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Fabrication And Mechanical Property Evaluation of Functionally Graded Materials with Zirconium Oxide (ZrO_2) and combination of Aluminum 7075 (Al 7075), Titanium diboride(TiB_2) by Powder Metallurgy

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Abstract

In present work, fabrication of five layers functional graded materials (FGMs) by using power metallurgy technique followed by sintering. We are using zirconium oxide (ZrO_2) with particle size 0.5 µm and combination of aluminum 7075 (Al 7075), titanium diboride (TiB_2) with particle size is 0.5. We prepared five different compositions (100 wt%, 70 wt%, 50 wt%, 30 wt %). The characteristics of FGM like hardness and compress strength are determined. The determined values are compared values with base material. The results reveal the successesful development of FGM.

Key words: Functional Graded Material (FGM), Powder Metallurgy (PM)

1. Introduction

The engineering field is developed day by day. So, the demands of innovative materials are also increased. Scientists and researchers seek to innovative or advanced materials according to their applications. FGMs are started during 1980 in japan for reusing rocket engines after reducing thermal stress and increase adhesiveness with the help of metal ceramic FGM. For development and characterization of advanced materials we must need FGM. By using different methods (Gas, Liquid, Solid based) FGM are developed. Powder metallurgy is one of the techniques in solid based method. FGM are the new class of composite advanced materials in which the percentages of compositions of the materials are gradually increased layer by layer. Due to requirement of conflicting property in engineering applications and designs, pure metals are less in use. The fabrication process is one of the most important fields in FGM research. A large variety of production methods have been developed for the processing of FGM, such as, powder metallurgy, sheet lamination, laser cladding, and chemical vapor deposition. It is noted that powder metallurgy method is one of the most commonly employed techniques due to its wide range control on composition and microstructure and shape forming capability. The strategy of FGM has been developed to build armors . In general, the two component phases in the FGMs are ceramics and metals, though ceramic–ceramic and metal–metal FGMs are also reported . Therefore, a careful powder particle size selection and processing control is critical for achieving a flat and crack-free FGM. The microstructure and the composition of the fabricated FGM were studied.

2. Experimental procedures

2.1 Raw material

Zirconium oxide (Zro_2) and combination of aluminum 7075 (Al 7075), titanium diboride (TiB2) powders were used as raw materials to fabricate the FGMs. Alumina powders with an average particle size of 0.5 µm were to form pure layer. Iron powders with an average particle size of 0.5 µm were to form pure metallic layer. The formation of the intermediate layers in the FGM was from the mixtures of alumina powders with an average particle 0.5 µm, properties of materials are as shown in table 1

Property	**Units**	**Zirconium dioxide (ZrO_2)**	**Titanium Diboride (TiB2)**	**aluminum 7075 alloy**
Modulus of elasticity	GPa	250	550	71.7GPa
Bulk modulus(K)	GPa	212	191	71.7
Shear modulus(G)	GPa	86.4	191	331
Melting point	°c	2700°c	2970°c	477
Density	gm/cm^3	5.7	4.52	2.81
Specific heat	J/kg K	540	601	714.8
Thermal conductivity	w/m-k	2.7	26	150

Table:1. Material properties of Zirconium dioxide, Titanium diboride and aluminum 7075 alloy

2.2 Processing

The FGM was designed to comprise five layers. In addition to pure zirconium oxide Zro_2 and combination of aluminum 7075 (Al 7075), titanium diboride (TiB2) layers at the two ends, the intermediate structure consisted of three layers with different ratios of ceramic and metal, namely, 70 wt% Zro_2 –30 wt% (Al7075+TiB2), 50 wt% Zro_2–50 wt% (Al7075+TiB2), and 30 70 wt% Zro_2–70 wt% (Al7075+TiB2, respectively. In the present work, the layers are termed as Layer 1 to Layer 5 from pure zirconium oxide Zro_2 end to combination of aluminum 7075 (Al 7075), titanium diboride (TiB_2) end, as shown in table 2

Layer number	**Percentage**	**Total weight (grms)**
1	100% Zro_2	1.5
2	70% Zro_2+30%(Al7075+ TiB_2)	1.5
3	50% Zro_2+50%(Al7075+TiB_2)	1.5
4	30% Zro_2+70%(Al7075+TiB_2)	1.5
5	100%(Al7075+ TiB_2)	1.5

Table:2. Weight fraction of each layer

The raw powders for the formation of the intermediate layers were first weighed according to the designed ratio. Mixing was done by manually. Mixing of powders according to the layers before taking the compositions the Al7075, TiB_2 are mixed equally. After that they are allowed to combine in compositions. The mixing is done by manually or by taking into the kettle and placed on the vibrating table. The proper mixing gives the best gradation and results. The die should be selected according to our requirements. i.e the die dimensions are decides the final product dimensions. The diameter is 12 and length is 65 mm.

Compression is the process of compacting metal powder in a die through the applications of high pressure. Compression process involves the filling of the mixed powder in the die. The each layer weight is 1.5 grms. Then weight the all ratios powders equally and clean the die before filling with cotton and apply lubrication on the inner walls of the die and die rod must be clean. Now check the hydraulic compression machine before starting the process. After reaching the selected load then the die is to be removed from the machine and ejecting the piece slowly from the die the gradually loads are applied for perfect ejection of piece .the ejected piece is 2.5Cm will be coming out of the die as shown in fig 1. Material flow from layer 1 to layer 5 are shown in fig.5

Fig: 1.

It is a heat treatment applied to a powder compact in order to impact strength and integrity. The temperature used for sintering is below the melting point of the major constituent of the powder metallurgy material i.e. Al7025melting temp up to 500 degree centigrade for this we can set the temperature lower than that. We can use muffle furnace for heating process it is electronic type heating equipment. The sintering temperature up to 400 centigrade continually 4 hours and 5 hours .The normal cooling is done after the sintering.

Fig: 2.

Fig: 3.

The sintered piece are then polished by fine grade emery paper and then polished on the disc grinder the disc polishing for easiest study of microscopic observation for getting smooth ,scratch free and mirror like appearance the polishing

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process is used.

3. RESULTS AND DISCUSSIONS

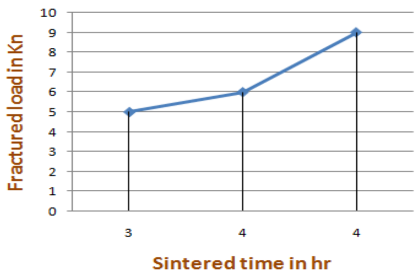
3.1 Mechanical properties

3.1.1 Compression test

The compression test specifies the method of determining the ultimate strength under uniaxial compressive loads. The test piece is placed between the two hard metals blocks of compressions testing. The axial load is applied until the crack deformation occurs. Fig.4 shows how the FGM piece broken during compression test.

Sl. no	Sintered time in hr	Fractured load in Kn
1	3	5
2	4	6
3	4	9

Table: 3. FGM fracturing load at time in hr



Graph: 1 Variation of compression test results at constant 400^0c

The results showed in table 3 & graph 1 is compression test values. We have seen that the ultimate strength value is not only depends on the sintered time and also depends on the time duration for cooling in sintering process.

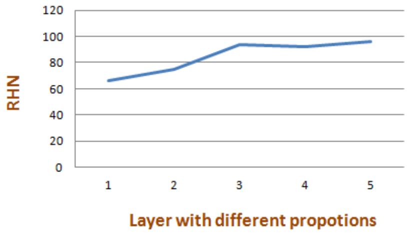
Fig: 4. **Fig: 5.**

HARDNESS TEST

The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel bar indenter. The indenter is forced into the test material under a preliminary minor load F usually 10kgf. Hardness of each layer tested by using Rockwell Hardness testing Machine with a load of 100 Kgf for duration of 1 minute. While observing the values less hardness in layer 1(ZrO_2), hardness is more at layer 3 (50% of materials) and slightly decrees than increase to 96

Table: 4.

Position from Base	Hardness in RHN
1	66
2	75
3	94
4	92
5	96

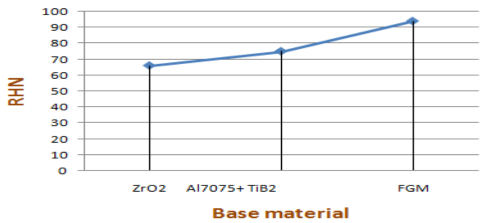


Graph: 2

Fig. Rockwell hardness test values of each layer with different proportion at 100 Kgf loads which is sintered at 400°C up to 4 hrs.

Table: 5

Base material	RHN
ZrO_2	66
Al7075+ TiB2	75
FGM	94



Graph: 3.

4. CONCLUSIONS

- We are successfully prepared the mixing of powder and weighted according to our requirement ,crack free FGM's was produced. By using powder metallurgy technique hybrid composites were fabricated successfully.

- The compression strength is to be increased according to the sintering time and cooling media also

- Variation of hardness in each layer of FGM piece. An increase in weight percentage of TiB2 particles along the deposition direction led to a progressive increase in hardness.
- Finally hardness variation as compared to base metal .i.e., we conclude that the FGM's piece will give the best hardness as compared to FGM's.

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