An organo-metallic polymer used in powder metallurgy: The effect of polycarbosilane in iron-chromium alloy

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A new material was developed by introducing an organo-metallic polymer into powder metallurgy. In the uniform mixture of Fe—13Cr* alloy powder and polycarbosilane (PC) using n-hexane, the Fe—13Cr particles were coated with PC. The product of Fe—13Cr + 10 wt % PC, obtained by hot-pressing the mixture, was subjected to an oxidation test, high-temperature hardness measurement and a wear resistance test, and found to be superior in all respects to that without the PC addition. The structure was observed by transmission electron microscope and it was found that grains of CrSi₂ and Cr₇C₃ about 0.1 µm in size, dispersed uniformly in the Fe—13Cr + 10% PC, contributed to improvement of the mechanical properties. Observation by scanning electron microscope showed some difference in the formation of the oxidation film between Fe—13Cr and Fe—13Cr +10% PC. This new alloy, while adding an organo-metallic polymer to powder metallurgy, has several outstanding features with the possibility of many applications in the future.

1. Introduction

Research on organo-metallic polymers has advanced greatly over the past ten or so years, to such an extent that the “organo-metal chemistry” is now termed the “third chemistry” as against organic and inorganic chemistry. The present authors worked on the process of converting organosilicon polymer, as an organo-metallic polymer, to silicon carbide, as an inorganic, by heating the former and this led to the synthesis of a continuous SiC fibre [1–3]. The starting material was polycarbosilane (PC), a space polymer [1–3]. Particles of the Fe—13Cr alloy powder are coated with this PC. The powder is then pressure-molded, and heat treated. The organo-metallic polymer is thus thermally decomposed, resulting in reactions between the released elements and the alloy metals. In this way, a heat-resistant Fe–Cr material with a uniform dispersion of fine-grain compounds, having excellent mechanical and thermal properties, can be obtained, which would be impossible by any conventional method. This introduction of an organo-metallic polymer to powder metallurgy is the first such attempt in the world.

2. Materials

Polycarbosilane was produced using dimethyl-dichlorosilane as the starting material [1–3]; the number-average molecular weight of the PC used

* i.e. Fe—13 wt % Cr.
being 1500. The Fe–13Cr alloy powder was produced by a water-spray process; the mean particle size being 3 μm and the wet chemical analysis 12.48% Cr, 0.86% Si, 0.06% Mn, 0.07% Ni, 0.01% C, with the rest Fe.

3. Experimental

Fe–13Cr alloy powder and polycarbosilane were taken in weight ratio 9:1. After mixing well n-hexane was added, and the mixture was stirred again. The n-hexane evaporated off in dry air. The resulting mass was crushed and the powder was passed through a 100-mesh screen. PC had been dissolved in the n-hexane to give viscous substance, so the particles of Fe–Cr alloy powder after sieving were thinly coated with PC. The alloy powder was hot-pressed in a carbon die of 50 mm inner diameter under an argon atmosphere. Heating was by induction using a 20 kW high-frequency oscillator. The temperature of the compressed powder was raised at rate 300° C h⁻¹ to 1100° C and kept there for 30 min. The pressure was released, the high-frequency power source was cut off, and the compact was allowed to cool by standing. A flowchart of the process is shown in Fig. 1. The specimen was cut and subjected to structural observation, oxidation resistance and mechanical tests.

4. Results and discussion

4.1. Structure

Structure of the sintered Fe–Cr body was observed by transmission electron microscope. The specimen was made into a thin film by jet polishing at 60 V, 3 A with a solution of 1 part perchloric acid to 7 parts ethyl alcohol. The electron microscope used was JEM-200A using an acceleration voltage 200 kV. Micrographs are shown in Figs. 2 and 3; the Fe–13Cr + 10% PC alloy has observable spherical and ellipsoidal in-