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CAVITATION EROSION OF CAST IRON DIESEL ENGINE LINERS

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Summary

Photomicrographs from vibratory facility cavitation specimens and from an eroded liner of a field diesel engine are compared. The causes of erosion are similar. Corrosion tests show that the results are different from those from cavitation. This further confirms that liner erosion of a diesel engine is primarily due to cavitation erosion caused, in most cases, by vibration of the liner wall.

1. Introduction

Cavitation erosion of diesel engine wet cylinder liners is still a major problem confronting designers and users (*e.g.* refs. 1 and 2) and has been investigated by many workers (*e.g.* refs. 3 - 6). Liner damage is usually well defined and occurs primarily within a band extending from the top to the bottom of the liner on the thrust side (Fig. 1(a)). It sometimes occurs also [3] on the antithrust side (Fig. 1(b)). Figure 1 shows erosion of a chrome-plated liner (bore, 180 mm) after operation for 400 h. If allowed to go unchecked, a hole completely through the liner may result. The first worker investigating a ship's engine was forced by cavitation erosion of the liner to stop operation after only 800 h. A hole completely through the liner wall had developed, allowing mixing of cooling water with lubricating oil, causing engine failure.

Cast iron is conventionally used as diesel engine liner material. The damaged surface acquires a honeycombed appearance which is different in appearance from any corrosion surface. An investigation of both cavitation and corrosion erosion of cast iron has been completed, and a metallographical analysis of the specimens both from laboratory tests and from a field engine

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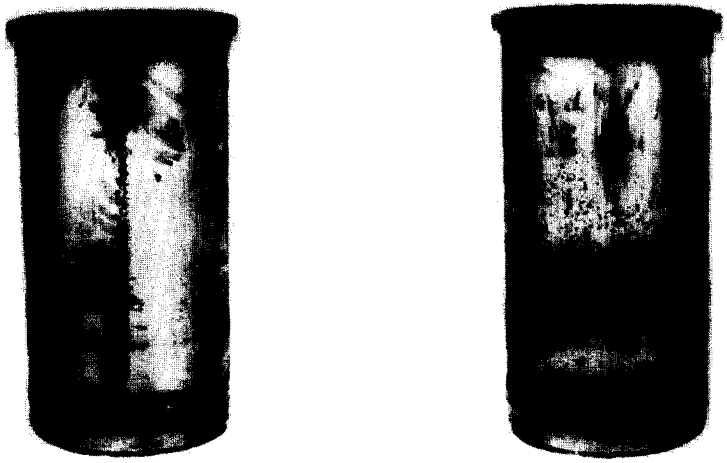


(a) (b)

Fig. 1. Cavitation damage on (a) the thrust side and (b) the antithrust side of the liner of a type 12V180 diesel engine (bore, 180 mm); the liner surface is chrome plated (hardness, 748 - 726 HV).

was made [7]. The results confirm that liner cavitation erosion in this particular engine was the result of radial vibrations of the liner wall caused presumably by piston slap under certain operating conditions. It was concluded that chemical corrosion had little effect on forming the honeycombed structure of the eroded surface.

2. Metallographic comparisons between vibratory cavitation specimens and a damaged liner

2.1. Specimen material

The test specimens were machined from the engine liner material (phosphorous cast iron) of Brinell hardness 190 - 260. The material contained less than 5% free ferrite and the graphite had a random orientation. All specimens for cavitation erosion or corrosion erosion tests were well polished before tests and had equal surface quality. Figure 2(a) shows the appearance of the specimen surface before tests.

2.2. Tests and results

2.2.1. Vibratory experiments

The vibratory experiments were performed in a magnetostrictive transducer assembly with a vibratory frequency of 15 kHz and a power supply of 100 W. The specimens were exposed to cavitation erosion for 90 min in tap water at 25 °C. The vibration amplitude (peak to peak) was about 20 μm (0.79×10^{-3} in). Figure 2(b) shows the specimen after subjection to the above vibratory cavitation environment. The honeycombed and deeply pitted

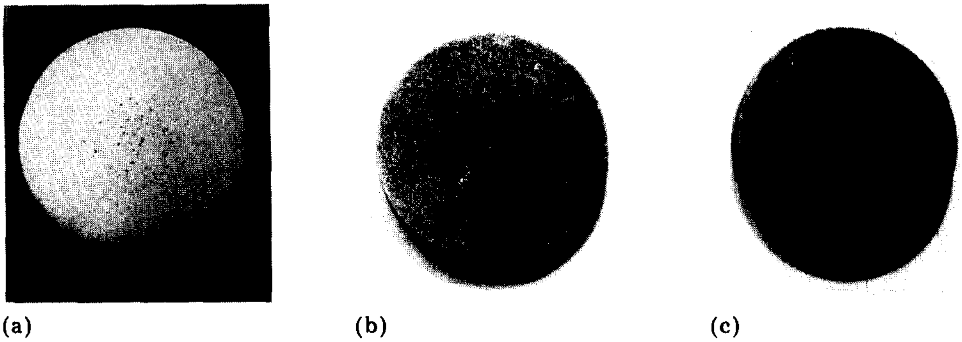

(a) (b) (c)

Fig. 2. Macrophotographs for phosphorous cast iron specimens: (a) before test; (b) after exposure for 90 min to vibratory cavitation; (c) after immersion for 30 min in 25% nitric acid.

appearance of the eroded surface is characteristic of cavitation erosion. Comparing Figs. 1 and 2, it is evident that the appearance of the damaged liner is similar to that of the vibratory specimen.

2.2.2. Corrosion experiment

A corrosion test of specimens of the same material (cast iron from the same heat) was performed along with the vibratory test to compare erosion form, appearance and metallography. In this test the specimens were immersed in a solution of 25% nitric acid at 25 °C for 30 min. The appearance of a corroded specimen from this test is shown in Fig. 2(c). Material was removed evenly from the surface, which is different from the cavitation result (Fig. 2(b)).

2.2.3. Metallography after tests

From macrophotographs (not included), the most distinctive difference between cavitation and corrosion specimens was the development of discrete pits on the cavitated surface, forming a honeycombed and deeply pitted structure, while the corrosion surface remained essentially flat but slightly roughened. Photomicrographs for both cavitation and corrosion were taken before and after the tests (Figs. 3 - 5). They were consistent with the different mechanisms for these two types of erosion, *i.e.* cavitation results from mechanical damage and corrosion from molecular chemical reactions (Figs. 4(a) and 4(c)).

The before-test photomicrographs (Fig. 3) indicate the surface microstructure of the phosphorous cast iron used. The after-test photomicrographs are from the cross section through the center of the maximum damage region (Figs. 4(a) - 4(c)). Figures 4(a) and 4(b) are from the cavitation test specimen (Fig. 2(b)) while Fig. 4(c) shows the corrosion specimen (Fig. 2(c)). The most evident difference between these (Figs. 4(a) and 4(c)) is that microcracks and their progressive development are found on the cavitated surface while metal removal is uniform for the corrosion surface.

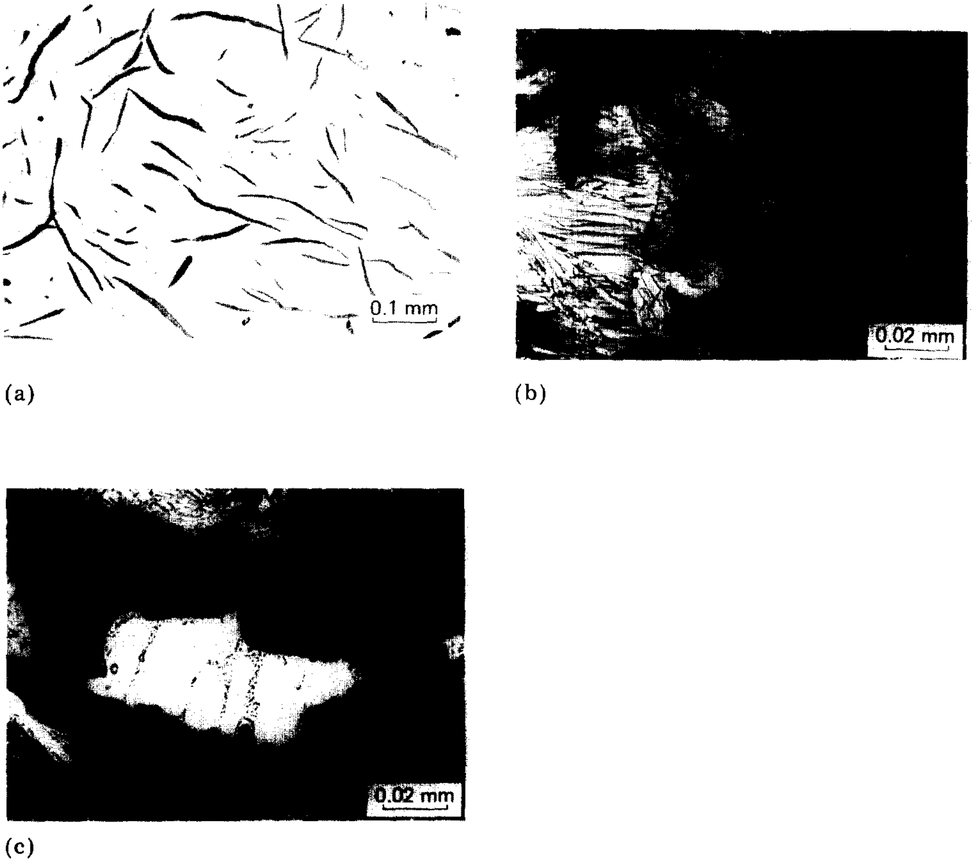


Fig. 3. Surface microstructure of the cavitation test specimens (material, phosphorous cast iron): (a) irregular orientation of flake graphite; (b) pearlite; (c) phosphide eutectic.

Figures 5(a) and 5(b) are micrographs through the damaged surface layer of a wet cylinder liner from a field diesel engine. The following points are significant.

(1) Figure 5(b) is similar to Fig. 4(a). In both cases it appears that particles of irregular shape and different sizes were eroded from both the test specimen and the liner.

(2) Cavitation erosion of the liner surface (Fig. 5(a)) develops, and extends along the graphite flakes. A network of cavities is formed apparently as graphite is broken up and removed in the initial stage of the erosion process. This is presumably due to repeated surface loading by bubble collapse. Cracks around the particles then appear so that, as the cracks further develop, metal particles are isolated and removed from the liner surface. Such metal particles are often found in the vibratory facility vessel.

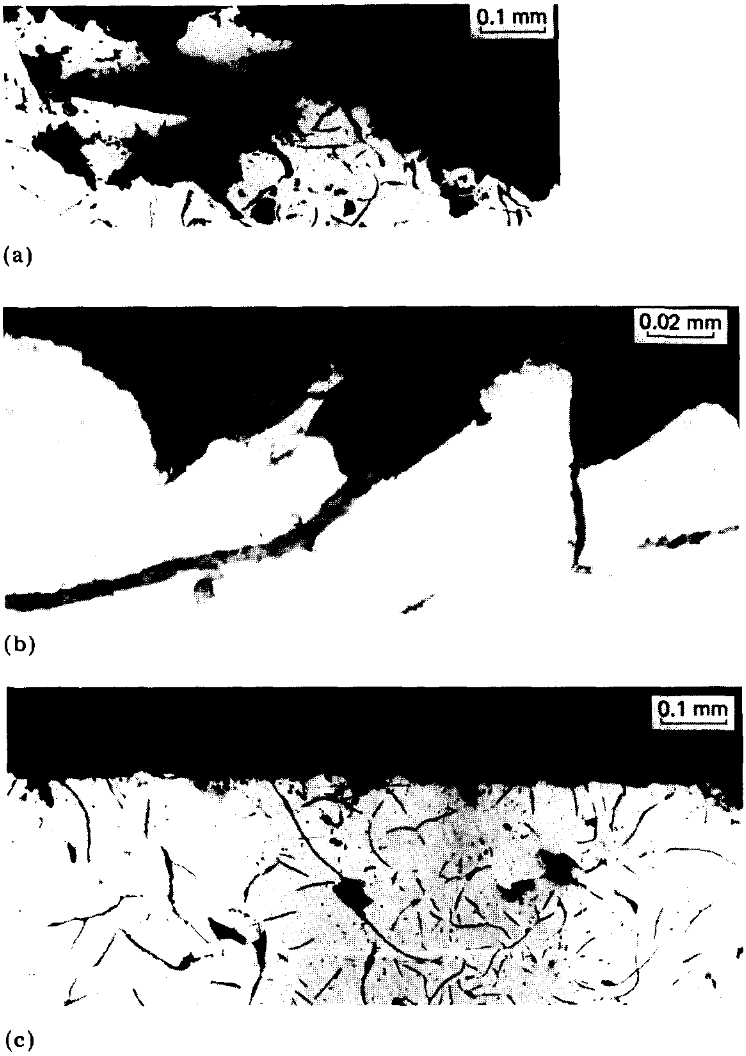


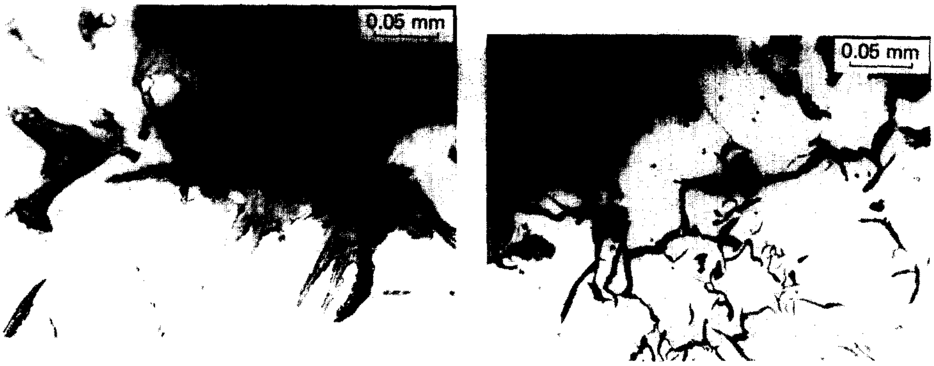
Fig. 4. Micrographs of the eroded specimens; (a), (b) cavitation damage of the specimen in Fig. 2(b); (c) corrosion of the specimen in Fig. 2(c).

3. Conclusions

The following conclusions can be drawn.

(1) It is evident that, at least in some cases, the erosion of wet cylinder liners is different to conventional corrosion, not only in the macroappearance of the eroded surface but also according to micrometallurgical examinations.

(2) With corrosion alone, material is etched relatively evenly from the exposed surface presumably in the form of molecular combinations while,



(a) (b)

Fig. 5. Micrographs of the cross section of the wet cylinder liner showing the cavitation-damaged surface layer.

for cavitation erosion, metal is removed in the form of relatively large particles.

(3) The cavitation erosion of diesel engine wet cylinder liners and that of specimens tested in a vibratory facility are similar both in surface macrophotographs and in micrographs of cross sections through the damaged regions. Thus, in some cases, diesel engine liner erosion is due primarily to cavitation bubble collapse. In most cases, cavitation is caused by vibration of the liner wall.

(4) From photomicrographs from the present erosion tests of cast iron, fatigue and fracture appear to be the main causes of the observed erosion.

Acknowledgments

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