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Production of Functionally Graded Material by Powder Metallurgy

[1] Harsh. R. Shah, [2] Sehul Mehta, [3] Dhrumil Mehta, [4] Harsh. Y. Shah, [5] Kirtan Patel, [6] Nirvan Sharma, [7] Dipali Pandya
[1][2][3][4][5][6][7] Mechanical Department, Navrachna University

Abstract:-- **The urge of getting properties of different components in a single engineering component is rising as technology surges. Typically, we desire a component must possess low wear resistance or thermal conductivity at its surface also with high interior toughness. For this manufacturing of Functionally Graded Material (FGM) becomes essential. Constitutional variation is the main factor on which the performance of FGM is dependent. Hence, it is mandatory to optimize the compositional distribution in FGM.There are many techniques which have been imposed to manufacture FGMs, including physical and chemical vapor deposition, sintering, plasma spraying, electroplating, Powder metallurgy and combustion synthesis. In this research FGM has been fabricated by powder metallurgy which is efficient and reliable method. This technique includes processes like cold compacting and sintering.By this method microstructure, composition and shape can be controlled. In this research FGM of Silicon carbide (Sic) and Aluminium (Al) has been made successfully. Also, test of mechanical properties and microstructure studies has been carried out.**

Index Terms:- Functionally graded materials, FGM, Powder Metallurgy, Aluminium (Al), Silicon Carbide (Sic).

I. INTRODUCTION

The rapid growth of technology demands much more new materials with new special properties or functions. Under many intense conditions like super high temperature and temperature gradient, most of the materials can't survive [1]. Functionally Graded Material(FGM) has been proposed as a solution to this need [2]. FGM consists of various materials like ceramics which offers heat-resistance property while metals offer strength. The change of constitution of FGM can reduce the thermal stress by temperature difference in use [3]. As the performance of FGM is strongly dependent on the constitutional variation, it is mandatory to optimize the compositional distribution in FGM [4]. On the contrary, it is also very essential to develop manufacturing methods that provide the micro structural control to produce the desired characteristics [5]. There are various methods to manufacture FGM such as physical and chemical vapor deposition, sintering, plasma spraying, electroplating and combustionsynthesis [6]. Powder metallurgy is the most reliable and easy route for manufacturing FGM [7]. With the help of powder metallurgy technique, it becomes very convenient to get layer by layer structure [8].In powder metallurgy technique FGM is produced using both hot and cold pressing methods [9]. However, in this research development of Al2124-Sic FGM was manufactured by cold-pressing which was then followed by sintering. The main aim of this research is to develop FGM by powder metallurgy, expecting to optimize FGM fabrication process and further optimizing its performance.

II. EXPERIMENTAL PROCEDURE:

A. FABRICATION:

In this research, FGM has been made by Al2124 and Sic according to our desired properties. Once the material was selected, it was weighed according to the requirement for a sample. Then for manufacturing a sample, the weighed material of Al and Sic was mixed properly with the help of Stirrer. Subsequent layers were prepared according to the ratio. All the layers were added one after other in cylindrical steel die of 46mm Dia for pressing. The first layer consisted of 100%Al2124 and 0% Sic. In each subsequent layers the amount of Al2124 went on decreasing and amount of Sic was increased linearly. The last layer consisted of 60% Al2124 and 40% Sic. When all the 5 layers were put into die, it was pressed on Compression Testing Machinefor a pressure of 5-7. Succeeding to this, the sample was ready for sintering. So, the compacted sample was then moved to muffle furnace for pressure less sintering at 400-600˚C for 1-3 hours. Once the sample was sintered, testing of the sample was required to determine its hardness and micro structure.

B. MECHANICAL PROPERTY AND MICROSTRUCTURE STUDY:

The hardness of the manufactured sample was measured with the help of Rockwell hardness tester with ball indenter was used to obtain more accurate results at room temperature. The load given to perform hardness test was 60kgf. The microstructure and the element distribution of the FGM was observed with the help of Scanning Electron Microscope (SEM).

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III. RESULT AND DISCUSSION:

A. MECHANICAL PROPERTIES TESTING:

With the help of Design of experiments (DOE) by Box-Behnken method 13 different combinations were obtained. The below table depicts the hardnessof each of the manufactured sample by the means of Rockwell hardness tester. It was observed that the hardness was found increasing when the sintering temperature was kept 600˚C and the compacting pressure was kept at 7 ton. On the contrary, the hardness was found to be minimum when the sintering temperature or the compacting pressure was minimized.

Figure 1: Manufactured Samples

carried out and hardness for each sample is represented in the below table:

Table 1: Hardness Result of each Sample

Sample No.	Compacting pressure (TON)	Sintering Temperature (˚C)	Sintering Time (Hours)	Hardness (HRC)
1	5	400	2	80
2	7	400	2	78
3	5	600	2	78
4	**7**	**600**	**2**	**86**
5	5	500	1	72
6	7	500	1	77
7	5	500	3	72
8	7	500	3	84

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9	6	400	1	81
10	6	600	1	79
11	6	400	3	76
12	6	600	3	76
13	6	500	2	79

B. MICROSTRUCTURE STUDY OF MANUFACTURED FGM

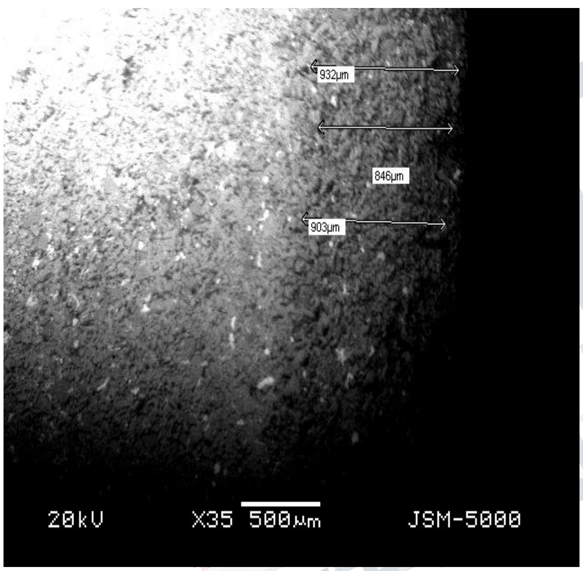

Figure 2: SEM result of optimized sample at 35x zoom

The above image depicts that the first layer of FGM that consisted of 100% Al2124 is the black portion which can be seen from above image. The white color particles are of Sic (Silicon Carbide). It can also be observed that the length of second layer is approximately around 9mm. The above image was taken at 35x Zoom.

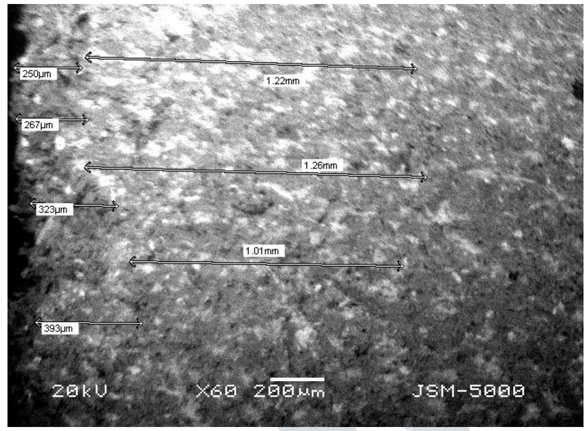

Figure 3: SEM result of optimized sample at 60x zoom

The above Figure was captured focusing on the back surface. Here the last layer and the layer above it can be clearly seen. It is evident from the image that the last layer which consisted of 40%Sic was around 4mm in length. Moreover, the layer above it which consisted 30%Sic was found to be very less i.e. 2mm in length.The above image was taken at 60x zoom.

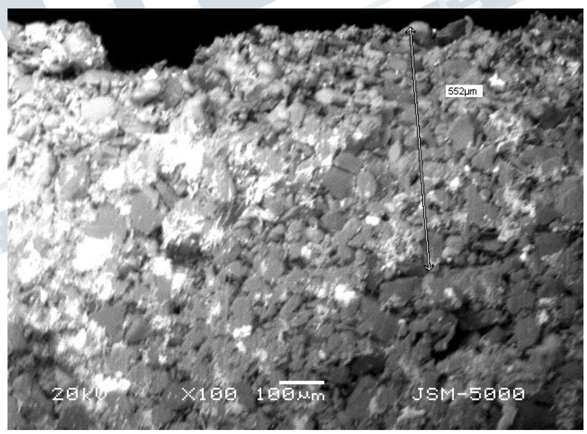

Figure 4: SEM result of optimized sample at 100x zoom

In this image the Sic can be clearly seen which is dispersed and uniformly spreaded. Also, this image was captured placing the sample horizontally and then the reading was taken. The interesting part of this image is that it was taken at 100x zoom. Therefore, here the microstructure of both aluminum and Silicon Carbide can closely be observed.

CONCLUSIONS:

1. Successful manufacturing of FGM was carried out using Powder Metallurgy having stepwise layer consisting of 100% Al at the bottom which decreased to 60% at the top. The

upper layer was made of only Al whereas after that 10% Sic was added to each layer up to 40%. The last layer was made of 60%Al2124 and 40% Sic.

2. Designing of Experiments was carried out using Box-Behnken method and optimum manufacturing parameters obtained were

Sintering Temperature – 600C.
Sintering Time – 2 hours.
Pressing Force – 7 ton.

3. The optimized sample was studied under SEM to see the microstructure and behavior of the particles inside it.

4. It was concluded that the hardness obtained of this FGM was higher than that of aluminum. And so, this FGM could be used in variety of application.

5. It was observed that if the pressing force was increased then it would result in increasing of hardness of the sample. Sintering time could not be increased as it would result in melting of Al2124.

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