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Failure in Fuel Injector Nozzles Used in Diesel Engines

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Abstract: This paper aims to conduct a study of the problems associated with the wear of the needles and fuel injection nozzles utilized in diesel engines. The wear found on the needles is mainly associated to impurities in the fuel oil and microcavitation occurred due to high pressure in the phase of the air compression for combustion of the combustible fluid. These pressures associated with the temperature and the fluid velocity results in the occurrence of vaporization, which releases shock waves that cause damage to the affected surface. The impurities solid particles from the fuel oil cause problems inside the nozzles as obstruction of the holes and wear on the needle tip and nozzle seat surface. These failures affect in the atomization of the fuel, since the deterioration of the internal passages of the nozzles interferes in the spray formation and in the end passage of the fluid. For the execution of this study it will be used digital microscopic analysis in specimens that suffered damage, in order to investigate the effects of fuel property, and the temperature conditions and pressure in the formation of the wear on the needles and injector nozzle.

Key words: Fuel injector nozzle, injector needles, wear.

1. Introduction

Fuel injector nozzles consist of fuel injection system in diesel engines, where the fuel is powdered in spray form through the small holes of the nozzle. In order to comply with the exhaust emission requirements, the injection system projects are increasingly sophisticated, so that the holes are being designed smaller and smaller, in order to enhance fuel atomization [1]. Therefore, in order to know the factors that influence the wear and fatigue in the nozzle components, are studied in the cavitation and particulate deposits from fuels, factors that can influence the efficiency and adequacy of the fuel injection process.

1.1 Cavitation

When heat is supplied to a liquid at constant pressure, after a period of time, the liquid is converted into vapor, and this phenomenon is known as boiling. However, when phase shift occurs due to a pressure drop in the running liquid in constant temperature, then the phenomenon is referred as cavitation [2]. Nozzles of diesel engines typically operate with 25 MPa or higher, and these conditions are favorable for the occurrence of cavitation in the needles of the nozzles due to high pressure [3].

Cavitation erosion is liquid erosion mechanism, which refers to the nucleation and growth of cavities or bubbles on a fast flow or liquid vibration when the local pressure of the liquid falls below its vapor pressure. When the bubbles find a zone with a high pressure, they collapse and cause release of shock waves on the surface. The shocks on the surface cause localized deformation and pitting. Pits are microscopic plastic deformations from cavitation, which mainly

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progresses in depth, causing surface roughness and material removal. Damage caused by cavitation is similar to those caused by erosion of particles, but the surface formed by cavitation is surrounded by microcrateras, wide pits and grooves. The cavitation damage will eventually result in material loss and fatigue failure [3].

The formation of vapor bubbles during cavitation and increases the maximum speed in the core of the injection port, which nozzles for diesel translates to an increase in the cone angle of the fuel spray, the process of improving the mixture air -fuel. However, the cavitation also damages geometry of the fuel injection needles interfering with the formation of the spray and the passage of fluid, which increases fuel consumption [4].

1.2 Formation of Deposits

The use of vegetable oils in diesel engines produce acceptable levels of emission of pollutants when used in a short period of time, but when used over long periods is observed carbon deposits, coking (formation of coking deposits) and adherence in the nozzles. The formation of deposit blocks the holes, reducing the diameter and increasing fuel consumption, since the quality of the spray is greatly changed, resulting in a decrease in engine performance [1].

The injection system comprises pistons which are self-lubricated by the fuel, which consists of an engine working fluid. If there is failure in lubrication, due to the nozzle clogging, so the components of the injection system parts will wear out by abrasion [5].

According to studies, temperatures above 300 °C as well as the presence of zinc (Zn) and copper (Cu) in the fuel at lower levels than 1 ppm can lead to coking problems in the needle nozzles. Lubricant additives in the fuel can contribute to metal uptake, especially if the additives are acids [6]. The temperature of the needles is directly linked to the problem of storage of materials, combustion arrangements and air management resulting in higher temperatures at the tip of the needle, which promotes deposits [7].

Factors such as conicity of the nozzle and the internal erosion of the hole by the fluid passage are related to cavitation. Cavitation can determine the quantity of coke to be deposited on the needle. From research, it has been found that with the increase of cavitation decreases the erosion of the inner hole and the taper nozzle formation [6]. However, needles with high efficiency with improved dimensional tolerances with a needle entry hole, the tapered holes cause reduction or elimination of cavitation within the flow needle. The deposit formation is related to fuel contaminants, combustion reactive products, soot and volatile lubricating oils [7].

The main objective is the macroscopic and microscopic investigation of the section failures in the needle and nozzle of an injection unit

2. Experimental Apparatus

It was used one injection unit in the engine brand MTU model ADEC S4000 damaged as specimen for conducting the case study. The needle and nozzle were characterized by optical macrograph using an optical microscope stereoscope brand Tecnival model SQF-F. The specimen was handled in order to prevent damage to and fracture surface. To analyze the inside of the nozzle it was used a metallographic cutter brand Arotec Arocot-40 model.

3. Experimental Results

During the analysis, it was found that the needle of the injector nozzle has excessive wear on the tip, resulting in a higher flow at the specified limit (Fig. 1). The fracture by fatigue was caused by contact under high cyclic stress of the needle tip with the internal nozzle region (Fig. 1b) [8]. The initial crack fracture was initiated by the erosive wear.

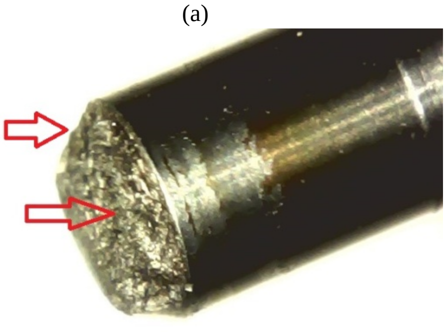
The Figs. 1a and 1b show the needle nozzle with the presence of failure caused by wear by erosion with solid particles (Fig. 2b—central region) as well as fatigue fracture (Fig. 2b—outer region). Failure by erosion with solid particles was caused by contaminated fuel [7].

It was conducted one metallographic cut in the nozzle to examine the inside of the nozzle (Figs. 2a and 2b). Fig. 2b shows the macrography of the internal region of the nozzle where occurs the limit of the needle, the arrow shows the abrasive wear under high cyclic stress caused by contact of this area with the needle tip. It is also observed a hard, dark layer that is organic deposits caused by fuel impurities [7].

Fig 2a shows the wear by erosion with solid particles located in the fuel inlet port. The cause of this wear was due to contaminated fuel [7].

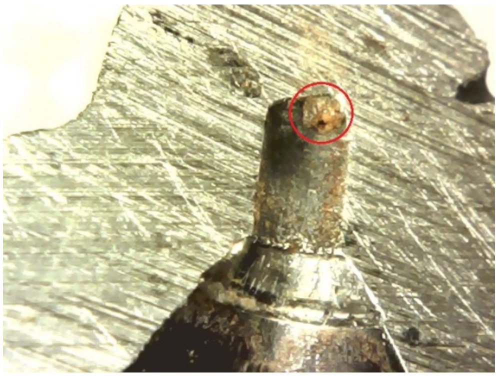
According to Fig. 2b, there was the occurrence of wear by cavitation in the inner region near the nozzle head. Cavitation occurred due to the reduction of pressure in the fuel flowing in the inner region of the nozzle. The reduction of pressure in the liquid fuel caused nucleation and growth of air bubbles that collapsed (exploded). The energy released by these

(a)

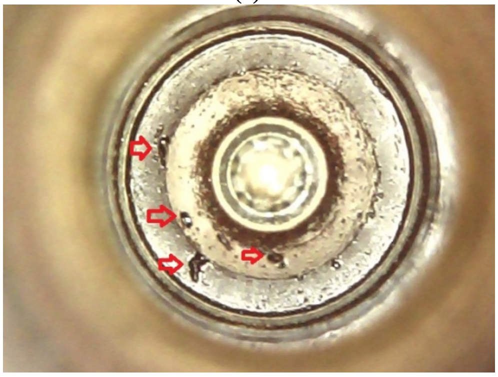


(b)

Fig. 1 (a) Macroscopic wear of the needle and (b) wear at the needle tip.



(a)



(b)

Fig. 2 Analysis microscopic wear on fuel injector nozzle (a) localized erosion wear by the oil inlet hole and (b) of the inner nozzle region with cavitation pits.

explosions promoted the impact of liquid fuel against the inner regions of the nozzle. The shock due to the impact caused the plastic deformation and material removal, resulting in failure formed as deep and rounded microcrateras called pits, as indicated by arrows in Fig. 2b.

4. Conclusions

Through the analyzes of the needle nozzle and its inner region can be seen that the wear was caused by the fuel contamination, which gave rise to wear by erosion by solid particles, abrasion at high voltage and cavitation.

Study must be done about the fuel properties, such as high viscosity, low volatility and reactivity of unsaturated hydrocarbon chains; which are related to coke deposition in the nozzles.

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References

[1] Karamangil, M. I., and Taflan, R. A. 2013. "Experimental Investigation of Effect of Corrosion on Injected Fuel Quantity and Spray Geometry in the Diesel Injection Nozzles." *Fuel* 112: 531-6.

[2] Aleiferis, P. G., Pereira, J. S., Augoye, A., Davies, T. J., Cracknell, R. F., and Richardson, D. 2010. "Effect of Fuel Temperature on In-Nozzle Cavitation and Spray Formation of Liquid Hydrocarbons and Alcohols from a Real-Size Optical Injector for Direct-Injection Spark-Ignition Engines." *International Journal of Heat and Mass Transfer* 53: 4588-606.

[3] Osman, A. 2006. "Failure of a Diesel Engine Injector Nozzle by Cavitation Damage." *Engineering Failure Analysis* 6: 1126-33.

[4] Salvador, F. J., López, J. M., Caballer, M., Alfonso, C. 2013. "Study of the Influence of the Needle Lift on the Internal Flow and Cavitation Phenomenon in Diesel Injector Nozzles by CFD Using RANS Methods." *Energy Conversion and Management* 66: 246-56.

[5] Qu, J., Truhan, J., and Blau, P. J. 2005. "Investigation of the Scuffing Characteristics of Candidate Materials for Heavy Duty Diesel Fuel Injectors." *Tribology International* 38: 381-90.

[6] Galle, J., Verhelst, S., Sierens, R., Goyos, L., Castaneda, R., Verhaege, M., Vervaeke, L., and Bastiaen, M. 2012. "Failure of Fuel Injectors in a Medium Speed Diesel Engine Operating on Bio-Oil." *Biomass and Bioenergy* 40: 27-35.

[7] Liaquat, A. M. 2013. "Impact of Palm Biodiesel Blend on Injector Deposit Formation." *Applied Energy* 111: 882-93.

[8] Yu, Z. W., and Xu, X. L. 2009. "Cracking Damage of Diesel Engine Injector Nozzles." *Engineering Failure Analysis* 16: 112-8.