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Investigation into the wear behaviour of Tribaloy 400C during rotation as an unlubricated bearing at 600 °C

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ABSTRACT

The wear behaviour of a cobalt-based superalloy, Tribaloy 400C, was studied during self-mating rotational sliding in a specially constructed bearing rig at 600 °C between 2 min and 12 h at a rotation speed of 3 ms^{-1}. Stable wear protective oxide films often referred to as 'glazes' were formed with their coverage of the wear scar increasing with time. Six stages were identified in the formation of the wear protective oxide films: (i) transient oxidation to form a mixed oxide layer, (ii) preferential oxidation of the chromium to form a chromium oxide layer at the substrate interface, (iii) removal of this layer and compaction onto the surface, (iv) diffusion of mainly Co and Mo cations to the surface through the chromium oxide forming an oxidised layer above it, (v) slow breakdown and formation of the oxide films with further diffusion of mainly Co and Mo to the surface to form Co and Mo dominated layers on top a mixed Co, Cr, Si and Mo oxide film, and (vi) further breakdown and formation of the oxide film to form a uniform distribution of elements within the wear protective oxide film.

1. Introduction

In many industrial situations, rotating shafts are held within a lubricated support bearing. However, a constant supply of oil with a minimum pressure is required with the oil needing certain viscosity and chemical properties such as anti-wear properties. Any deterioration in the oil pressure or in the chemical properties of the oil can lead to failure of the bearings.

One possible way to avoid the use of lubricating oil is to use unlubricated bearings running at elevated temperature in which 'glaze' formation provides wear resistant surfaces at the rotating interface. 'Glazes' are formed through wear debris particles, which are oxidised, fractured into small particles (some down to 5 nm) and consolidated/sintered together onto the contacting surfaces [1–5]. The 'glazes' are very wear resistant and provide low friction surfaces. Journal bearings should encourage 'glaze' formation as the geometry of the bearing encourages the retention of the wear debris produced. Previous work has shown the retention of the wear debris in the wearing zone to be a very important influence on 'glaze' formation [6,7].

Wear testing normally involves using pin-on-disc or block-on-cylinder arrangements in which wear debris retention is not aided due to their geometry. In this investigation a specially constructed rig was used in which a shaft rotated within a bearing (promoting retention) and was enclosed within a furnace allowing ambient temperature control.

A group of alloys that have been shown to be very wear resistant and excellent 'glaze formers' during wear testing are the Tribaloys [8,9]. Within this group is Tribaloy 400C which is a cobalt-based alloy comprised of a hard intermetallic phase dispersed into a softer solid solution. The intermetallic phase is a Laves phase of the type $MgZn_2$ and its composition is approximately Co_3Mo_2Si or CoMoSi [10].

2. Experimental

The alloy composition of Tribaloy 400C is shown in Table 1.

Tests were conducted using the high temperature bearing rig as shown in Fig. 1. The rig comprised of a variable speed motor that drove a shaft supported by standard bearings. A high temperature flexible coupling linked this shaft to a Nimonic shaft located in a horizontally split furnace. This shaft was supported by two test material bearing discs which were fixed to a bearing cradle. The Nimonic shaft itself was comprised of a sleeve separating two collars of the test material that ran within the two bearing discs (see Figs. 2 and 3). The collars and sleeve were held in place with a counterbalance sleeve tightened against two locking nuts. The specimen collars and discs were machined to bearing clearances between 30 and 50 μm with a surface finish of 1200 grit.

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Fig. 1. High temperature bearing rig.

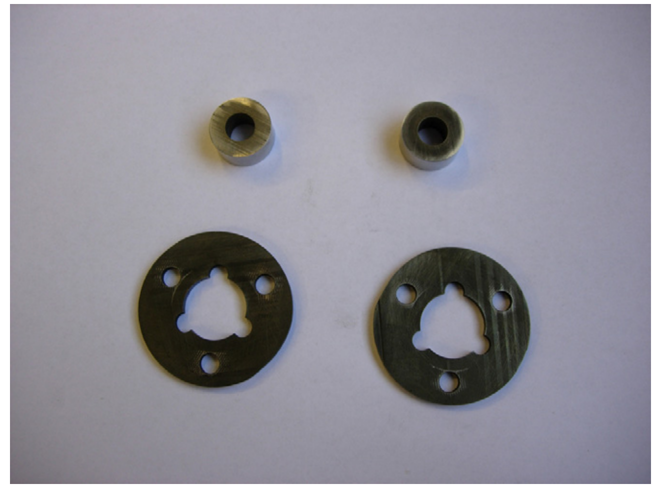

Fig. 3. Tribaloy 400C collars and discs.

Table 1
Nominal composition of Tribaloy 400C.

Alloy	Chemical composition (wt%)						
	C	Cr	Si	Fe	Co	Mn	Mo
Tribaloy 400C	0.09	13.10	2.65	0.17	Bal.	0.02	26.48

Three holes on the inner bearing surface of the disc were machined to encourage oxidation. Testing was conducted at a rotation speed of 3 ms^{-1} at 600 °C between 2 min and 12 h. Weight change measurements of the two collars and two discs were recorded. Static oxidation weight changes previously recorded were used to readjust weight changes for oxidation outside the contact zone. SEM using secondary electron imaging, EDX analysis of the surface, cross-sectional EDX analysis and line scans were conducted on the collars. In addition, X-ray diffraction traces were recorded of the collar wear scars.

3. Results

3.1. Weight losses

The weight loss measurements of Tribaloy 400C tested at 600 °C (see Fig. 4) revealed losses between 0.004 and −0.008 g for testing between 2 min and 3 h for the collars and disc samples. The increase in weight of the discs indicated material transfer between the collar to the disc during the test. However, after 12 h both the collars and discs were showing weight losses between 0.006 and 0.015 g.

3.2. SEM analysis

SEM micrographs of the collars as shown in Fig. 5 revealed that the wear protective oxide plateaux (‘glazes’) were formed after only 2 min and their coverage of the wear scar increased slowly with testing time from 30% to 95% after 12 h of testing.

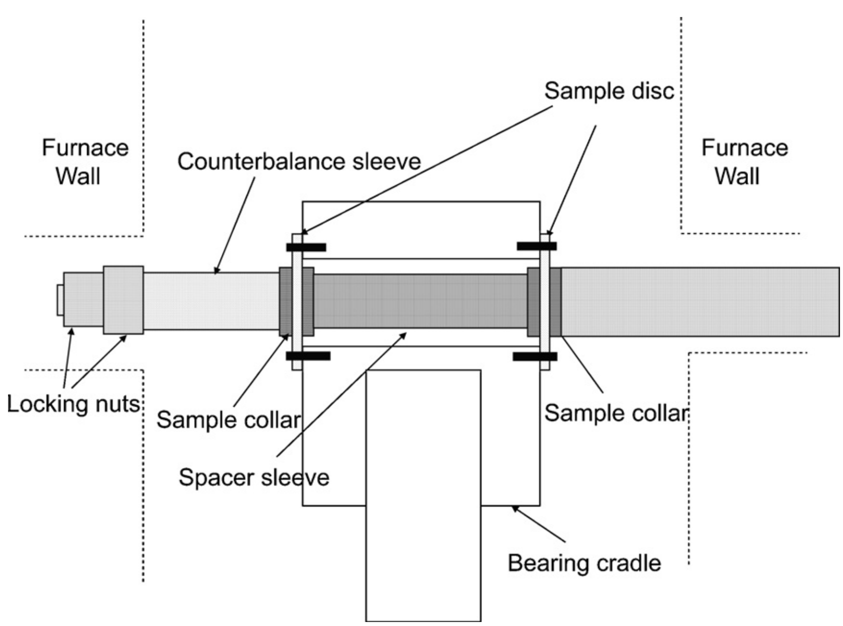

Fig. 2. Schematic of shaft and collar assembly in the bearing rig.