult to diagnose” engines. It operates in the fork-like system of cylinders and it does not have indicator taps. The problem was due to the change of pressure under the needle caused by scorching of the atomizer needle cone (Fig. 9). It was important that the scorching took place during the guarantee period (just after a short period of operation time). Again it was caused by bad quality of atomizer parts.

Figure 9 Scorched atomizer needle cones.

Typical wear of injection pump leads to erosion and cavity formation action of fuel on the overflow hole of the pump (Fig. 10).

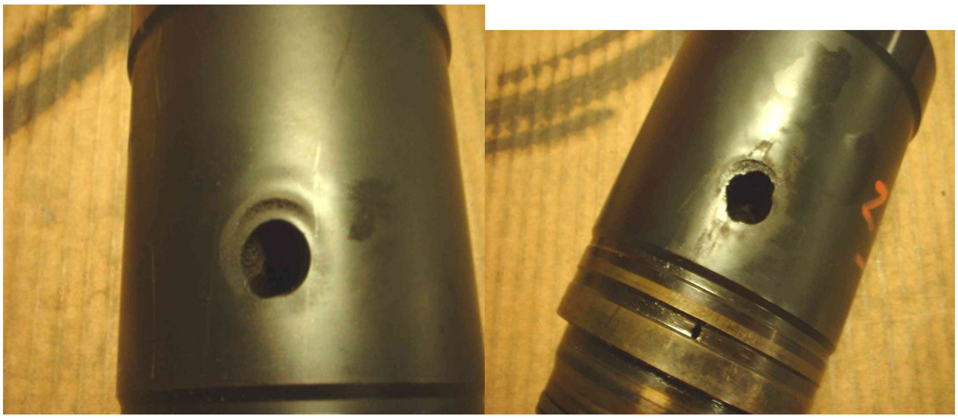

Figure10 Erosion - cavity formation of overflow hole of the injection pump cylinder

At the moment the failures caused by low quality spare parts are more common. Figure 11 shows seizing of a precision pair of an injection pump after about only four hours of operation.

Fig. 11. Seizing of a precision pair of a (new) injection pump after four hours of operation due to very low quality of manufacturing of parts (Chinese manufacturer)

Summary

In the case of elements of the marine engine injection systems, two groups of failures can be observed: the first ones are caused by bad quality fuel, the second ones- by inadequate quality of system parts. The cases analysed by the author show that renowned ship engine manufacturers, considering the economic side of purchasing new parts, more often replace their sub-suppliers with cheaper ones, endorsing the supplied parts. This is for example the case for both MAN as well as Wartsilla.

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