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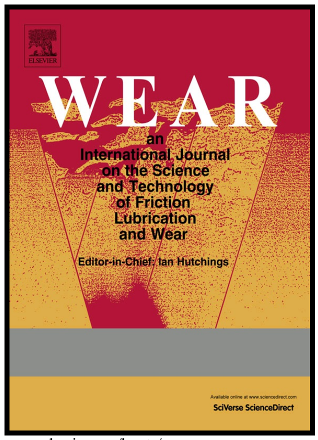

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High-temperature sliding wear behaviour of Stellite®12 and Tribaloy®T400

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Abstract
In this work, the sliding wear behaviour of the hardfacing alloys Stellite®12 and Tribaloy®T400 during interaction with a CrMo-steel is investigated at elevated temperatures. These materials are typically used for gas exchange valves and seat rings in large bore gas engines where they are subjected to severe operating conditions. The clean combustion and a decreased oil flow towards the tribosystem valve spindle/seat ring in the natural gas-fuelled engines cause excessive wear when operating at high combustion pressures and elevated temperatures.

Commonly employed Co-based alloys for the valve seating faces show a vast variation in their wear behaviour when the high tribological loads act directly on the contact surfaces which are not protected by any type of tribofilm. In order to understand the mechanisms under unlubricated and metal-to-metal contact situation, reciprocating pin-on-disc sliding wear tests were carried out at high temperatures for the two common material combinations, mentioned above. The effects of temperature, initial hardfacing roughness, microstructure, and hardness on the friction and wear response are investigated. The quantitative wear results in combination with microstructural and wear mechanism analysis provide the foundation for a phenomenological description of the wear behaviour. The tendency to form oxides has been found to be a decisive factor in terms of the severity of wear of the investigated hardfacings. Stellite®12 shows low surface oxidation at elevated temperatures whereas the intermetallic phases in Tribaloy®T400 oxidize significantly.

Keywords: Valve wear; Co-based alloy; hardfacing; oxide layer; gas engine

1. Introduction

Valve wear in combustion engines, mainly valve seat recession, has been an issue for several decades and in various types of engines. Investigations started from first detailed damage analysis and the observation of a protective oxide layer followed by analysis of operation parameters (e.g. combustion pressure, temperature) affecting valve wear using special test rigs , and development of alternative valve materials . State of the art large natural gas engines are highly efficient and often used for environmentally friendly power generation. However, the trend to higher efficiency and lower emissions results in higher combustion pressures and temperatures during operation of the valve spindles. The reduction of combustion residues from fuel and lubricants reduces the emission values on the one hand but prevents the formation of a protective layer on the valve seating faces on the other hand. Without this protective layer, metal-to-metal contact of the seating faces occurs and the free surfaces and the subsurface microstructures bear the full tribological load, as Forsberg et al. reported for diesel-fuelled engines . The authors could confirm in previous works that the absence of a tribofilm aggravates valve wear in natural gas engines as well .

From a tribological point of view, the operation of the valve cycle in the combustion process can be separated in valve closure (impact) and peak combustion pressure causing deflection of the valve disc (sliding) . Tests with a newly developed component test rig that separates these two modes show that micro-sliding wear significantly contributes to valve wear but is less sensitive to temperature than the impact wear. Furthermore, the latter reference reports that Tribaloy®T400 shows significantly lower wear rates than Stellite®12 in field engine tests. Understanding the wear mechanisms in the unlubricated contact without a protective layer is crucial in developing appropriate hardfacings that can replace conventional materials.

Previous studies on the high temperature wear behaviour of Stellite®12 derivatives or the impact wear behaviour of Stellite®6 employed mostly inert counter bodies made of alumina or cemented carbide. This work covers the sliding wear of a conventional hardfacing alloy (Stellite®12) against a CrMo seat ring steel (PL12MV) in order to have a close-to-reality material pairing and tribological interactions. It has been previously suggested that Tribaloy®T400 can be an excellent hardfacing for valves and seat inserts in natural gas engines , and its superior performance in this application has been described recently in . Renz et al. reported that Tribaloy®T400 performs very well as a substitute for the conventional Stellite®12 in real application, but the reason for this wear behaviour is not fully understood. The authors assume that the microstructure of Tribaloy®T400 provides improved impact resistance compared to Stellite®12, but no direct comparison of wear mechanisms under sliding and impact wear conditions has been carried out yet. This study therefore aims at detailed comparison of high temperature sliding wear behaviour of Tribaloy®T400 vis-à-vis that of Stellite®12. The wear rates of the hardfacing alloys are correlated with the formation of oxides at high temperatures. Especially Tribaloy®T400 is expected to be prone to oxidation due to its relatively low chromium content of 9.5 wt% and high amounts of molybdenum and cobalt . In order to evaluate possible effects of surface roughness, discs