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Tensile Fracture strength of Boron (SAE-1042)/Epoxy/Aluminum (6082 T651) Laminated Metal Composite (LMC)

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***Abstract:*-- To become familiar with the mechanical property of a component is very important, before it is used as an reason to keep away from any breakdown. Composite structures put into practice can be subjected to different types of loads. One of the major loads among such is tensile load. This paper shows experimental study and results of the flat rectangular dog bone tensile specimen of Boron (SAE-1042)-Epoxy/Aluminum (6082 T651) (B/Ep/Al) laminated metal composite (LMC). LMCs are a single form of composite material in which alternating metal or metal containing layers are bonded mutually with separate interfaces. Boron metal is amongst the hardest materials from the earth's crestjoined with the aluminum metal, it is known that one side of boron and aluminum plates are appropriately knurled and afterward adhesively bonded with an epoxy which perform as binder and consolidated by using heavy upsetting press. Processes of tensile tests have been carried out with a hydraulic machine where three specimens with the same geometry were tested which all of them showing alike stress-strain curves. These results of tensile tests were clearly indicated the nature of ductility.**

***Keywords:*-- FML, GLARE, LMC, Boron (SAE-1042), Epoxy, Aluminum (5083 H112), Aluminum (6061-t6), Aluminum (6083-t6), LMC, BEA, tensile behavior, Stress- strain curve..**

I. INTRODUCTION

Composites made-up with fiber reinforcement which includes a resin, some carbon or a small number of metal matrixes are adaptable materials that propose several advantages for today's ground-breaking and severe changes. In general, composites are light weight, strong and impact and fatigue resistant. They can be cost competitive and are flexible for a lot of applications. Composites can be readily customized in composition and manufacturing processing to meet accurate engineering – design applications and loading circumstances. Fiber metal laminates (FML) are hybrid composites consisting of intermittent thin layers of metal sheets adhesively bonded to fiber-reinforced epoxy prepreg. Glass fiber reinforced aluminum (GLARE) is one such material. It contains aluminum alloy and glass fibers and has been assessed for many possible applications in aircraft structures [1]. Because GLARE exemplifies the advantages of both the metal and fiber components of the composite, it not only improve ultimate strength, fatigue properties and corrosion resistance when compared to monolithic aluminum alloys but also improves the bearing strength, impact resistance and ductility when compared to conventional fiber-based composite laminates [2–5]. GLARE has been included into primary aircraft structure as the upper fuselage skin for the Airbus A380, where weight reduction and improved damage tolerance are crucial.

One of the more serious shortcomings of current-generation GLARE laminate is its low Young's modulus. As a result of the low tensile modulus of S2 glass fiber (86.9 GPa) used in GLARE, the resulting modulus of the fiber prepreg layer (containing 60%volume fraction of glass fibers) is only about 55 GPa. This is even lower than the Young's modulus of the aluminum alloy (72 GPA). Consequently, the Young's modulus of GLARE is unavoidably lower than that of monolithic aluminum. A low Young's modulus may critically affect the application of GLARE laminates in aircraft structures, especially where the stiffness is a leading design requirement. Premature crack initiation is another critical shortcoming of GLARE. In previous research [6–8], GLARE has shown good fatigue resistance and a low crack propagation rate during fatigue tests due to the overpass effect. However, during the initial stage of cyclic loading, the significant load carried by the aluminum layer will be higher than the load carried by S2 glass/epoxy prepreg. The presence of high stress in the aluminum layer causes a short fatigue crack initiation life of GLARE [6]. In order to reduce the stress level in the aluminum layer and to retard the fatigue

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crack initiation of GLARE, it is necessary to increase the modulus of the composite layer [9, 10]. The notch strength of high modulus hybrid fiber/metal laminate (FMLs) was investigated [11]. The materials used in this composite layers which contain both boron fibers and S2-glass fibers, were adhesively bonded to 2024-T3 aluminum sheets and consolidated using an autoclave process. The results of tensile tests clearly showed that high modulus FMLs with a good ductility can be achieved by mingling of boron and glass fibers.

Apart from these type of composites, Laminated Metal Composites (LMCs) consist of alternating metal or metal containing layers that are bonded with 'sharp' interfaces. These materials represent a unique laminated or layered composite form that should be distinguished from graded materials, which have diffuse interfaces, or layered materials, in general, which can consist of alternating layers of a wide range of materials including metal/metal, metal/ceramic, ceramic/ceramic, or intermetallic/ceramic combinations. Laminated metal composites can dramatically improve many properties including fracture toughness, fatigue behavior, impact behavior, wear, corrosion, and damping capacity or provide enhanced formability or ductility for otherwise brittle materials. In many cases through the choice of laminate architecture (such as volume percent of the component materials and layer thickness), component materials, and processing history, LMCs can be engineered to produce a material with prescribed properties. [12]

The review paper of D. R. Lesuer et al.,[12] This review deals with the mechanical behaviorof LMCs - including history, processing, and properties.This general subject was reviewed in 1974 in an extensive paper by Wright and Levitt.[13] Since then, significant advancements in this technology have occurred including improved mechanistic understanding of impact behavior and stress-strain response as well as detailed studies of fracture toughness, fatigue behavior, and super plasticity. In addition, considerable work and commercial application of LMCs in the former Soviet Union is becoming known in the western world. Some of this work hasbeen documented in a book by Potapov et aI., [14]which emphasizes the processing and application of LMCs including bimetals. In the West, commercial applications of layered materials have occurred including macro laminates of aluminium alloy and aramid fibre reinforced epoxy (ARALL) as well as aluminium alloy and glass fibre reinforced epoxy (GLARE). In addition, a wide range of laminates and bimaterials for non-structural applications are commercially available.

Accordingly to study the tensile propertyof the composite layer experimentally,an effort is made in this work by using Boron (SAE-1042)-Epoxy/Aluminum (6082 T651) (B/Ep/Al) Laminated Metal Composite (LMC)

2. Boron/epoxy/aluminum laminated metal composite. Recently, a new generation matrix metal laminate with enhanced stiffness and improved crack initiation properties is developed as a solution for the shortcomings such as low stiffness, low yield strength, low fatigue and low impact properties at room and moderate temperatures. Laminated metal composite consists of boron and aluminum layers with epoxy in between them. Boron metal plate is used for their high young's modulus (400 GPa) in comparison with glass fibers (86.9 GPa). Due to high modulus of boron plate, the overall modulus of laminated metal composite can be improved and is higher than the conventional GLARE. Experimentally we investigate the mechanical properties of the tensile specimens of all the three specimens in this paper.

3. Experimental Details.Two different metal plates' viz. Boron Steel plate (SAE-1042) and Aluminum plate (6082 T651) (of dimensions 450x350x12 mm each) were chosen for this research work. One side of both plates are knurled to a depth of 2 mm and are sandwiched with the help of epoxy (thermostat). Epoxy, which is a composition of standard mixture of Resin X (M-544) of 100 parts by weight (pbw) with clear uniform paste of color yellow and Hardener y (H-209) of 40 pbw with clear uniform paste of color beige. The ratio of this cold setting is 60:40 with resin X and hardener Y respectively were kept with room temperature for 20 to 25 minutes.

To prepare the finished composite metal laminate, the sandwiched plate is pressed under the capacity of 400 tonnes upsetting press with a temperature of 900 C and the duration of press was 155 Seconds. The composite laminate was removed from the upsetting press and allowed to cool under room temperature. Figure 1 shows the finished composite metal laminate.

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Fig. 1 Laminated Metal Composite (LMC) of Boron (SAE-1042) / Epoxy /Aluminum (6082 T651) of dimensions 450 mm x 380 mm x 24 mm (each metal plate has a thickness of 12 mm), manufactured at M/s Permali Wallace Pvt. Ltd. Bhopal. MP (India)

Three specimens were extracted and tested from newly developed Boron (SAE-1042) / Epoxy / Aluminum (6083-T651)Laminated Metal Composite (LMC) and the results of tensile strength, yield strength and percentage of elongation were recorded as shown in the following figures.

Fig. 2 Before Testing of Boron (SAE-1042) / Epoxy /Aluminum (6082 T651) Laminated Metal Composite (LMC) Tensile Specimen No. 1 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India

Fig. 3 After Testing of Boron (SAE-1042) / Epoxy / Aluminum (6082-T651) laminated Metal Composite (LMC) Tensile Specimen No. 1 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India.

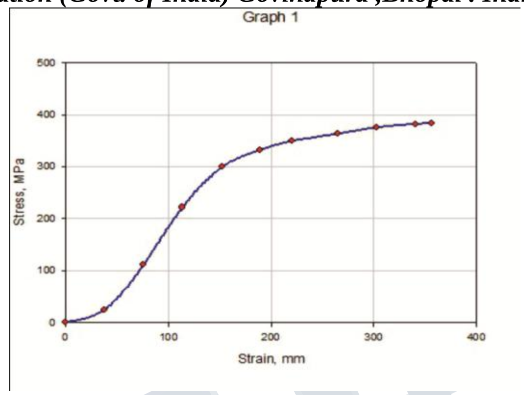

Fig. 4 Stress-Strain curve of tested Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) Laminated Metal Composite (LMC) Tensile Specimen No. 1 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal. India.

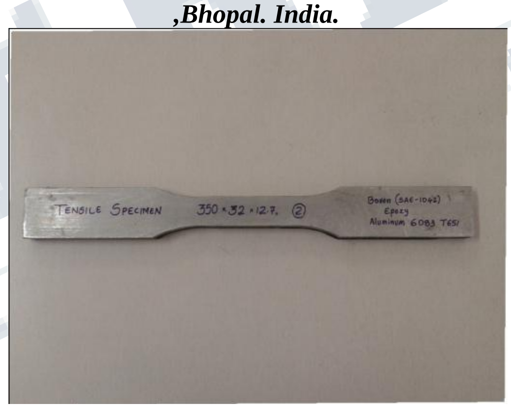

Fig. 5 Before Testing of Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) Laminated Metal Composite (LMC) Tensile Specimen No.2 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India

Fig. 6 After Testing of Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) laminated Metal Composite

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(LMC) Tensile Specimen No. 2 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India.

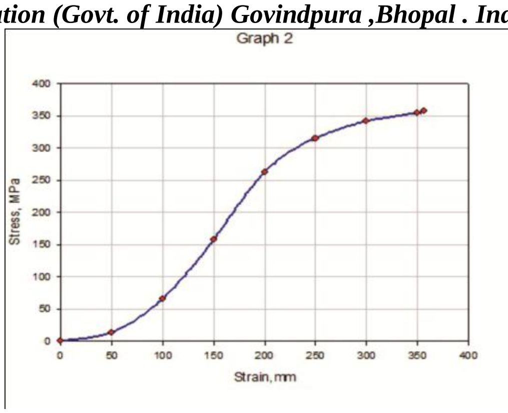

Fig.7 Stress-Strain curve of tested Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) Laminated Metal Composite (LMC) Tensile Specimen No. 2 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal. India.

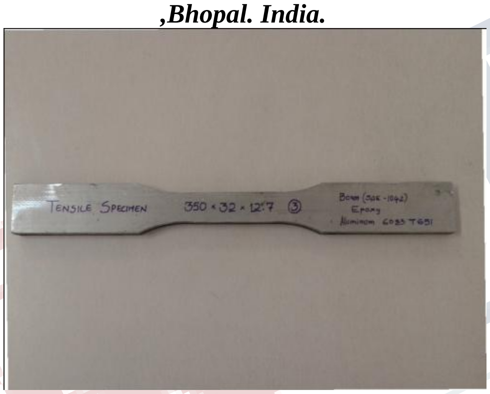

Fig. 8 Before testing of Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) laminated Metal Composite (LMC) Tensile Specimen No. 3 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India.

Fig. 9After Testing of Boron (SAE-1042) / Epoxy / Aluminum (6082 T651) laminated Metal Composite

(LMC) Tensile Specimen No.3 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal . India.

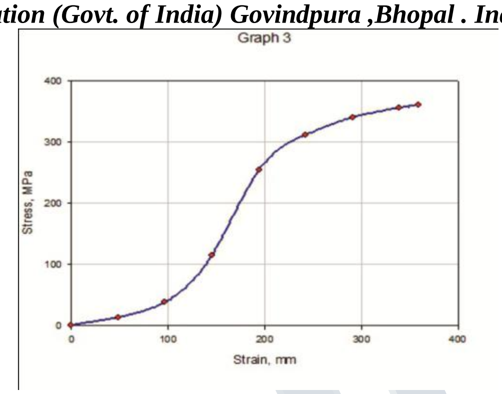

Fig.10 Stress-Strain curve of tested Boron (SAE-1042) / Epoxy / Aluminum (6082-t651) Laminated Metal Composite (LMC) Tensile Specimen No. 3 of dimension 350x32x12, at Micro, Small and Medium Enterprise (MSME) Testing station (Govt. of India) Govindpura ,Bhopal. India.

Table1.Summary of the results of tested Tensile Specimens of Boron(SAE-1042)/Epoxy/Aluminum (6082 T651) Laminated Metal Composite (LMC).

Specimen	Dimensions	No. of Samples tested	Tensile Strength (MPa)	Yield Strength (MPa)	% elongation in mm
1	350*32*12.7	01	384	316	2
2	350*32*12.7	01	357	308	2.86
3	350*32*12.7	01	361	304	2.58

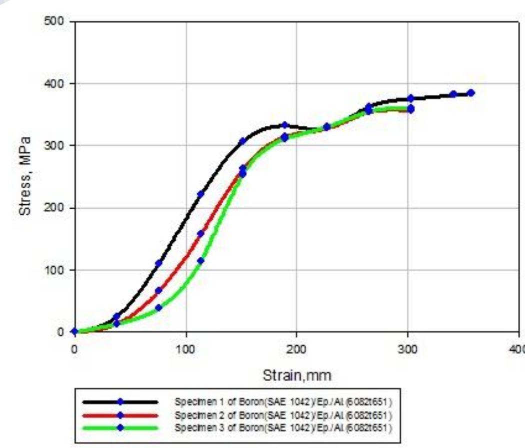

Fig.11 Consolidated Stress-Strain curve of testedBoron (SAE-1042) / Epoxy / Aluminum (6082-t651) Laminated Metal Composite (LMC) for all the 3 tensile Specimens of dimension 350x32x12.

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The average values of tensile strength, yield strength and percentage elongation of all the three specimens are 367 MPa, 309 MPa and 2.48 mm respectively were found from the above table.

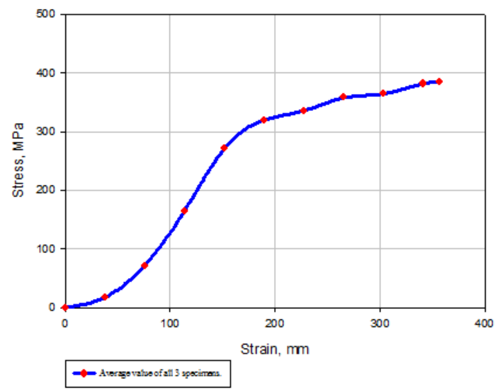

Fig.12 Average Stress-Strain curve of testedBoron (SAE-1042) / Epoxy / Aluminum (6082-t651) Laminated Metal Composite (LMC) for all the 3 tensile Specimens of dimension 350x32x12.

II. CONCLUSIONS.

The tensile specimens from newly developed Boron (SAE 1042)/epoxy/Aluminum (6082 T651)LMC have been investigated. The overall experimental results of all the three tensile specimens clearly indicated the nature of ductility.

a. For specimen no. 1, initially as stress increases to 24 MPa, it does not show considerable increase in length. After this immediately the curve shows a steep rise up to 221.5 MPa, and thereafter as the stress increases the strain rate starts increasing as well. The fracture occurs at an ultimate stress of 384 MPa. As the original length of the specimen was 350 mm, after fracture of specimen the total length remains 357 mm, this indicates the overall elongation of the specimen is 2 %.

b. For specimen no. 2, initially as stress increases to 13 MPa it does not show considerable increase in length.. After this immediately the curve shows a steep rise up to 262.5 MPa, and thereafter as the stress increases the strain rate starts increasing as well. The fracture occurs at an ultimate stress of 357 MPa. As the original length of the specimen was 350 mm, after fracture of specimen the total length remains 360 mm, this means the overall elongation of the specimen is 2.86 %.

c. For specimen no. 3, initially as stress increases to 12.7 MPa it does not show considerable increase in length.. After this immediately the curve shows a steep rise up to 114.39 MPa, and thereafter as the stress increases the strain rate starts increasing as well. The fracture occurs at an ultimate stress of 361 MPa. As the original length of the specimen was 350 mm, after fracture of specimen the total length remains 359 mm, this means the overall elongation of the specimen is 2.58 %.

The overall tensile strength of the three specimens varies varies from 357 MPa to 384 MPa yield strength variesfrom 304 MPa to 316 MPa, an increase in percentage of elongation ranges from 2 % to 2.86 %.
The above results may be improved, if the depth of knurling would increase from 2 mm to 3 mm. It is assumed that the data presented here will be useful to others for development of constitutive theories.

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