RELATIONSHIP BETWEEN WEAR PERFORMANCE AND SOLID LUBRICANTS IN SINTERED FRICTION MATERIALS

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ABSTRACT
Cast iron (FC and NCM) and forged steel (ST) discs, and four types of sintered friction material pads have been employed in the braking systems of Japanese high-speed trains. These sintered friction materials have complex microstructures. This paper reports result of an investigation to establish correlations between friction, wear and temperature characteristics of the disc – pad friction pairs and pad microstructure. A scale friction rig was used to examine friction, wear and temperature performance of the selected brake friction pairs. Area fraction of lubricants in the sintered friction materials was, depending on formulation, in the range 30-47%. It was found that increasing the lubricant area fraction up to 40%, was effective in reducing pad wear. Above 40% lubricant, wear rate either remained constant or increased slightly to decrease pad wear. For FC discs wear was a minimum at 40% lubricant whilst wear decreased with increasing overall lubricant content for NCM discs and wear was unaffected by variation in lubricant content for the ST discs. The harder ST forged steel discs exhibited less wear than the softer FC and NCM cast irons.

INTRODUCTION
Sintered friction materials have been used especially for heavy-duty applications because of their good braking performance and low wear rate under high temperatures and heavy-duty conditions [1]. The French high-speed train TGV and the German high-speed train ICE as well as Japanese high-speed trains (Shinkansen) normally use sintered brake pads [2] which comprise various phases dispersed in copper alloy matrices. Copper-based braking materials have also been used in aircraft [3 and 4].

Brake pad manufacturers tend to be secretive about the components used in their materials and how they are produced. Consequently, it is difficult to find published papers dealing with sintered friction materials in detail, though components of sintered friction materials used in aircraft brakes, brakes on TGV train and on trains operating in mountain regions are explained in Reference 5.

MICROSTRUCTURAL ANALYSIS
Polished sintered friction material samples, viz. A1, A3, N2 and N3 which are used in the Shinkansen as braking pads were examined using a JEOL 6400 SEM to characterize the analysis of the microstructure. Phases present in the materials were investigated by atomic number contrast and morphology combined with Energy-dispersive X-ray (EDX) microanalysis. Image Tool software (UTHSCSA) and Photoshop (Adobe) were used to carry out image analysis. Individual phases were isolated using the threshold process in Image Tool. This threshold operation creates a binary image from the original grey scale image in which the phase of interest is black and everything else is white. The opening and closing operations [7] available within Image Tool were used to clean up the images. However, due to slight differences of grey level, it was not always possible to use the threshold operation directly to discriminate between different phases. In these situations, the individual phases were selected using the selection tools available within Photoshop. Selected phases were copied to create a new grey scale image which was then thresholded in Image Tool. Area fractions of each phase were calculated by image analysis for all materials and assumed to be equal to the volume fraction.

EXPERIMENTAL
Three types of disc materials viz. FC, NCM and ST, and four kinds of pad materials as above were used in the friction tests. The scale friction rig was used to measure friction, wear and temperature performance for high energy friction pairs. The test conditions were: sliding speeds = 4.5, 6.8, 9.0, 11.3, 4.5 m/s, applied force = 454N (0.55MPa), initial disc temperature = 100°C, time of application = 20 sec and number of applications = 20. Before testing, the rubbing path of the disc was cleaned by 60 grit abrasive cloth at the rotational speed 500rev min⁻¹ and then wiped with a cloth and acetone.
The initial average roughness (Ra) of the rubbing path of disc was about 1μm. A disc was preheated using a pad load of 100N until the disc temperature reached 100°C and then the pad load of 454N was applied. After 20s, the application force was removed and applied again when the disc temperatures had cooled to 100°C. This was repeated 20 times. The contact condition between the pad and disc before testing is very important because data obtained can be dramatically affected by it. Bedding tests were carried out at the sliding speed = 4.5m/s until all the rubbing path of pad would clearly in contact and geometric conformability was obtained.

RESULTS AND DISCUSSION

Average area fraction of phases is shown in Figure 1. Total area fractions were not 100% in all sintered friction materials. Discrimination of the various phases was difficult since all sintered friction materials have complex structures, comprising intimate mixtures with similar contrasts and porosities. These phases can be classified into three categories, i.e. matrix (Cu-Sn, Cu-Sn-P and Fe), friction stabilizer (PSZ, SiO₂) and lubricant (Graphite, Pb and MoS₂) [2].

It was concluded that the lubricant area fraction in sintered friction materials was the best values about 40% to decrease wear of pad and disc.

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