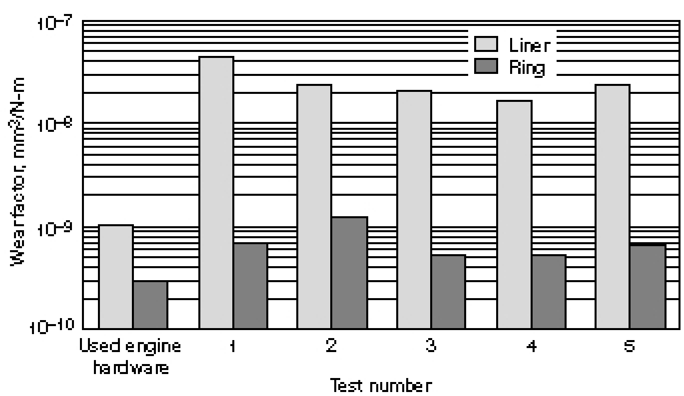
Test Method Designed to Evaluate Cylinder Liner-Piston Ring Coatings for Advanced Heat Engines

Research on advanced heat engine concepts, such as the low-heat-rejection engine, have shown the potential for increased thermal efficiency, reduced emissions, lighter weight, simpler design, and longer life in comparison to current diesel engine designs. A major obstacle in the development of a functional advanced heat engine is overcoming the problems caused by the high combustion temperatures at the piston ring/cylinder liner interface, specifically at top ring reversal (TRR). TRR is the most critical part of the engine cycle because the ring and liner undergo a majority of their wear at this location. In a conventional engine, where TRR temperatures are near 200 °C, the cylinder kit materials consist of chrome-coated piston rings and cast-iron liners. These materials usually provide adequate service for about 500,000 miles before a major overhaul is needed. The TRR temperature in an advanced heat engine; however, has been predicted to be in excess of 300 °C, with some estimates as high as 650 °C. These high temperatures preclude the use of chrome-coated rings and cast-iron liners because the extreme temperature severely degrades their wear life. Therefore, advanced cylinder liner and piston ring materials are needed that can survive under these extreme conditions.

To address this need, researchers at the NASA Lewis Research Center have designed a tribological test method to help evaluate candidate piston ring and cylinder liner materials for advanced diesel engines. The selected test method uses a commercially available, pin-on-plate, reciprocating wear test rig with specially modified specimens machined from conventional top compression piston rings and cast-iron liners. Loads, speeds, and temperatures are selected to approximate engine wear conditions present at the ring-liner interface at TRR. It is intended that this test setup be used as a screening tool to eliminate poor coating combinations before any effort is expended on costly engine tests.



Wear factor results for used engine hardware and baseline tests.

As a way to validate the test method, repeated baseline tests were run with conventional chrome-coated ring and cast-iron cylinder liner specimens, and the results were compared with used engine hardware. On both the used and test specimens, the worn areas had a smooth glossy finish, which indicated the presence of a fine polishing wear mode. In addition, wear factors, which quantify the amount of wear produced over a given time, were calculated for the used hardware and test specimens. As shown in the figure, the baseline wear factors for both specimens were very repeatable from test to test. When individual components are compared, the ring specimen wear factors are very similar to that of the used ring. The baseline liner wear factors, on the other hand, are an order of magnitude greater than for the used liner, which suggests that the test conditions with respect to the liner are more severe than actual engine experience. Since studies have shown that ring wear is of greater concern, the corroboration exhibited between the wear factors of the used ring and the ring specimen suggests that the test rig and established procedures can be used to conveniently screen material candidates for advanced heat engine applications.

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