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Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Fabrication of Fine Diamond Dispersed Metal-Based Grinding Wheel by a Centrifugal Mixed- Powder Method

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Recent trend in aviation industry, weight reduction by using composite, such as a carbon fiber reinforced plastic (CFRP), has been positively promoted to save weight without sacrificing reliability. With increasing amount of usage of CFRP, improving quality and accuracy of CFRP drilling holes for a faster is one of the important requirements in order to ensure the safety of aircraft. To achieve the requirements, gyro driving grinding wheel system for CFRP drilling was proposed. For the grinding wheel, we have proposed functionally graded material (FGM) fabricated by a centrifugal mixed-power (CMP) method. The CMP method is one of the powerful and cost-effective processes to obtain composite materials by means of pressure impregnation. The mixed-powder method in addition to the centrifugal casting will make the fine particle dispersed FGM achievable. In this study, we attempted to fabricate Al/diamond and Cu/diamond composites by this method. Effect of casting temperature and metallic powder diameter on diamond abrasive powder dispersion was discussed.

Keywords: *functionally graded materials, metal-matrix-composite, Cu/diamond composite, Al/diamond composite, centrifugal casting method*

1. Introduction

Nowadays, carbon fiber reinforced plastic (CFRP) is starting to positively promoted for the next generation aircraft to save weight without sacrificing reliability since the composites are lightweight and have high specific strength. On the other hand, one of the major problems against application of CFRP to aircraft is machinability. Especially, improving quality of drilling hole is one of the urgent matters.

Takekoshi *et al*. proposed gyro-driving grinding wheel system for CFRP drilling as these requirements[(1)]. This system can provide high quality drilling hole by means of a two-axes rotating drive with a metal-matrix grinding wheel. For the grinding wheel, Watanabe *et al.* had proposed functionally graded materials (FGMs) fabricated by a centrifugal mixed-power (CMP) method [(2-4)]. The CMP method is a unique type of the centrifugal casting method, which can makes it possible to obtain FGMs on which surface fine reinforcement particles are dispersed.

In this study, we attempted to fabricate diamond dispersed Al or Cu matrix FGMs by the CMP method. Effect of casting temperature, centrifugal force and cast design on transverse particle distribution and effect of matrix powder diameter on particle distribution along depth direction were investigated in order to optimize casting condition for Al/nano-diamond and Cu/micron-diamond FGMs by the CMP method.

2. Experimental procedures

Mixed powder was prepared by mortar mixing with diamond powder and metallic powder. In this study, same element was used for the metallic powder and the matrix. Regarding Al/nano-diamond composites, Al power was employed for the matrix and nano-sized diamond powder was employed for dispersed particles. Mean primary diameter of nano-sized diamond powder (d_{diamond}) was approximately 50 nm. The used Al particle diameters (d_{Al}) were 425 - 850 μm, 250 - 245 μm, and 20 - 150 μm. After casting, matrix composition was 99.5 % Al. Cu powder and micron-diamond powder was prepared. Diamond powder with d_{diamond} = 149 μm was used for this study, and particle size of Cu powder was less than 40 μm. From now on, nano-sized and micron-sized diamond will be abbreviated to nD and mD, respectively.

Two types of centrifugal casting machines were employed for the CMP method. Vertical-type and parallel-type centrifugal casting machines were used to Al/nD composites and Cu/mD composites, respectively. Details of the casting machines were shown in elsewhere[(2, 5, 6)].

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3. Results and Discussions

3.1 Effect of casting temperature on powder distribution of the Al/nD composite

Fig. 1 shows side overview of the casts fabricated at the casting temperature at 984 K and 1038 K. The cast at 984 K, it seems that powder distribution was inhomogeneous in a longitudinal direction to the spin-mold. Powder was segregated and was mainly distributed within 50 mm from the runner side, where molten Al was infused, and less than 10 mm from motor side (the most far side from the inlet). On the other hand, at 1038 K, powder was successfully distributed uniformly along transverse direction. X-ray diffraction (XRD) profiles obtained from the cast surface indicated that nD kept diamond structure after casting, and no major reaction phase was observed on the sample surface. Therefore, it can be concluded that not only Al oxidation but also diamond-to-graphite transformation was sufficiently prohibited in the low pressure.

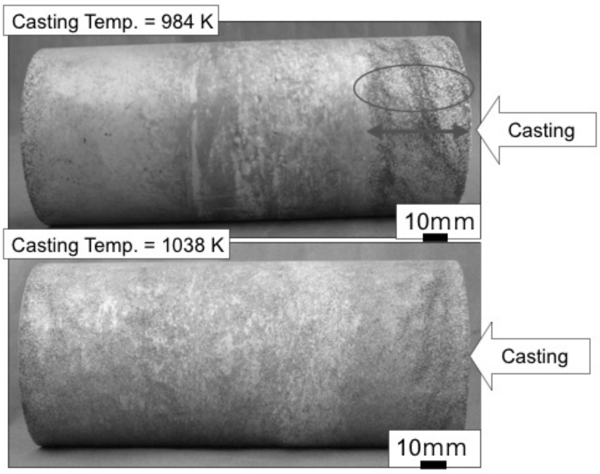

Fig. 1 Side overview of the Al/nD cast tubes fabricated at 984 K and 1038 K by the CMP method.

3.2 Fabrication of Cu/mD composites by CMP method

Initially, in case of poor wettability combination such as Cu and diamond, threshold impregnation pressure (P_c) can be roughly estimated in terms of wettability. According to Nishida[7], minimum spinning rate (N_p) in order to overcome P_c can be estimated by following equation;

$$N_p \geq \frac{1}{2\pi}\sqrt{\frac{2P_c}{\rho_m\left(r_1^2 - r_0^2\right)}}$$

ρ_m is density of molten metal; r_0 and r_1 are distance at medial surface of molten metal from rotation axis and that of mixed powder, respectively. Based on this equation, 34.7 G was applied for the centrifugal casting. In conclusion, Cu/mD FG composite was successfully obtained with 5 mm length of sprue at 1473 K of casting temperature. On the other hand, not only pre-form threshold stress also molten metal flow during casting played important role for the immobilization of diamond powder.

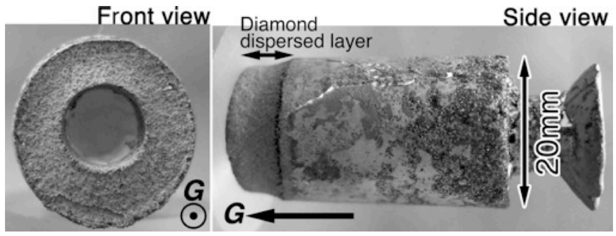

Fig. 2 Front and side overview of the Cu/mD cast grinding wheel fabricated by the CMP method.

4. Conclusions

Both diamond-particle-distributed Al and Cu FGM composites for a grinding wheel can be successfully obtained by CMP method.

Acknowledgements

This work was supported by Ministry of Education, Culture, Sports, Science and Technology, Regional Innovation Cluster Program (Global Type) "Tokai Region Nanotechnology Manufacturing Cluster".

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