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Tribological investigations on tribofilm formation and retention under dry sliding conditions with increasing loads

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Abstract

This paper presents a tribological investigation of austenitic steel 21-4N exhaust valve material, dry sliding against ductile cast iron GGG-40 seat material, at a temperature of 500°C, to study the effect of increasing loads on tribofilm formation and retention at the contact interface. The effect of these tribofilms, on the friction and wear behaviour of the tribo-pair, is highlighted. High temperature reciprocating pin-on-disc tests were performed on a tribometer at loads of 20 N to 50 N with a constant stroke of 2 mm and an oscillating frequency of 20 Hz. A distinct running-in behaviour is observed at loads up to 40 N with the coefficient of friction attaining a very low and stable level with increase in sliding time. The average Coefficient of Friction ranges between 0.12 and 0.15. Optical/Scanning Electron Microscope micrographs and Energy Dispersive Spectroscopy analysis indicate the creation of compact and durable tribofilms at loads up to 40 N. At the highest load of 50 N, the Coefficient of Friction behaviour is slightly different. With a low value at the beginning, it shows an increasing trend and reaches a peak around the 10-min mark and reduces thereafter. At this load, despite indications of higher abrasive wear, the Coefficient of Friction behaviour, Optical/Scanning Electron Microscope micrographs and Energy Dispersive Spectroscopy analysis indicate evidence of early deterioration and subsequent reformation of the tribofilms with increase in sliding time. The seat material exhibited comparatively more wear than the valve material; however, the wear coefficients lie in the mild wear regime for the tribo-pair. The results of this investigation indicate the compatibility of the tribo-pair and suggest its use in the exhaust valve/seat application.

Keywords

Austenitic steel, ductile cast iron, exhaust valves, tribofilm, contact load, high temperature, friction, wear

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Introduction

It has been a constant endeavour of researchers to find new ways of improving the fuel economy of internal combustion engines leading to far reaching economic and environmental impacts.[1] In such engines, efforts made to reduce frictional losses, resulting from contacts between different tribo-elements, are critical in attaining these goals. Towards achieving this end, the valve-train in engines has been at the centre of much research.[2–4] In the engine, the valve-train system is used to convert the rotational motion of the camshaft into the linear motion of the valves, whereby the working fluid flow is controlled within the combustion chamber. During the course of the combustion process, the piston rings/cylinder liner and the inlet/exhaust valves along with their corresponding seat faces help to seal the working fluid within the combustion chamber. As the exhaust stroke commences, the high temperature exhaust gases flow out through the passageway between the exhaust valves and their corresponding seat faces.[5] These high temperature gases create a harsh environment in which the exhaust valves and their seats have to operate, resulting in the wear of the contact faces. In order to provide good lifelong performance and reduce the maintenance cost of engines, the wear of the valves and their seat faces has to be quite low. In the absence of any lubrication in the exhaust valve/seat contacts, this is quite difficult to achieve.

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