A German Class 122 Frigate on exercises.

BY BORIS KAMCHEV

Solving a Sticky Problem

German Navy Changes Engine Oils to End Breakdowns

A decade ago, a problem both troubling and puzzling arose for the German Navy. Ships that historically had been reliable began to suffer serious engine failures without warning. Solving the problem took several years, during which more than a dozen breakdowns occurred. Eventually, a research institute in the German armed forces concluded that the problem stemmed from a change in fuel quality. The Bundeswehr Research Institute also helped end the breakdowns by recommending a switch in engine oils.

Johannes Bader, a damage analyst and application engineer in the institute's fuels, lubricants and tribology section, recounted the story in January at the Oildoc Conference in Rosenheim, Germany. He said the breakdowns started in 2004 during a time when Germany's Navy was undertaking an increasing number of missions away from its traditional areas of operation in the seas around Europe and the Atlantic Ocean.

There were no warning signs beforehand, such as an increase in temperature or crankcase pressure, Bader said, but the breakdowns followed a consistent pattern. In each case, diesel engines – usually those on frigates used to generate electricity and for backup power – experienced sudden and violent breakdowns. Upon investigation, the research institute found that piston connecting rods had been torn off their crank pins, allowing broken pieces to fly about loosely, damaging components and the engine housing until the engine came to a halt.

These accidents were expensive. A warship generator set engine weighs six tons and sits in the bed of the ship below the water line. "The average cost for an engine restoration was [U.S.] $975,000 [€760,000]," Bader told *Lubes'n'Greases* in a follow-up interview. "Because the engine is placed deep inside the ship, many components must be disassembled to lift the engine from the lower to the upper decks. The [process of changing out engines] costs $650,000 for each engine."

The Navy suffered 13 of these breakdowns between 2004 and 2009, so it is no surprise that it became a priority to find the cause and a solution. "Generally, the German Navy warships' engine components are designed for heavy-duty use and high reliability, so such technical problems occur quite seldom," said Bader, who is based in Erding, Germany.

A team of technicians and the institute's specialists launched an extensive investigation, following several tentative theories before finding where the problem began. Eventually, they determined that deposits on the piston and cylinder restricted piston movement creating enough stress for the connecting rod to break. Significantly, these deposits were sticky, not brittle.

"Complex infrared and gas-chromatography probes showed that these deposits mainly contained soot, carboxylates, sulfates, phosphates and high-boiling point hydrocarbons," Bader observed. "They can come from the fuel as well as the engine oil."

The next step was to study engine oil condition after breakdown to determine whether deposits formed as a result of lubricant deterioration or an adverse interaction with the fuel. The investigation team found that the oil was still in satisfactory condition. Their analysis also showed normal levels of iron, copper and lead, indicating that the breakdown was not the result of excessive wear of components.

At that point, Bader's team turned its attention to the fuel. In his presentation, Bader noted that these problems began after the Navy began spending more time away from Europe, as the country increased its support for United Nations and NATO missions in places such as Lebanon and East Africa and antipiracy campaigns in the Indian Ocean. When it took on these missions, the Navy recognized that marine fuels in those areas differed from fuels used in Europe. The service decided its ships would use local fuels rather than transporting European fuel.

The Navy normally uses diesel fuel that meets NATO Code F-75, which is similar to the DIN EN 590 diesel specification that prevails in the European Union, except that it is high in sulfur (450 to 900 parts per million) and is free of fatty acid methyl ester (FAME) biofuel. Away from European coasts, however, the Navy's ships are refueled with DMA category marine gas oil (MGO). The research institute conducted an assessment of MGO from the mission region in 2009 and found its mean aromatic content to be 50 percent higher than in F-75 diesel. This is important, Bader said, because aromatics have poor auto-ignition properties. Therefore, they tend to burn only partially

German naval ships suffered engine failures caused by connecting rods breaking off crank pins. Above bottom, an intact connecting rod. Above top, pieces from a broken conrod.

Photos courtesy of Bundeswehr Research Institute for Materials, Fuels and Lubricants in the combustion chamber, especially at low and high speeds, which can be typical operating conditions for genset engines. This creates soot and other components that get swept into the oil sump where they contribute to sticky deposits.

Replacing local fuels still seemed a dubious proposition, but the research institute believed the high aromatic MGO could be made more tolerable by switching engine oils. The Navy's ships had been using ACEA E2 engine oils, a specification that was the lowest quality of four categories of heavy-duty diesel engine oils when retired by the European Automobile Manufacturers' Association in 2008. At that point, ACEA deemed that evolving engine designs had made E2 obsolete for on-road applications, but oils meeting its requirements continue to be marketed for marine use.

The institute's team decided to try a new engine oil meeting ACEA E7, which is recommended for heavy-duty diesel trucks equipped with selective catalytic reduction emissions controls but not particulate filters. The institute conducted a 3,000-hour field trial with two ships, one using an E2 oil in its genset engine, the other using an E7 oil. Both engines were inspected and equipped with new cylinder liners, pistons and injection nozzles before heading to the Indian Ocean.

After completing the trial, the ships returned to Germany where the engines were disassembled and inspected. "Where the new oil was applied, the engines behaved differently," Bader said. The engine lubricated with the E7 oil had significantly lower deposits, and the deposits that it did have were hard and brittle rather than sticky. This meant that the pistons and cylinders in that engine did not stick and cause strain on the connecting rod.

The institute analyzed the two oils with infrared spectography to ascertain their chemical differences. The main differences were higher concentrations of two functional additives in the E7 oil. It contained 25 percent more succinimid, which is used as a dispersant and detergent, and 20 percent more zinc dithiophophate, an anti-wear, antioxidation and anti-corrosion agent. "Both engine oils are produced with API Group I mineral base oil," Bader said. Therefore we

Sticky deposits on piston crowns and cylinder liners restricted piston movement, creating stress that caused connecting rods to break.

concluded that better engine cleanliness is a result of the identified higher additive content."

After these findings, the Navy changed its lubrication protocols to require that ships use E7 oils instead of E2. That was the end of the engine failure problem. "Since implementation of this decision and introduction of the new oil quality in spring 2010, no further engine breakdown showing similar damage patterns occurred," Bader concluded.

Undoubtedly that has eased the minds of officials as the service continues conducting missions in distant seas. □