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SUSTAINABILITY ANALYSIS OF KEVLAR AND BANANA FIBER COMPOSITE

K.Sudhan[1], S.Deepak[2],R.Karthick[3]

[1,2,3] Assistant Professor, Dept. of Mechanical Engineering, Dhanalakshmi Srinivasan College of Engineering, Tamil Nadu, India

ABSTRACT

Natural fiber reinforced composites is an emerging material that has great potential to be used in various industrial component and applications. It has raised great attention in recent years due to that the composites give a combination of superior mechanical property, dielectric property, and environmental advantages such as renewability and biodegradability. Natural fiber serves as an important option to manmade fibers because they are in large quantities available, cost-effective, recyclable, ecofriendly and have a high mechanical strength .which has less weight and eco-friendly with the energy conservation system. The woven fabric form of fiber is reinforced with epoxy LY556 resin and hardener HY951in different volume ratios by increasing the thickness of fiber material and it is prepared by compression moulding process. This work is to find out the mechanical property like hardness, tensile strength, bend strength, impact and micro structure of the natural fiber reinforced composites and to suit this material for an alternative material for aerospace and ship building industries.

Keywords: Natural Fiber Reinforced composites, Woven fabric, Epoxy resin.

I.INTRODUCTION

Composite materials have been dominant among all emerging materials because of its better mechanical properties. The utilization of composite materials proved that it conquered new markets relentlessly. The mechanical properties of polymers have shortcomings in fulfilling many structural functions. Generally the mechanical strength of polymers is less compared with metals. However such limitations can be overcome by using treated natural fiber reinforced polymeric composites. While focusing on composite materials, the main points to be considered are cost effectiveness and environmental friendliness. The two main phases of composites are, a discontinuous phase called as ‘‘reinforcement’’ and a continuous phase called as ‘‘matrix’’ which is the major constituent of the product. Natural fibers/particle have been extensively used seeing that reinforcements into polymer matrices as an alternative to the commonly used synthetic fillers such as carbon, glass or aramid because of their low-density, good mechanical properties, abundant availability and biodegradability [1]. The use of

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lignocellulosic natural fibers/particles as fillers or reinforcements has been gaining acceptance in commodity polymer applications in the past few years [2,3]. The natural fillers can be obtained from several sources, both from forestry and agricultural assets. Waste from agriculture provides ecological, plentiful, natural materials that serve as fillers for resins, with the benefit of lower cost and improved mechanical properties. Many researchers have been reported on natural filler reinforced thermoplastic composites, which have successfully proved their applicability in various fields [4]. Thermoplastics such as polyethylene (PE), polypropylene (PP) and polyvinylchloride (PVC) enclose subsist compounded with natural fillers such as wood, hemp, banana, coir pineapple leaf, oil palm and banana to prepare composites [4–6]. Athijayamania et al. [1] extracted the roselle and sisal fibers by simple manual water treatment process. The experimental tensile and flexural strength results were compared with the Hirsch theoretical model. Later, Bakare et al. [5]. Silva et al. [7] investigated the tensile properties of the sisal fiber for the different fiber gauge length. Herrera-Franco and Valadez-Gonzalez [8] accomplished that the stress distribution between the fibers and matrix for a short discontinuous fiber were better than the continuous fibers. Igor et al. [9] investigated the significance of phormium (flax fiber)/epoxy laminated composite with short fiber and long fiber. Various chemical compositions of the fibers were compared with the other natural fibers. Jayabal and Natarajan [10] analyzed the tensile, flexural and impact properties of the non woven coir fiber reinforced composites with various fiber lengths and fiber contents. Reinforcing materials generally survive maximum load and serve the desirable properties. The natural fiber composites can be very cost-effective material especially for building & construction industry (panels, false ceilings, partition boards etc.), packaging, automobile & railway coach interiors and storage.

2. Experiments

2.1 Material Selection

In this experiment, for fabricating the composite specimen coir fiber is used. The Raw banana and kevlar fiber is collected form of woven from Erode District, Tamil Nadu, India.

2.1.1 Banana Fabric

Banana is a natural fiber of vegetable origin like linen, jute or hemp Banana is a single fiber entity having an average length of 25-40 mm^2. De-seeded banana is cleaned, spun, and woven into a fabric. Banana is easily spun into yarn as the banana fibers flatten, twist, and naturally link for spinning. It is used to make clothes and other products, like towels**, carpets.** Every part of the banana plant can be used. The long banana **fibers** are used to make **cloth,** the short fibers can be used in the paper industry. Woven fabric is a textile formed by weaving. It is twisted on a loom, and made of many threads woven on a warp. Woven cloth only stretch diagonally on the bias directions. The major end uses for banana fiber including wearing

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apparel, home utensils and other industrial uses (such as medical supplies).There are also possibilities of using waste fiber as fillers in cement, latex and other industrial adhesives.

2.1.2 Kevlar fabric

Kevlar is both a partially artificial fabric, formerly called kevlar rayon, or rayon and a solution of cellulose. The latter is produced by treating dissolving pulp with aqueous sodium hydroxide and carbon disulfide which is used to spin the kevlar rayon. Kevlar rayon fiber is a soft fiber
Commonly used in dresses, linings, shirts, shorts, coats, jackets, and other outerwear. It is also used in industrial yarns (tyre cord).

2.1.3 Polyester resin

Commercially available Epoxy LY556 resin is used for the investigation. The HY951 hardener is used to cure the resin. The Epoxy resin is one of the economical resins when compare to other resins due to its very low water absorbing capability and excellent bonding tendency as well as mechanical properties.

Fig 1.1. Epoxy resin and hardener

Fig 1.2. Die Preparation

3. Manufacturing Processes

3.1.1 Die Preparation

A simple die is made; 200mm×200mm rectangular in shape is taken. It is prepared according to ASTM D 638 for tensile testing.

3.1.2 Compression molding

Compression molding is a method of molding in which the molding material, generally preheated with 110°C, is first placed in an open, heated mold cavity The mold is closed with a top force or plug member, pressure of 30 bar applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured.

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Fig 1.3 Compression molding process

4. Analysis

4.1.1 Tensile test

Specimens of the composites were prepared according to the ASTM D 638 standards. The specimens were machined to a standard size of 12.77mmX10.88mm.The specimens were tested using universal tensile testing machine.

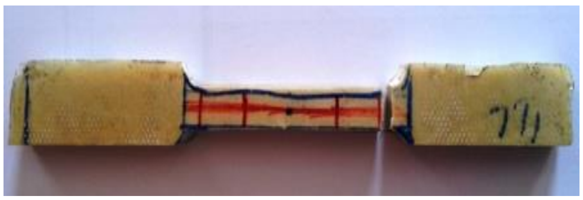

Fig1.4 preparation of tensile test specimen

Fig 1.5. Bending test specimen

4.1.5 Impact test

Izod impact testing is an ASTM standard method of determining the impact resistance of materials 10X10mm and length of 55mm prepared.A V notch cut in the specimen. Impact tests are used in determining toughness of material and it is a factor of ability to absorb energy during plastic deformation.

Fig 1.6 Specimens of izod impact test

5. Results and Discussion

The present work has been undertaken, with an objective to explore the potential of the banana-kevlar fabric polymer composites and to study the mechanical properties of composite. The tensile strength of the specimen with different weight ratio is epoxy resin showed 16.30 KN, 50% of Banana-Kevlar woven material. The average bending strength of specimen was 4 KN; the izod impact test of specimen was 7 Joules.

6. Conclusion

Surface roughness, microstructure of Banana-Kevlar fabric going to be compared with combination of Coir-banana fabrics with addsion of water absorbsion test, Parameter variation on cutting the materials for Surface roughness measure.

References

[1] Bibo GA, Hogg PJ, Kemp M. Mechanical characterization of glass and carbon fiber reinforced composites made with non-crimp fabrics. Composite Science and Technology 1997; 57:1221–41.

2] Bledzki AK, Gassan J. Composites reinforced with cellulose based fibers. Progress in Polymer Science 1993; 24(2):221–74.

[3] Godwin EW, Matthews FL. Review of the strength of joints in fiber-reinforced plastics: part 1 mechanically fastened joints. Composites 1980; 11(3):155–60.

[4] Casaurang M, Herrera P, Gonzalez I, Aguilar VM. Physical and mechanical properties of henequen fibers. Journal of Applied Polymer Science 1991; 43:749–56.

[5] Joseph K, Thomas S. Dynamic mechanical properties of short sisal fiber reinforced low density polyethylene composites. Journal of Reinforced Plastics and Composites 1993;12(2):139–55.

[6] Pothana Laly A, Oommenb Zachariah, Thomas S. Dynamic mechanical analysis of banana fiber reinforced polyester composites. Composites Science and Technology 2003; 63(2):283–93.

[7] Silva Flavio de Andrade, Chawla Nikhilesh, Filho Ramildo Dias de Toledo. Tensile behavior of high performance natural (sisal) fibers. Compos Sci Technol 2008; 68:3438–43.

[8] Short natural-fiber reinforced composites. Composites: Part B 2005; 36:597–608.

[9] Bos HL, Van den oever MJA, Peters OCJJ. Tensile and compressive properties of flax fibres for natural fibre reinforced composites. J Mater Sci 2002; 37:1683–92.

[10] Kuruvilla Joseph, Romildo Dias Toledo, Beena James, Sabu Thomas, Laur Hecker de Carvalho. A review on sisal fiber reinforced polymer composites. Rev Brasi Eng Agricola Ambiental 1999; 3(3):367–7

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most commercially available FMLs are ARALLI, based on aramid fibres and GLARE1 based on high strength glass fibres.

II.METHODOLOGY FOR PREPARING GLARE

The steps involved for the making of the GLARE are:

SURFACE TREATMENTS FOR ADHESIVE BONDING

All the treatments for modification of metal surfaces can be grouped as:
1. Mechanical.
2. Chemical.

Solvent degreasing is important, because it removes contaminant materials which inhibit the formation of the chemical bonds. However, solvent degreasing, while providing a clean surface, does not promote the formation of acceptable surface conditions for longer term bond durability. The degreasing stage usually makes use of chlorinated solvents such as trichloroethylene,1,1,1-trichloroethane, erchloroethylene, or dichloromethane, or alternatively, non-chlorinated solvents including methyl ethyl ketone, methanol, isobutanol, toluene or acetone. All aluminium alloy sheets were initially degreased prior to further surface pre-

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treatment steps. The first step in the fabrication of baseline test specimens was methyl ethyl ketone (MEK)-wiping of aluminium substrates with lint-free tissues to degrease the surface.

MECHANICAL TREATMENT

As a preliminary preparation step in the multi-stage schedules, mechanical abrasion has been used to produce a macro-roughened surface, different roughness level of the surface textures and to remove an undesirable oxide layer, respectively. This method typically involves abrasive scrubbing of the substrate surface with sand paper. This mechanical treatment would introduce physicochemical changes which yield a wettable surface and modify the surface topography, i.e., a macro-roughened surface.

CHEMICAL TREATMENT

The most commonly applied chemical treatments are based on a chromic–sulphuric acid etch. This treatment consists of immersion of the substrate in a solution of sulphuric acid and potassium dichromate. Typically, chemical treatment, i.e., acid etching, is an intermediate production step between degreasing, alkaline cleaning, and electrochemical treatment. Three classical acid-etching solutions were introduced to modify the metallic surfaces: chromic–sulphuric acid (CAE), Forest Product Laboratory (FPL), and sulfo-ferric acid (P2) etches. The most effective etches incorporate mixed chromic and hydrofluoric acids. However, non-chromated acid etchants have been demonstrated to provide good adhesion results. Early experiences in bonding techniques demonstrated that surface treatment prior to bonding is the single most critical step which cannot be disregarded, even for tertiary-loaded structures, since it is essential to achieve long-term service capability. A particular surface treatment tends to modify the substrate surface by delivering the following features: free from contamination; wettable with either primer or adhesive; highly roughened; and mechanically and hydrolytically stable.

BONDING

Bonding procedures of the GLARE are:

1. Measure and mix the epoxy resin with hardener as per requirement. Stir well until the mixture gets smooth and less viscous. Do not let it harden until it is used. So stir in a spiral way until it loses its hardenability.
2. In a table, cover up with a smooth surface such as glass and add wax all over it. The wax is used for non-sticking purpose and fix a thin lamination sheet with the dimensions should be more than the aluminium sheet. Also apply the wax on the lamination sheet.
3. Place the aluminium sheet on the surface of the lamination sheet. With the help of a paint brush, fill the surface of the aluminium sheet with epoxy resin mixture. Cover all the edges properly and do not mix it with the wax.

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4. Take the E Glass fibre (CSM or Woven) and place it on the resin applied aluminium surface. Then again apply the resin on the fibre completely. For mixed GLARE, the first fibre placed is woven and CSM is place above it, then it is placed with aluminium sheet upon it. Each surface is applied with the epoxy resin mixture except the first and top surface of the GLARE.
5. For the normal type 3/2 GLARE the first sheet is aluminium, then covered with resin and fibre (either CSM or Woven), apply resin on the fibre, then upon it aluminium sheet. Again apply resin and place fibre and at last apply the resin on the fibre and place the top aluminium sheet. This is the way of doing for the other type of GLARE.
6. Cover the top of the aluminium sheet with waxed lamination sheet. Do not let the resin to come out.
7. Place the finished laminates in the die according to their size. Tight up the die with bolts and nuts.
8. Remove the die after 24 hours. At this time the epoxy will get setted and bind the aluminium sheets and fibre together.

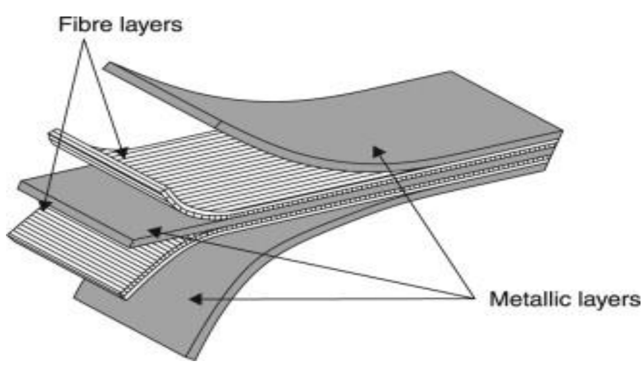

Figure- Lay-up of Metal and Fibre.

I. MATERIAL PROPERTIES

ALUMINIUM (AL 6061)

Aluminium / Aluminium alloys are sensitive to high temperatures. They tend to lose some of their strength when exposed to high temperatures of about 200-250°C. However, their strength can be increased at sub-zero temperatures. They also have good corrosion resistance. Aluminium / Aluminium 6061 alloy is the most commonly available and heat treatable alloy.

The following datasheet gives an overview of Aluminium / Aluminium 6061 alloy.

CHEMICAL COMPOSITION

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The following table shows the chemical composition of Aluminium / Aluminium 6061 alloy.

ELEMENTS	CONTENT (%)
Aluminium / Aluminium, Al	97.9
Magnesium, Mg	1
Silicon, Si	0.60
Copper, Cu	0.28
Chromium, Cr	0.20

PHYSICAL PROPERTIES

The physical properties of Aluminium / Aluminium 6061 alloy are outlined in the following table.

PROPERTIES	METRIC	IMPERIAL
Density	2.7 g/cm^3	0.0975 lb/in^3
Melting point	588°C	1090°F

MECHANICAL PROPERTIES

The mechanical properties of Aluminium / Aluminium 6061 alloy are tabulated below.

PROPERTIES	METRIC	IMPERIAL
Tensile strength	115 MPa	16680 psi
Yield strength	48 MPa	6962 psi
Shear strength	83 MPa	12038 psi
Fatigue strength	62 MPa	8992 psi
Elastic modulus	70-80 GPa	10153-11603 ksi
Poisson's ratio	0.33	0.33
Elongation	25%	25%
Hardness	30	30

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MACHINABILITY

Aluminium / Aluminium 6061 alloy has good machinability in harder T4 and T6 tempers. It can be machined in annealed temper.

FORMING

Aluminium / Aluminium 6061 alloy can be easily formed and worked in the annealed condition. The standard methods are used to perform bending, stamping, deep drawing, and spinning operations.

WELDING

Aluminium / Aluminium 6061 alloy has excellent weldability. Thinner sections can be welded using gas tungsten arc welding technique. Heavier sections can be welded using gas metal arc welding technique. Alloy 4043 filler wire can be used to achieve good result, but it will affect T 6 properties.

E GLASS FIBRE CSM

E-Glass or electrical grade glass was originally developed for stand-off insulators for electrical wiring. It was later found to have excellent fibre forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as Chopped Strand Mats of fiberglass.

E GLASS FIBRE WOVEN

E-Glass Woven is made from continuous glass fibre roving which are interlaced into heavy weight fabrics. Or we can say that Woven Roving is a bidirectional fabric made by interweaving direct roving in plain weave pattern. It is compatible with most resin systems. With Woven Roving as a general rule estimate the resin/reinforcement ratio at 1:1 by weight. Woven Roving is available in a variety of weaves, weights, widths and finishes to suit a wide range of applications.

II. DESIGN OF FML

In the design of fibre metal laminates, the design might changes according to the place of applications. The place where these composites are used, requires a very distinct set of properties. So the design considerations are made as per the requirement. Fibre metal laminates (FMLs) are materials that have composite layers sandwiched between metal layers. These composite layers typically consist of fibres embedded in an adhesive system.

Glass Laminate Aluminium Reinforced Epoxy (GLARE) is a very popular FML, especially in Europe. For this report, some background research was first conducted to study GLARE, which included its history, construction, features and properties. Next, an experimental investigation was carried out to determine how this material behaves mechanically and to compare its properties to conventional aircraft grade aluminium alloys. Microscopy examination and tensile testing provided important information about the material

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III. LITERATURE SURVEY - COMPOSITE MATERIALS

1. Y.D DWIVEDI**,** conducted the experiment on cost effective composite materials

An increase in the application spectrum of composite materials necessitates cost effective high quality rapid processing in order to meet stringent design as well as market requirements. Material selection has become one of the major problems in aviation. The objective of the current study is to compare the bending strength of Glass Fibre Reinforced Polymer (GFRP) with the conventional material of aviation industry (ie., aluminium). The deflection test was performed on standard bending test equipment by applying the concentrated loads on the cantilever specimens, which were made of Glass Fibre Reinforced Polymer fabricated by hand layup technique and the Aluminium specimen was made and supplied with the test equipment. On performing the bending test it is observed that aluminium shows promising results where high modulus of elasticity is considered and the GFRP is found to be the cheap and best material where lower weight is considered and young's modulus of material is of low importance.

IV. NEW FABRICATION

The arrangement are differently vary from the previous type of composite materials. Three different configurations we used.

3/2 LAYER
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure- construction of 3/2 layer

4/3 LAYER

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Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure-4/3 construction layer.

5/4 LAYER
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy
Epoxy/ Glass
Al alloy

Figure- 5/4 construction layer.

V.

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VI. RESULT

TENSILE TEST RESULT

The tensile strength are provided here in Mpa

GLARE	3/2 SEQUENCE	4/3 SEQUENCE	5/4 SEQUENCE
CSM EPOXY	76.3719	80.8163	85.2617
WOVEN EPOXY	125.7619	135.47	150.1646
MIXED EPOXY	80.8526	88.7874	94.6612

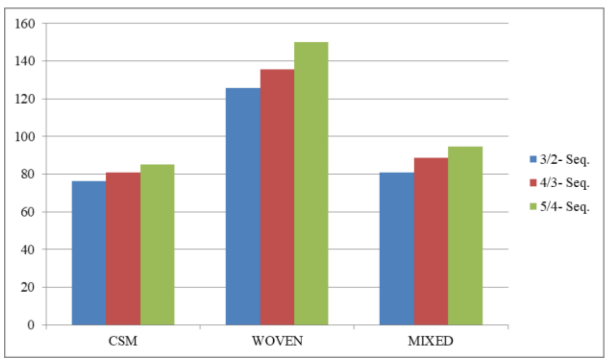

Figure-1. Bar Chart for Tensile Test Result

FLEXURAL TEST RESULT

The bending strength are provided here in Mpa

GLARE	3/2 SEQUENCE	4/3 SEQUENCE	5/4 SEQUENCE
CSM EPOXY	624.372	686.8163	722.2617
WOVEN EPOXY	788.762	868.47	912.1646
MIXED EPOXY	652.853	712.7874	742.6612

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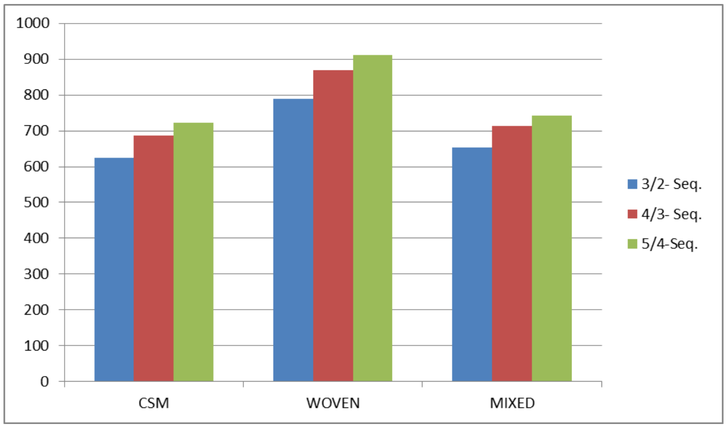

Figure-2. Bar Chart for Flexural Test Result

VII. APPLICATIONS

APPLICATION

- Marine vehicles
- Road Vehicles for high speed and low weight.
- Aerospace application.

VIII. ADVANTAGES AND DISADVANTAGES

ADVANTAGES

1. Lightweight: High static strength of GLARE contributes to weight saving over the aluminum.
2. High strength: It is apparent that the GLAREs reinforced with unidirectional glass fiber have anisotropic properties. This glass fiber contributes to increase in static strength and elastic modulus in the longitudinal direction along which the glass fiber is oriented. On the other hands, the aluminum sheets control overall mechanical properties of GLAREs in the transverse direction.
3. GLARE reduced the overall structural member weight by 20-50%.
4. GLAREs are good in corrosion and fatigue resistance.
5. GLARE Composites have lower assembly costs because it requires very few fasteners, bolts etc.

DISADVANTAGES

1. GLARE have high recurring costs.
2. GLARE have higher materials costs.
3. GLARE have very expensive repairs and maintenance.
4. GLARE needed isolation to prevent adjacent aluminium part galvanic corrosion.
5. GLARE will delaminate eventually, if not manufactured properly.

IX. CONCLUSION

The specimens are compared with each other on basis of the results provided, they are:

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1. The GLARE made with Woven Fibre has the highest flexural and tensile strength out of the three variants and the three sequences.
2. The GLARE made with Mixed Fibres holds the second position in this test.
3. The GLARE made with CSM Fibre has the least strength among the three types and sequences.

There are many variables that can be altered to improve GLARE properties. Those variables include but are not limited to different adhesives, different types of fibreglass, other metals and improved fabrication processes. This opens up countless possibilities for improvement

X. REFERENCES

[1] Roebroeks, G. H. J. J., Glare features, Vlot, A., and Gunnink, J. W., Fibre Metal Laminates an introduction, Kluwer Academic Publishers, The Netherlands, 2001, 23-37.

[2] Y.D Dwivedi, Sweta Dwivedi , A. Jyothsna, A. Puneeth Kumar Comparative Study on Aerospace Conventional Engineering Material and Glass Fibre Reinforced Polymer - An Experimental Approach

[3] Vlot, A., Historical overview, Vlot, A., and Gunnink, J. W., Fibre Metal Laminates an introduction, Kluwer Academic Publishers, The Netherlands, 2001, 3-21.