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Investigation of tensile deformation with micro structure of Three-Layered Functionally Graded (FG) Sandwich Structure

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Abstract - ***The purpose of this study was to manufacture a functionally graded material from Alumina (Al_2O_3) and Silica (SiO_2) with the application of a bonding agent i.e. epoxy resin by the route of compressive moulding technique, characterize as sandwich of metal and composite having transitional features from metal (Al) on one face to ceramic (Si) on the opposite face. Consequently, the study of the mechanical behaviour of the material i.e. tensile deformation with the micro structure of the deform surfaces by scanning electron microscope [SEM].***

Key Words: *FGM, Sandwich Structure, Mechanical Properties of FGM.*

1. INTRODUCTION:

Functionally Graded Material (FGM), a revolutionary material, own to a class of advanced materials with varying properties over a changing dimension. FGM may be specifying by the different in composition and structure, unhurriedly over volume, emerging in corresponding changes in the properties of the material. Functionally graded materials indicate an unbroken imbalance of material properties which out-turn from the heterogeneous microstructure. on account of the eccentric graded materials properties, FGMs have engage a affluence of immersion from researchers in many fields, along with aerospace, biomaterials and engineering among others in the past decades [1, 2].

A sandwich structure consists of two narrow, rigid, and strong face sheets connected by a thick, light and low-modulus core applying adhesive joints in form to achieve very competent lightweight structure. In most of the cases the faces carry the loading, on and the other in-plane and bending, although the core defer transverse shear loads. A sandwich structure progress in the same path as an I-beam with comparison that the core of a sandwich structure is of another material and is spread out as an unbroken medium for the face sheets. The main impact of a sandwich structure is its particularly steep flexural stiffness to weight ratio compared with other architectures. As a repercussion, sandwich construction results in curtailed lateral deformations, higher buckling resistance, and higher natural frequencies than other structures. In kind, for a given intent of mechanical and environmental loads, sandwich construction usually results in a lower structural weight than do other composition. Sandwich structure has few drawbacks as manufacturing methods, quality control and joining difficulties [3, 4].

In the fig. 1, the layer 1 is considered as the homogeneous composite and the bottom layer is considered as the metal alloy with the unit thickness of each layer.

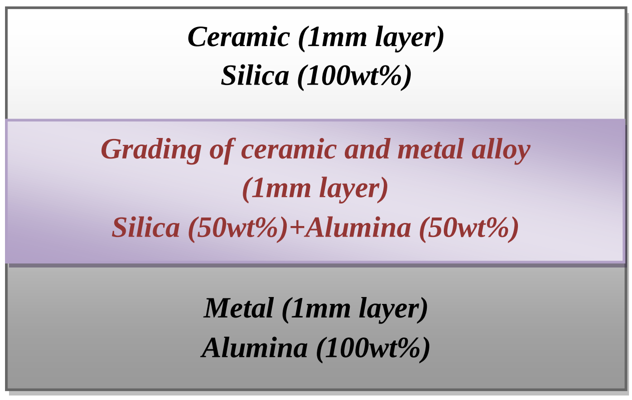

Fig -1: Three-Layered Structural Model

We have plan to characterize as ceramic metal composite which transition from metal on one face to ceramic on the opposite face, the metal surface is designed for hardness and the toughness and insulator property on the ceramic surface.

In 1984, the famous research plan of Functionally Graded Materials, Fundamental Studies on the Relaxation of Thermal Stress by Tailoring Graded Structures was pioneered in the thermal barrier for a space plane in Japan. The capabilities of withstanding a surface temperature of 1700°C and a temperature gradient of 1000°C across only a 10 mm section were achieved by FGMs as a thermal barrier. More general concepts applied to convey new properties and behaviour of materials was planned by continuous control of the microstructure; also the layout of such materials was first brought in. The term of functionally graded materials (FGMs), was conceived for these gradient composites and materials for further detailed explanation and grammar, in 1986. Due to their unique graded material properties, FGMs brings huge extent of researcher concern, In addition to the aforementioned thermal barriers, laminating and joining in aerospace research projects, this material have also been established for other novel functions [5].

Apetre N.A. (2005), Establish analytical models for sandwich structures with graded core and solve the contact and impact problems affecting sandwich structures with graded core and analyze the trade between using a functionally graded core as opposed to the ordinary sandwich design. Research presents analytical solutions based on different models for sandwich structures with graded core when the core Young's modulus is expressed by exponential and polynomial variation. A finite element model validates analytical solutions [6]. Birman and Byrd, et al., (2007), functionally graded material structure that interpolate uniquely between properties of two materials are generally considered to curtail stress concentrations in engineering and medical applications, ranging from semiconductor thin films to prosthetic joints and limbs [7] and a lot of studies on functionally graded materials were presented by the authors Choi and Sankar's (2005) [8], Genin et al., (2009) [9], Noor et al. (1996) [10], Vinson et al. (2001) [11], Reissner (1945) and Midlin (1951) [12, 13], Jerzy J. Sobczak et al. (2013) [14]. The present work aims to study the mechanical behaviour of three-layer functionally graded sandwich structure fabricated from Alumina (Al_2O_3) and Silica (SiO_2) with the application of epoxy resin as a bonding agent by compressive moulding route and all the process were performed by hand layup method to complete the above technique of layer preparation.

2. EXPERIMENTAL PROCEDURE:

The materials adopted for achieving the objective and the desired properties are Alumina (Al_2O_3) in nano powdered, Silica (SiO_2) in nano powdered and Epoxy Resin and the development of three-layer functionally graded sandwich by hand lay-up compressive molding technique. The overview of process is illustrated in the figure 2.

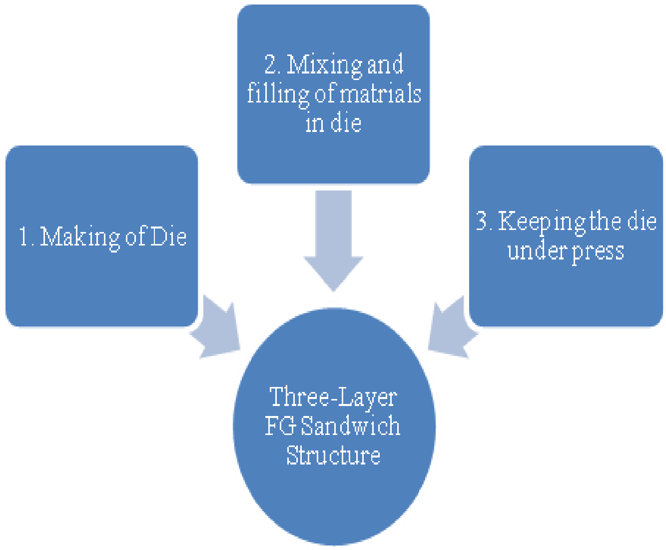

Fig -2: Overview of Process

The mould used for developing three-layer functionally graded sandwich structure is a rectangular mild steel plate with a dimension of 150×150×12mm (in figure 3), assembled with a top plate, side plate and a base plate. To help complete removal of the material from the mould, a polymer sheet is plant on the neat and dry mould before fabrication of the three-layer functionally graded sandwich structure.

At first, epoxy and hardener is mixed into the beaker then the material is filled in beaker and mixed then this mixture is spread all over the die and keeps the die under press of 20KN for 2 hours. This process is repeated thrice for the formation of three layers, of unit thickness. After spreading the final layer the die is kept under the press for next 24 hours at room temperature for curing. The composition of each layer is given in the table 1.

The first layer is made of 100wt% of silica, the mid layer or core is made of 50wt% of Silica and 50wt% of Alumina and the next layer is made of Alumina of 100wt% with the application of load as described in the table 1, after developing the third layer the die is keep under the press for next 24 hours at room temperature for curing.

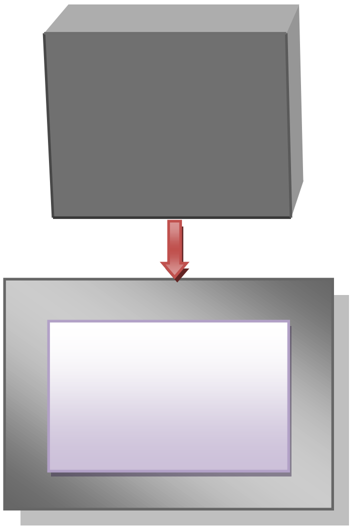

Fig -3: Die of the dimension 150×150×12mm

After, 24 hours the die is kept out and the sheet is removed from the mould and processes machining for the preparation of samples of standard shape and size for the testing of mechanical properties.

Table -1: Composition of each layer

Layer	Material	Composition (Wt%)	Time (Hour)	Load (kN)
1	SiO_2	100%	2	20
2	SiO_2+ Al_2O_3	50%+50%	2	20
3	Al_2O_3	100wt%	24	20

For the tensile testing the samples are prepared according to the ASTM D 638-03 [15] type I sample and the test was carried out using universal testing machine of TINIUS OLSEN 25kN, model H25K-S UTM and the results were taken out and discussed below, and the microstructure of tensile deform surface and each layer was studied by using JEOL-JSM-5600, Scanning electron microscope (SEM).

The actual pictures of the die used and the hydraulic press used for the fabrication of the three-layered functionally graded sandwich structure are shown in figure 4 below-

(a) (b)

Fig -4: In Processing of Compressive Molding Technique by Hand layup method (a) Die, (b) Hydraulic Press

The specimens prepared are shown below, in figure 5, the SiO_2 side surface shown and in figure 6, Al_2O_3 side surface shown.

Fig -5: Silica side surface of specimen

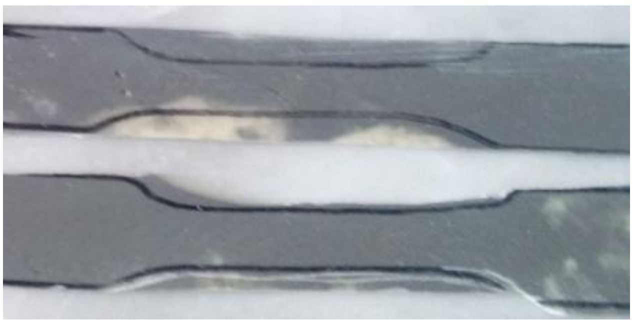

Fig -6: Alumina side surface of specimen

3. RESULTS AND DISCUSSION:

3.1 Scanning Electron Microscopy (SEM):

Scanning Electron Micrograms of Functionally Graded Three-Layer Sandwich Structure are shown in the figures below.

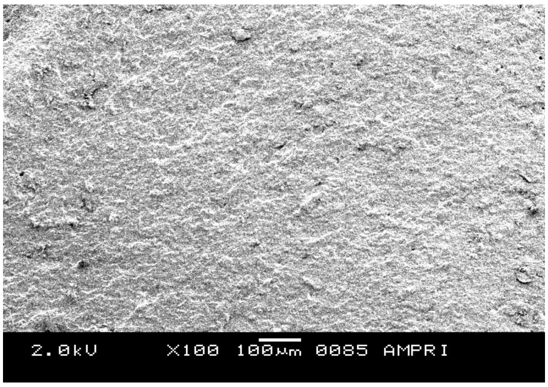

Fig -7: Microstructure of Silica (100%) side layer

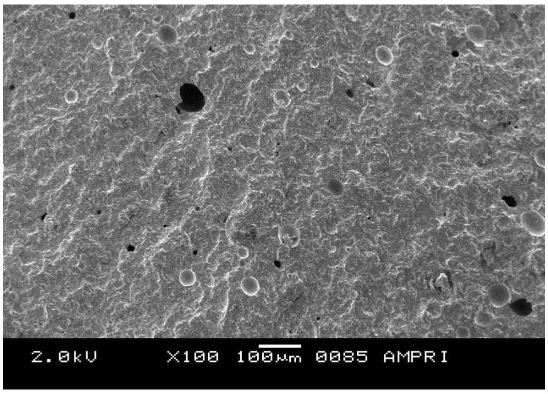

Fig –8: Microstructure of Core or mid layer (Silica 50% and Alumina 50%)

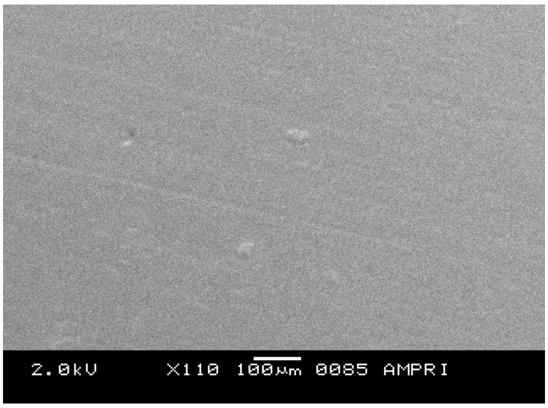

Fig –9: Microstructure of Alumina (100%) side layer

As we seen above that when the materials are mixed in 100wt% ratio it presents a relative smooth and lamellar surface with some parallel superficial grooves distributed along the surface but when it mixed as 50wt% ratio it present the porous surface.

The fracture surface with interface of three-layer functionally graded sandwich structure, shown below:

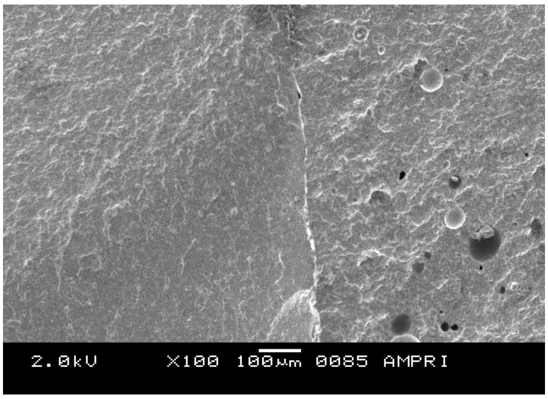

Fig –10: Fracture surface between layer 1 and layer 2

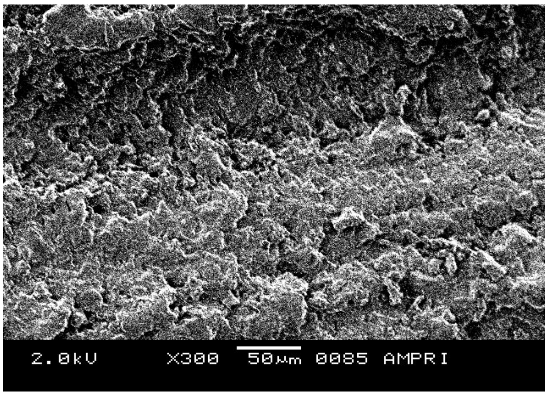

Fig -11: Interface between layer 1 and layer 2

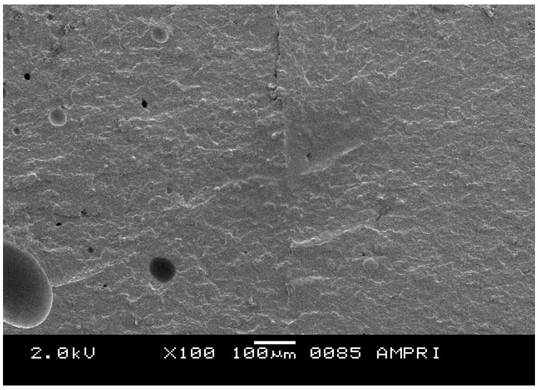

Fig –12: Fracture surface between layer 2 and layer 3

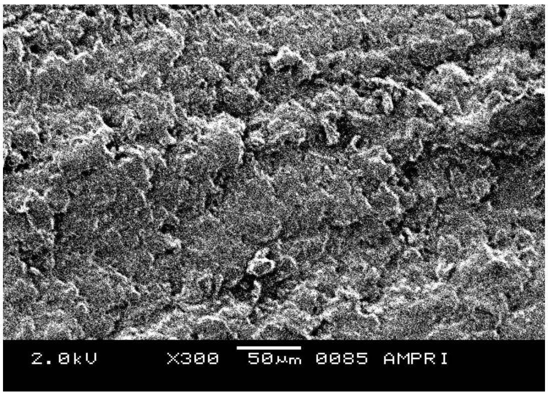

Fig -13: Interface between layer 2 and layer 3

3.2 TENSILE DEFORMATION:

The results of tensile test are shown below in the form of force v/s extension and stress v/s strain in figure 14 and figure 15 respectively.

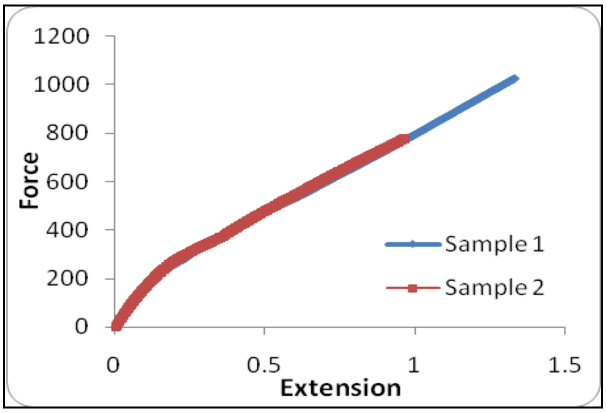

Fig -14: Force V/s Extension curve

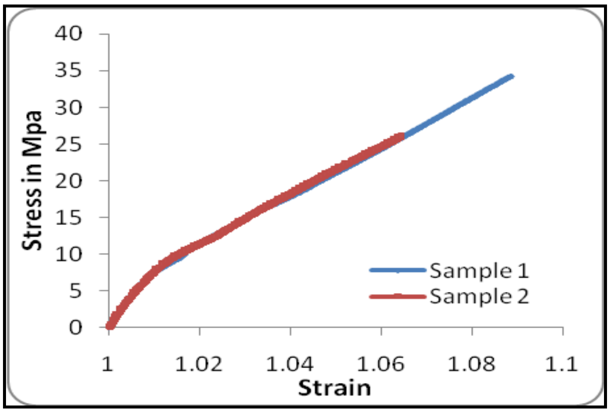

Fig -15: Stress V/s Strain curve

Fig. 14, shows the load bearing capacity of the three-layer functionally graded sandwich structure, which can withstand the maximum force of 1028N with the extension of 1.330mm and figure 15, shows the stress V/s strain curve of three layered functionally graded material that the specimen was capable to provide resistance to continued elongation and displayed brittle failure.

4. CONCLUSION:

It is concluded that the bonding between the layers is very high hence it increases the strength of the material and it can withstand a large amount of force and the material is very light weight as compare to the parent material which enables the material to use in the space craft or plane project as it also have a good ability to resist force and the extension of the material is very low as compare to the force applied.

5. FUTURE SCOPE:

The above method is good and one can perform it easily for making this material with different composition and can investigate the remaining mechanical properties with these properties to validate them and for making this material useful for different industrial and other house hold applications as requirement because this method can form the material easily and have scopes of further improvement of the mechanical properties.

ACKNOWLEDGEMENT:

It is indeed extremely difficult, if not impossible, to undertake a venture of this magnitude without the wholehearted cooperation and guidance of peers and seniors in the field.

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