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Temperature Dependence of Cavitation Erosion Damage Caused by Heavy-Duty Engine Coolants

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Extended Abstract

The effects of heavy-duty engine coolant temperature on its cavitation-erosion protection-capability were experimentally investigated and analyzed in combination with other coolant characteristics, such as chemical composition, vapor pressure, and the presence of inhibitors and suspended particles.

Cavitation erosion damage occur on several components of heavy-duty trucks, including cylinder liners that are kept at a desired temperature by engine coolants. These aqueous mixtures of ethylene glycol with corrosion inhibitors and other additives are formulated to prevent freezing and corrosion while providing adequate heat flow inside the engine.

Vapor pressure, chemical composition, surface tension and viscosity may affect the severity of cavitation erosion caused by a liquid medium [1, 2]. Most of these properties are temperature-dependent and understanding how this influences the cavitation protection capability is crucial in the improvement of component design and thus engine performance.

Therefore, cavitation experiments were performed to investigate the effect of temperature on the weight loss of a metal sample exposed to ultrasonically induced vibrations while immersed in a commercial coolants with 35% glycol by volume.

Testing was carried out with samples made of lamellar cast iron, taken from real cylinder liners. Coin-shaped specimens were screwed onto an ultrasonic apparatus vibrating at 20 kHz, based on the setup described for the direct method in ASTM G32. The coolant was set to temperatures of 50, 70, 76, 82 and 90 °C, and the mass loss of the samples were measured at set intervals up to 2.5 h of testing.

The results indicated that the mass loss rates of the samples were higher, the lower the temperature was. At 50, 70, 76 and 82 °C, the mass loss rates of the samples were, on average, 80%, 60%, 50% and 10% higher than at 90 °C, respectively. This inverse relationship of erosion rate and coolant temperature is expected only for a certain temperature range. It has been reported in previous studies [3] that distilled water reaches maximum cavitation erosion rates at around 70 °C, whereas temperatures close to the boiling or freezing points exhibit detectably lower rates. This implies that cavitation erosion is maximized when neither the formation of bubbles (favored by higher temperatures via a higher vapor pressure) nor their implosion (promoted at lower temperatures by the driving force for the vapor to condensate) are significantly hindered. Moreover, as reported in similar studies, so-called corrosive water, i.e. a solution of salts in water, is most aggressive at around 50 °C [4]. This does not only demonstrate the effect of the chemical composition but also indicates an interaction with the temperature. As a liquid phase stabilizer, salt shifts the temperature of maximum erosion rate. Considering ethylene glycol plays this role in the engine coolant, but to a much stronger effect, it is reasonable that it will also shift the maximum erosion towards lower temperatures. Furthermore, after a prolonged exposure to high temperatures, the coolant decomposes into, among others, glycolic acid; incidentally, experiments with used engine coolants taken from serviced trucks in operation indicated that they caused significantly less damage than their fresh counterparts [5].

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