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Effect of Die on surface characteristics and properties of Powder Metallurgy Processed Al-Cu Composite.

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Abstract

Powder metallurgy is one of the various processes used for the development of composite material. Powder metallurgy processed composite material has a high surface finish and strength to weight ratio. The surface characteristics and properties of powder metallurgy processed components not only depends on the powder material and process parameters but also on the material and manufacturing process of die and punch setup. This is a comparative study on surface roughness (R_a value), crack and hardness of powder metallurgy processed aluminium copper composite prepared by high carbon steel and hardened stainless steel grade die-punch set. 118% better surface characteristics and 5% better hardness were achieved in the Al-Cu composite of the same composition prepared in the hardened stainless steel die and punch set.

Keywords: Powder metallurgy, laboratory experiment, Al-Cu composite, surface characteristics, hardness, Die and punch set.

1. Introduction

Powder metallurgy is one of the most suitable processes for making composite material. The researchers and technicians are investigating different methods, parameters, pre and post-processing techniques of it. The process consists of mainly three steps. They are mixing, compaction and sintering. Mixing is used to achieve uniform distribution of different powder materials. Compaction is used for making primary or green compacted sample which is then taken for sintering to prepare a solid composite. In this paper, two Aluminium- 10% Copper (Al-Cu) composites are prepared by using die-punch sets of two different materials.

Aluminium (Al) is popular in the industry like aerospace, automobile as well as in our households for its lightweight and high strength to weight ratio [1]. Copper (Cu) is commonly used for its high electrical and thermal conductivity. Research works are carried out to find formability [2], thermal, mechanical[3], electrical properties and microstructure [4-6] of Aluminium- Copper (Al-Cu) composite.

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Die compaction has an important role in the densification and properties of powder metallurgy samples [7-8]. That's why the design and manufacturing of die[9], the effect of lubricant, die wall friction, part geometry [10] are important areas of research. In this study, the effect of die-punch setup on surface characteristics and hardness of Al-Cu composite is observed. No lubrication is used for this study as mechanical properties decrease with the increase in admixed lubricant quantity [11]. Two different composite samples of weight percentage 90% aluminium-10% copper (Al-10%Cu) are prepared by using two different die-punch setups when all other parameters remained constant.

2. Materials and Methods

The powder metallurgy process followed here to prepare Al-Cu composite consisting of three steps. They are mixing of powders by ball milling, compaction of powder in a die-punch set and sintering of cold compacted sample within muffle furnace. For this experiment, all parameters of mixing, compacting and sintering have remained the same except two different Al-10%Cu samples were prepared by using two different die-punch setups. One die-punch set is prepared with EN 31 high carbon steel and the other setup is prepared with EN 24 hardened stainless steel. The fabrication process was also different for these two setups. The inner, outer diameter and height of both the dies are the same as 16 mm, 50 mm and 61 mm respectively. The first die and punch set up as shown in the following Fig. 1 is prepared by facing and turning. The inner hole is prepared by drilling. Here both base and pin are attached.

Fig. 1 - High carbon steel die-punch set-1

The other EN 24 hardened stainless steel die-punch set is supplied by ANTS Ceramics (P) Ltd, India as shown in the following Fig 2.

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Fig. 2 - Hardened stainless steel die-punch set-2

The surface roughness of both the die set as shown in Fig. 1 and Fig. 2 respectively are measured using a Talysurf. Surface roughness is measured at five different spots of each set and the average value is shown in the following Table 1.

Table 1 - Surface Roughness of Die-Punch Set

Die-Punch Set	Surface roughness (Ra value in micron)
EN 31 high carbon steel Die-Punch	21.385 micron
EN 24 hardened stainless steel Die-Punch	0.49 micron

Two samples of Al-10%Cu metal matrix composite are prepared by using these two above mentioned die-punch sets. 36 gm of 98% pure aluminium powder is taken with 4 gm of 99.8% pure copper powder in a steel container. 40 stainless steel balls of 6 mm diameter are also taken within the container. The container is then attached with the laboratory ball milling machine and rotated at a speed of 240 rpm for 30 minutes clockwise and then 30 minutes anti-clockwise. After 1 hour the mixed powder is taken out of the container. 0.05 % deviation in weight observed before and after the ball milling of mixed powders.

The mixed powders are divided into two equal weight divisions and filled separately in two dies prepared by two different materials. Then the powder is compressed in the die cavity by an axial load applied with a punch. The die-punch set is placed inside a tabletop hydraulic press to apply the pressure. 35 KPa pressure is applied in both the die-punch sets for 10 minutes and then the load is withdrawn. The green compacted samples are removed from the die-punch set and transferred to the muffle furnace for sintering.

Both the samples are heated inside the muffle furnace up to 500^0 C temperature for 45 minutes and then stayed inside the switched off the furnace for another 3 hours to reach again to the atmospheric temperature. The inter-metallic bonding is created due to fusion and sintered and solid samples are taken out from the furnace. The two Al-10% Cu composites are shown in the following Fig. 3 and Fig. 4. Fig. 3 is the sintered sample-1 which is green compacted in the high carbon steel die-punch set-1. Fig. 4 is the sintered sample-2 which is green compacted in the hardened stainless steel die-punch set-2.

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Fig. 3 - Sintered sample-1 (compacted in the high carbon steel die-punch set-1)

Fig. 4 - Sintered sample-2 (compacted in the hardened stainless steel die-punch set-2)

3. Surface Characteristics and Property analysis

Lots of cracks are observed in sample-1 which is green compacted in the high carbon steel die-punch set-1. No visible crack is observed in sample-2. The surface finish of sample-1 is also very poor compared to sample-2 which is prepared in hardened stainless steel die-punch set-2. We have measured the surface finish of both the samples on top, bottom faces and cylindrical surfaces.

"Rockwell hardness tester" is used for checking the hardness of both samples. 1/16 " steel ball indenter is used with 100 Kgf of the load is used to find out Rockwell hardness number. Care should be taken as there are chances of breaking the sample-1 due to a significant amount of cracks. The observations are shown in the following Table 2.

Table 2 - Surface finish and Hardness of both the samples

Sample	Surface roughness (Ra value in micron) (Top/Bottom Face)	Surface roughness (Ra value in micron) (Cylindrical surface)	Hardness
Sample-1(compacted in high carbon steel die-punch set-1)	24.49	22.90	92 HRC
Sample-2(compacted in hardened stainless steel die-punch set-2)	11.24	4.36	97 HRC

Clusters of powder observed in the SEM images of the top face of sample-2 is shown in the following Fig. 5.

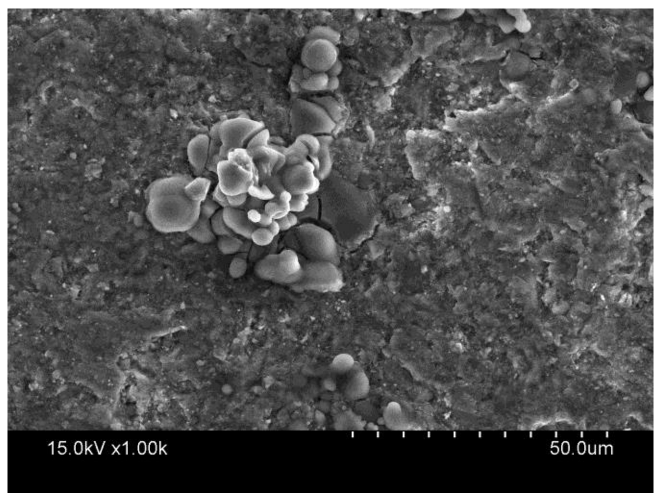

Fig. 5 - SEM images of the top face of sample-2

4. Results and Discussion

Surface roughness is almost the same on the top, bottom and side face of the sample-1. In the case of sample-2 surface roughness of the cylindrical side is significantly low

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compared to top/bottom faces as shown in the following Fig. 6.

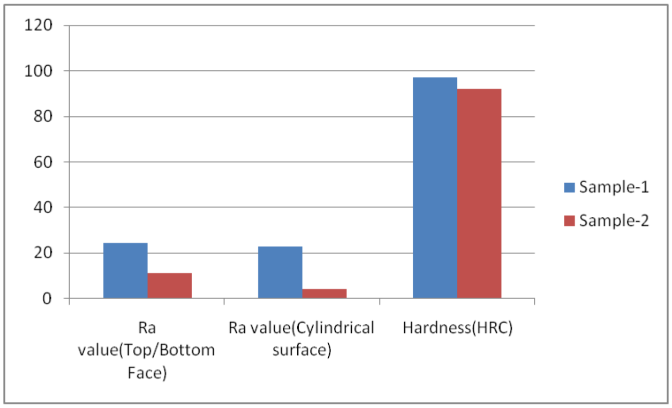

Fig. 6 - Experimental Results

This happens due to the axial pressure being applied on those surfaces directly. In both, the samples surface finish is poor than the surface of the die punch set due to the friction between the die wall and the compacted sample. The removal process of the green compacted sample from the die punch set by sliding it from the bottom of the die also makes permanent damage to the inner die wall. After repeated use of the same die the inner wall surface finish deteriorates which will produce samples with poor surface finish. Clusters of powder observed in the SEM images as shown in figure no 5, is another reason for increasing the surface roughness.

Both the hardness is almost the same but Sample-1 is more brittle due to the formation of cracks. Cracks are forming due to the poor surface finish of the high carbon steel die-punch set-1. During the sintering process, the air enters inside sample-1 through those cracks and oxygen reacts with the aluminium present inside the Al-10% Cu composite. Aluminium oxide (Al_2O_3) is formed due to those reactions which made the sample-1 more brittle. Sample-1 is not suitable for contact testing methods whereas sample-2 is suitable for any type of contact testing method.

5. Conclusions

High carbon steel die-punch set-1 prepared by turning, facing and drilling is not suitable for making green compacted samples developed by the powder metallurgy process. Due to its poor surface finish, it creates lots of cracks on the surface of the sample. The surface finish of the sample also becomes very poor due to friction between the inner wall of the die and the compacted sample. The air enters from the cracks during the sintering process, and oxygen reacts with the aluminium and makes aluminium oxide. It makes the sample brittle and unsuitable for any contact testing procedure. Sample-2 which is compacted in hardened stainless steel die-punch set-2 is better in surface characteristics and suitable for any contact testing procedure.

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