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Rolling contact fatigue studies on spray formed ceramics composite rolling elements

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Abstract

Spray formed ceramic rolling elements can enhance the scope of high speed anti-friction bearings. Spray forming offers distinct advantages over other manufacturing processes, in that it is possible to tailor make structural properties of the rolling element. Selection of ceramic composite material, hollowness ratio (*D*/*d*) and also post-heat treatment after spray forming will ensure the desired rolling contact performance. Alumina–titania (AT40) composite rings of different wall thicknesses (1, 2 and 3 mm) were spray formed and post-heat treated at 1200, 1400, 1500 and 1600 °C. observations clearly illustrate best possible performance of thinner rings with post-heat treatment at 1200 °C. Performance was evaluated in terms of structure–property relationship and also rolling contact wear.

Keywords: Spray forming; AT40 composite; Post-heat treatment; Porosity; Wear

1. Introduction

Spray forming is a potentially attractive process for production of ring shaped components for gas turbine applications. Fielder et al. [1] and Chang et al. [2] have shown favorable results for gas turbine materials through spray forming. Payne et al. [3] have shown that fully dense preforms could be sprayed and extruded into piping. Though not much literature on spray forming of ceramics and ceramic components are available, few attempts have been made. Schindler et al. [4] and Lutz [5] have carried out thermal shock as strength measurement studies on spray formed ceramic composites.

Spray forming of ring shaped for tribological applications such as rolling contact bearing becomes significant, especially for development of high speed bearings. For such application ceramics will be ideal materials owing to the lower density, high hardness and relatively enhanced wear resistance characteristics.

Frechetle et al. [6] discussed on wear of ceramics. Mujawar et al. [7] and Butler et al. [8] have reported on the potential tribological applications of ceramics. Low co-efficient of friction and negligible wear for Zirconia ceramic have been reported by Hannink et al. [9]. Of late tribological applications call for ceramics with reinforced microstructure. Alumina reinforced with titania is an important composite material. Bowen and Bhatejea [10] have reported on significant rolling contact properties of hollow rolling elements. Bamberger and Parker [11] have shown that specific hollowness ratio can enhance the fatigue life. The present paper illustrates rolling contact fatigue response of spray formed annular alumina–titania (AT40) ceramic composite rings.

2. Experimental details

Rolling contact fatigue trials have been carried out on AT40 rings of *d*/*D* (0.7, 0.8 and 0.9) in a laboratory fabricated roller-disc set-up. The specimens were tested with 4.1, 5.6 and 7.0 MPa contact stress levels. The wear of test specimens by way of weight loss, was evaluated by weighing the test specimens in a precision balance of 0.1 mg accuracy. Weight loss measurements were carried out regularly, after every 0.3 million stress cycles.

3. Results and discussion

Spray formed rings of AT40 composite, were evaluated for the response to rolling contact fatigue. Both as-sprayed and post-heat treated rings were tested for rolling contact fatigue. The observations are presented in this section.

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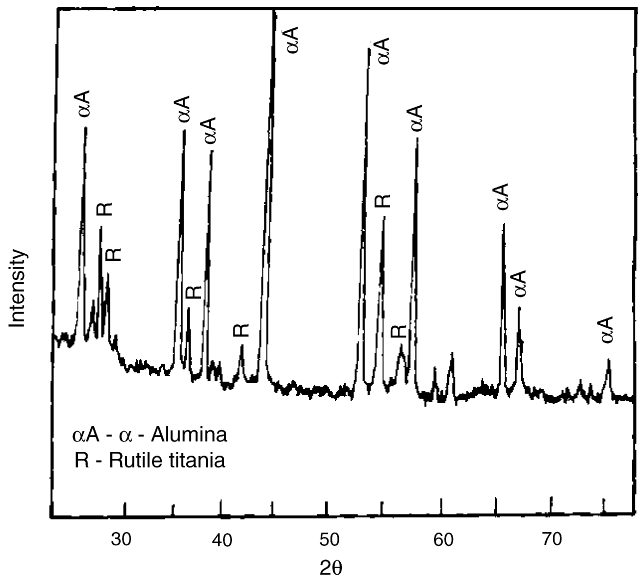

Fig. 1. X-ray diffraction patterns of the starting powder (AT40).

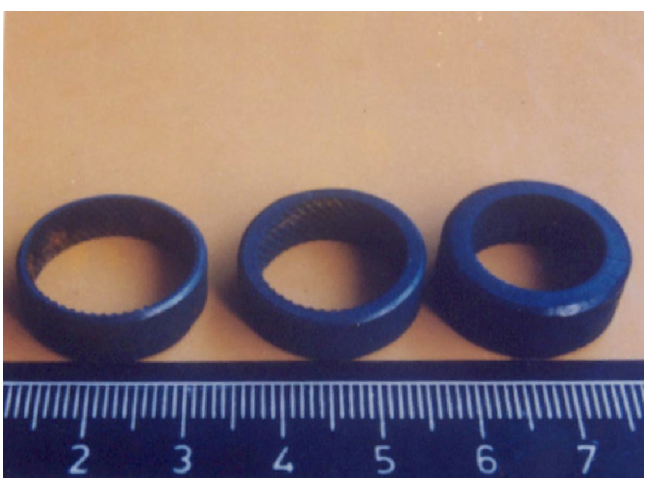

Fig. 2. Spray formed free standing parts.

3.1. Characterisation of AT40 ceramics

Typical XRD profile indicating the phase content of powder of AT40 ceramic is illustrated in Fig. 1. It is seen that the major phases in the powder are α-Al_2O_3 and rutile TiO_2. Typical micro-structure of spray formed rings is illustrated in Fig. 2. In all the cases, layered morphology can be clearly seen. Plasma

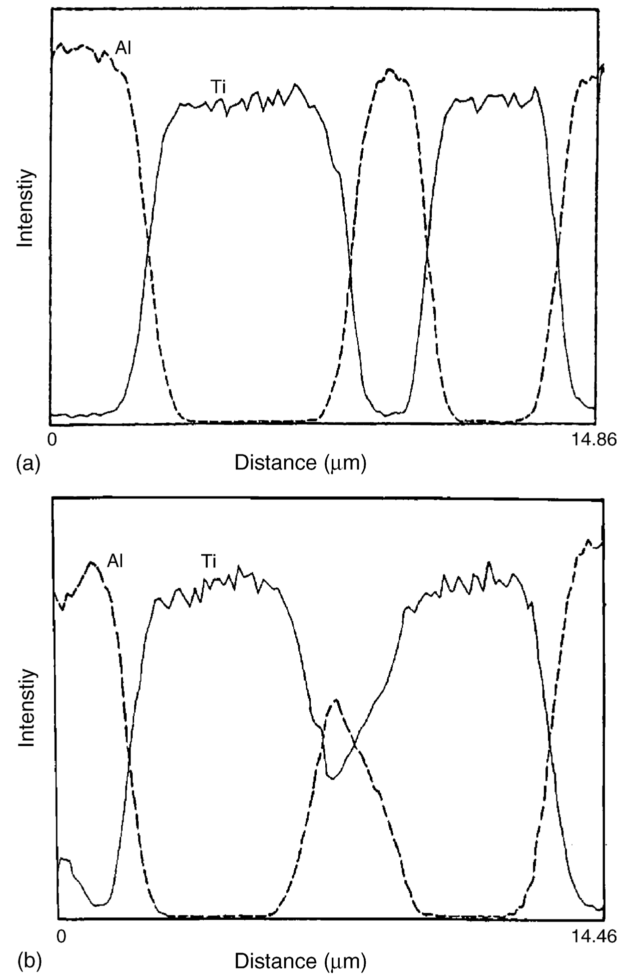

Fig. 4. (a) EPMA profiles for the cross section of the as sprayed sample. (b) EPMA profiles for the cross section of the as sprayed sample.

sprayed ceramic coating composed of a stack of alternate soft and hard layers as confirmed by the EPMA profile in Fig. 3. The profile consists of dominant peak of Al and Ti alternately indicating the presence of Al_2O_3 and TiO_2 phases alternatively. The sandwiching of layers enhances the toughness of ceramic composites.

3.2. Influence of post-heat treatment

Spray formed rings were post-heat treated for possible refinement of microstructure. Typical scanning electron microscope

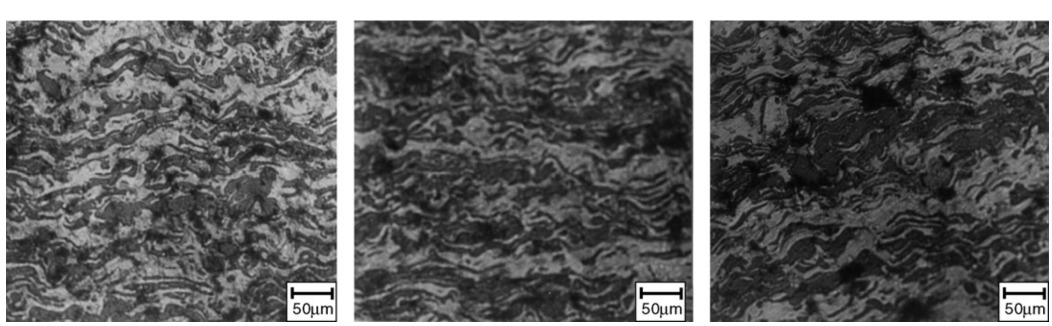

Fig. 3. Optical micrographs of the cross section of the as sprayed samples: (i) 1 mm; (ii) 2 mm; (iii) 3 mm (wall thickness). Low magnification.