Introduction to Composite Materials, Glass Fibres and Adhesive bonding, A Review Article

Banda Venkata Prashanth

Mr Akash Gupta, professor in Lovely Professional University, Jalandhar, Punjab.

Department of mechanical engineering, student and faculty, Lovely Professional University, Jalandhar, Punjab.

Abstract: Composite materials are playing a vital role in engineering applications. Their unique properties and adaptability to various conditions are attracting many industries to manufacture innovative components. Light-weighted composites are having high demand in the manufacturing sectors. Usage of Adhesives, laminates, glass fibres is also very useful in the preparation of the composite material. Usage of different adhesive joints gives high mechanical strength to the component and gives high strength and resistance to damage impact.

This review paper gives information about composite materials, laminates, Glass reinforced polymers and adhesive joints.

Keywords: Composites, Bonded joints, Adhesives, Glass Fibres

1 Introduction:

Composite materials are those useful materials that are combined with two or more materials on a macroscopic scope. These are can be seen through the naked eye. A well designed composite material has good strength, stiffness, corrosive resistance, fatigue life and other properties. These composite materials do not dissolve or merge into each other. Composite materials are used very widely all over the world because of their good adaptability to sustain in any situation and ease of combination with other components or materials which exhibit required properties[1]. As these materials have high strength and stiffness with less density when compared to bulk materials is the main advantage.

1.2 Classification of Composite Materials:

Matrix and Reinforcement are two constituents present in the material.

Matrix is further divided into many phases

- **Polymer Matrix Composite (PMC):** It is composed of different short or continuous fibres which are combined to form an organic bond. These help to transfer the load between the fibres of the matrix. Lightweight, strength and stiffness are very high can be considered as the main advantage.[2]
  A **Thermosetting polymer** is also called the thermoset, a three-dimensional body or structure after the curing. It is obtained from an irreversible hardening process by curing it of a viscous polymer.[3] Thermosets are divided into many others such as epoxies, polyurethanes, phenolic and epoxy is most widely used.
  A Thermoplastic polymer has a one or two-dimension structure and plays a small part in the polymer industry. These are non-reactive materials where there is no chemical reaction required only temperature and pressure to process the final component[4]. These can be reheated and can be changed into another shape where it is not possible in the thermosets.
- **Metal Matrix Composite (MMC):** It is a composite material that has one metal compulsory and any other materials such as organic or ceramic compounds[5]. It is called a hybrid composite when it consists of three materials. These are used in engineering applications and their temperatures vary from 250 C to 800 C. Steel, Titanium, Aluminium, Super alloys, Magnesium can be considered as the matrix materials.

- **Ceramic Matrix Composite (CMC):** Ceramics are made from ceramic fibres embedded in a ceramic matrix. Carbon, Alumina, Silicon Carbide are used as reinforcing materials to form ceramic. These have a high melting point, very high compressive strength and their temperature vary between 800 C to 1650 C.[6]
- **Carbon/Carbon Composite Matrix:** These contain carbon fibres and good resistivity even in high temperatures. Due to this these are widely used in aerospace industries. Carbon yarn fabric, 3-D woven fabric and others are reinforced materials for this matrix.[7]

1.3 Functions of Matrix:

- It holds the fibre together
- It protects on damaging of fibre from environmental conditions.
- Uniform load is distributed so that strain is subjected to equal amounts.
- Fracture and impact resistance of the component is increased.

1.4 Properties of Matrix:

- Moisture absorption is reduced.
- The coefficient of thermal expansion is low
- Chemical resistance is high.
- Shrinkage is very less.

1.5 Reinforcements:

Reinforce material is added to the matrix to enhance the physical and chemical properties of a composite material.[8]

- **Fibre Reinforced Composites:** Fibres are very useful and very important in a class of reinforcement. It is made up of a polymer matrix that is reinforced with fibres. The most commonly used fibres are glass, aramid and carbon other fibres like paper, wood is used rarely.
- **Laminar Composite:** These are the combination of the number of materials and have different grain or fibre orientations.
- **Particulate Reinforced Fibre:** It is less effective on strengthening when compared to fibre reinforcement. The particles of ceramics and metals which strew in a phase are called particulate reinforced fibre.
- **Flake composites:** These contain flat reinforcement matrices and glass, silica, mica, silver are flake materials. Metal flakes conduct electricity whereas glass and mica have the resistance of both. These are less in cost compared to fibres.
- **Filled composites:** These are irregular in shape and is a mixture of thermoset or thermoplastic granules.

1.6 Factors affecting the composites:

- Size
- Shape
- Orientation
- Arrangement of reinforcements

1.7 Advantages:

- These are light in weight and low density
- Creep resistance is high
- Properties of fatigues are very high than other materials
- Corrosion will not take place like steel
- Resistance is very high for damage impact.
- Easy to fabricate large complex structures or shapes.

1.8 Limitations:

- Raw materials and fabrication cost is very high
- Properties of transverse may be weak
- Fluctuation in cost
- Difficult to reuse

2. Laminates:

A lamina has a thickness of 0.125mm it is a thin layer of a composite material. A laminate is constructed by the arranging number of laminae in the thickness direction.

Laminate -Structure made of multiple layers (laminae)

Symmetric laminate -For each layer above the mid-plane, there is an identical layer at the same distance below the midplane.[9]

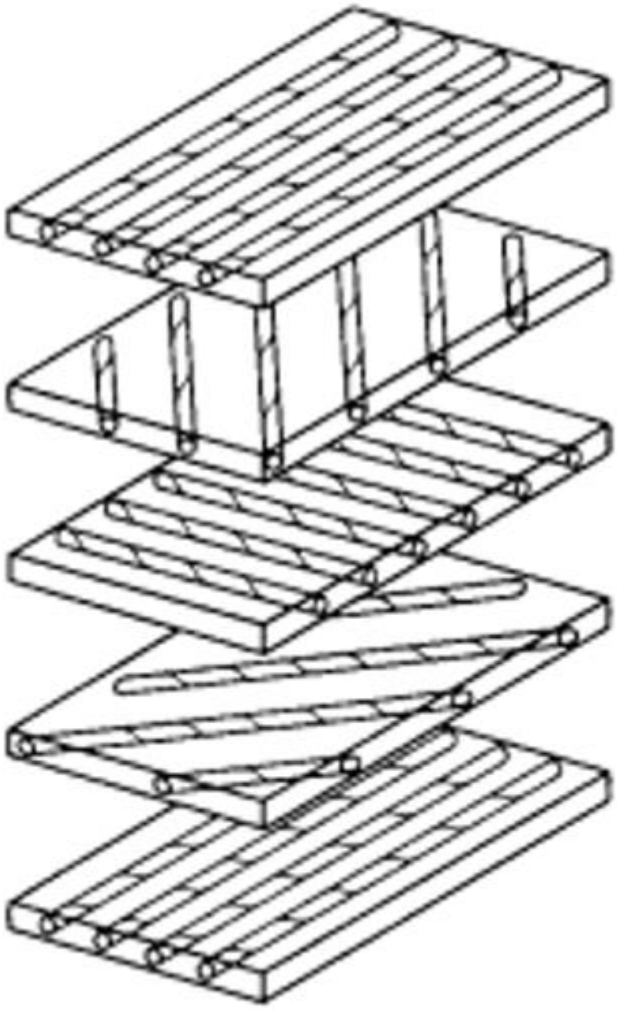

Figure2: Shows how laminate is formed by different layers.

3. Glass Reinforced Polymer

Glass Reinforced Plastic (GRP) is a composite material, is a combination of polymer matrix and glass fibres. The polymer matrix is an epoxy, vinyl ester, or polyester thermosetting resin. The resin is the binder for the fibres in the structural laminate and defines the form of a GRP part. The glass fibres add strength to the composite materials. They may be randomly arranged or oriented accordingly[10]. The most common type of glass fibre used for GRP is E-glass, which is alumina-borosilicate glass.

As with many other composite materials, the two materials combine to form a stronger bond. Resins made up of plastic are strong in compressive loading while the glass fibres are very strong in tension. By combining both of them Glass Reinforced Polymer becomes a material that resists both compressive and tensile forces**.**

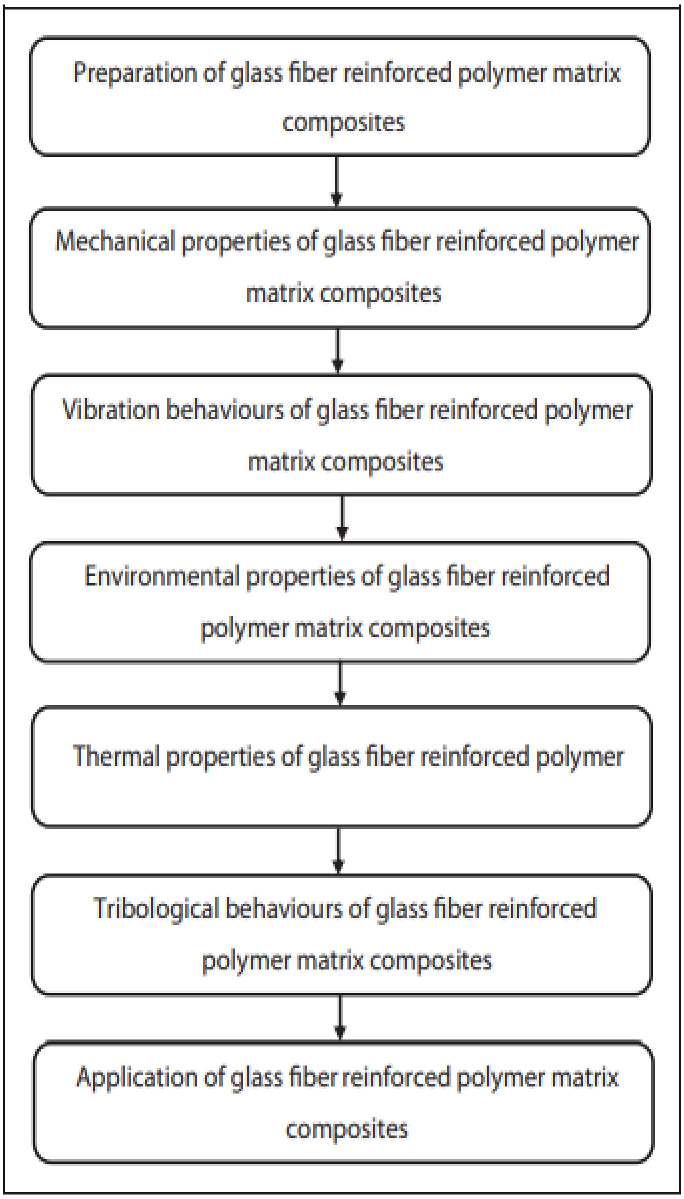

Figure 3 Showing flowchart of the GFRP matrix composites preparation

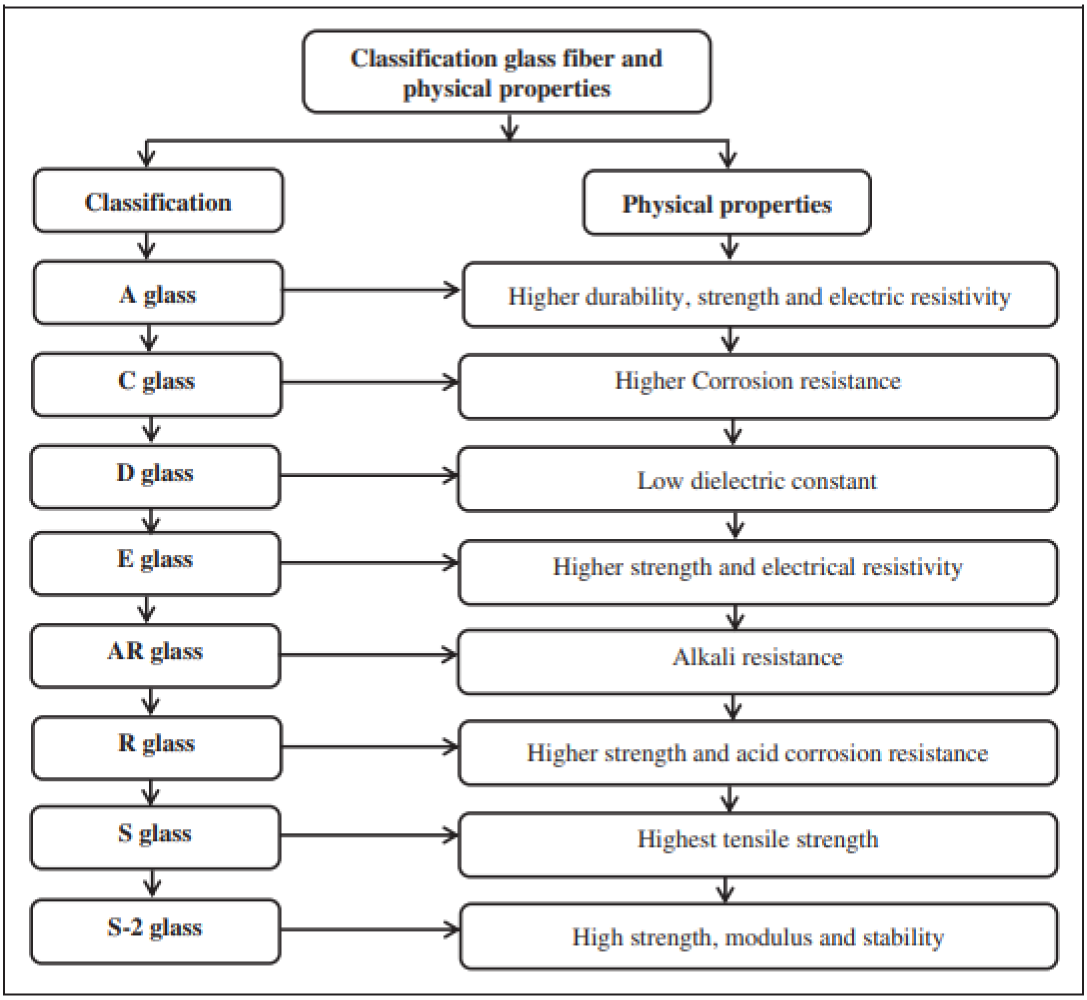

Figure 3.1 Classification of glass fibres

3.1 Types of Glasses

- **A Glass**: It is manufactured with alkali glass and also known as soda-lime glass. It helps in making jars, bottles etc. It is chemically stable, very hard and inexpensive. This type of glass can be melted many times.
- **C Glass**: Chemical glass shows the high resistivity of chemical reactions. Calcium borosilicate is present in high quantity in this type of glass. Pipes and tanks which are used to store chemicals are examples.
- **D Glass**: Due to the presence of boron trioxide in its composition, this glass is known as a low dielectric constant.[11]
- **E Glass**: It is called Electric glass. It is widely used in aerospace and other industries because of its lightweight and electrical resistance property.
- **AR Glass**: Alkali resistant glass used in concrete. It prevents cracking and provides flexibility and strength to the concrete. It does not rust like steel and has high tensile strength.
- **R Glass, S Glass, T Glass**: These are similar type of fibreglass having high tensile strength and modulus when it is compared to the E glass. These glasses are used in only specific industries so their cost is high.
- **S2 glass**: It has more silica when compared to other glasses and it has properties like better weight, high impact strength and temperature resistance.

3.2 Applications:

Electronics: GRP is being widely used for circuit board manufacture (PCB's), TVs, radios, computers, etc.

Home and furniture: Roof sheets, bathtub furniture, windows, sunshade, shoe racks, book racks, tea tables, spa tubs etc.

Aviation and aerospace: GRP has been broadly utilized in flight and aviation however it isn't generally utilized for essential airframe development, as there are elective materials that better suit the applications. Common GRP applications are motor cowlings, baggage racks, instrument walled in areas, bulkheads, ducting, capacity canisters and receiving wire nooks. It is likewise generally utilized in ground-taking care of the hardware.

Boats and marine: its properties are unmistakably fit boat development. Even though there were issues with water assimilation, the advanced tars are stronger and they are utilized to make the basic sort of boats. Truth be told, GRP is lower weight materials contrasted with different materials like wood and metals.

Medical: As a result of its low porosity, non-staining and hard-wearing completion, GRP is generally fit for clinical applications. From instrument fenced in areas to X-beam beds (where X-beam straightforwardness is significant) are comprised of GRP.

Automobiles: GRP has been widely utilized for vehicle parts like body boards, seat cover plates, entryway boards, guards and motor cover[12]. Be that as it may, GRP has been broadly utilized for supplanting the current metal and non-metal parts in the different applications and tooling costs are generally low as contrasted and metal congregations.

4. Adhesive joints

Adhesive bonding is a joining process of material where an adhesive is placed in between the body to make it solid which produces an adhesive bond. These are widely used alternatives in the engineering field for mechanical joints and has many more advantages than mechanical fasteners. These have very high improved damage tolerance, weight and fabrication cost is less compared to others.

Bonded joints have high flexibility, strength-to-weight ratio, high toughness and ease of fabrication. These are widely used in the aerospace, automotive and electrical industries. These joints have a frequent cyclic load applied to them.[13] In the bonding process, preparation of the surface is very important because it shows the quality of the adhesive. Proper surface treatment helps increase mechanical strength.

4.1 Adhesives which used in components have

- **Epoxies** have high resistance to temperature and strength
- **Cyanoacrylates**, bonds very fast to rubber and plastic materials but their resistance is very poor for temperature and moisture.
- **Anaerobic**, used for fastening and sealing applications without the use of light, heat or oxygen.[14]
- **Acrylics**, these adhesives have the capabilities of fast curing and tolerate worst and less prepared surfaces.
- **Polyurethanes**, it has high flexibility at low temperatures and also resistant to fatigue, impact resistance, and durability.
- **Silicones,** best sealant for low-stress components, flexibility is high and has very high resistance to temperature.
- **Phenolics** retains strength in a short period, thermal shock resistance is limited.
- **Polyimides,** high in thermal stability, dependent on various factor.
- **Bismaleimides,** it is very rigid with low peel properties.

4.2 Environmental factors of adhesive joints:

Adhesive joints are exposed to various environmental or climatic conditions which can reduce their service life when they are affected or exposed to harsh environments. Temperature and humidity are considered as the main factor that can cause damage to the joint. [15]Within the temperature rise, the strength of a bond is decreased and the moisture which is absorbed by the joints can lead to other damaging effects. The surface preparation and joint preparation should be done carefully keeping all these factors.

4.3 Failure Modes:

Adhesive selection: A perfect adhesive must be selected depending on its environmental effects, lifetime or durability of the adhesive.

Environmental factors: If the adhesive is selected properly, but the sudden change in the environmental conditions such as heat, cold, moist can damage the bond.

Surface preparation: Cleanliness must be taken very important factor while preparing the surface. Any contact with dirt, oil and others leads to damage in the bonding.[16]

Improper curing: Curing should be done perfectly as how time, airflow, and pressure is utilised in the process.

Lack of Strength and Elasticity: Selection of required adhesive with high strength and flexibility is very important.

5. Conclusion

- Composite materials have the best chemical, mechanical, electrical properties which help the industries to manufacture innovative components.
- There is a lot of scope for composition materials in many industries such as automobile, civil, aerospace and others. So there are many chances for the invention of new materials.
- Composite materials are very strong, light-weighted, the life cycle is high and they are resistant to corrosiveness.
- Glass fibres are a very important material widely used as reinforcement fibre have a lot of scope in future for their different resistant properties.
- Adhesive bonding has the best fatigue strength, absorbs shocks and vibrations used in material manufacture.

6. References:

[1] G. Gupta, A. Kumar, R. Tyagi, and S. Kumar, “Application and Future of Composite Materials : A Review,” *Int. J. Innov. Res. Sci. Technol.*, vol. 5, no. 5, pp. 6907–6911, 2016.

[2] R.-M. Wang, S.-R. Zheng, and Y.-P. Zheng, “Introduction to polymer matrix composites,” *Polym. Matrix Compos. Technol.*, pp. 1–548, 2011, doi: 10.1533/9780857092229.1.

[3] J. P. Pascault and R. J. J. Williams, “Thermosetting Polymers,” *Handb. Polym. Synth. Charact. Process.*, pp. 519–533, 2013, doi: 10.1002/9781118480793.ch28.

[4] G. R. E. Mărieş and A. M. Abrudan, “Thermoplastic polymers in product design,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 393, no. 1, 2018, doi: 10.1088/1757-899X/393/1/012118.

[5] M. Haghshenas, “Metal–Matrix Composites,” *Ref. Modul. Mater. Sci. Mater. Eng.*, no. October 2015, pp. 0–28, 2016, doi: 10.1016/b978-0-12-803581-8.03950-3.

[6] J. Mukerji, “Ceramic matrix composites,” *Def. Sci. J.*, vol. 43, no. 4, pp. 385–395, 1993, doi: 10.14429/dsj.43.4292.

[7] R. Taylor, S. B. Venkata Siva, and P. S. Rama Sreekanth, *Carbon matrix composites*, no. January. Elsevier Ltd., 2017.

[8] D. K. Rajak, D. D. Pagar, R. Kumar, and C. I. Pruncu, “Recent progress of reinforcement materials: A comprehensive overview of composite materials,” *J. Mater. Res. Technol.*, vol. 8, no. 6, pp. 6354–6374, 2019, doi: 10.1016/j.jmrt.2019.09.068.

[9] O. Mohammed and E. Suleiman, “Theories on Laminated Composite Plates Dedicated To the Memory of My Mother Khadra Author Assistant Professor : Osama M . Elmardi June 2017,” no. June, 2017.

[10] T. P. Sathishkumar, S. Satheeshkumar, and J. Naveen, "Glass fiber-reinforced polymer composites - A review," *J. Reinf. Plast. Compos.*, vol. 33, no. 13, pp. 1258–1275, 2014, doi: 10.1177/0731684414530790.

[11] A. Cevahir, "Glass fibers," *Fiber Technol. Fiber-Reinforced Compos.*, no. December 2017, pp. 99–121, 2017, doi: 10.1016/B978-0-08-101871-2.00005-9.

[12] N. S. Seksaria, A. Ganju, and S. K. Agarwal, "Glass fibre," 1972.

[13] A. Gursel and H. M. Cekirge, "Adhesive Joints Subjected to Impact Loading: A Review," *Int. J. Mater. Eng.*, vol. 9, no. 1, pp. 16–21, 2019, doi: 10.5923/j.ijme.20190901.03.

[14] S. Budhe, M. D. Banea, S. de Barros, and L. F. M. da Silva, "An updated review of adhesively bonded joints in composite materials," *Int. J. Adhes. Adhes.*, vol. 72, no. October 2016, pp. 30–42, 2017, doi: 10.1016/j.ijadhadh.2016.10.010.

[15] D. R. A. Carvajal, R. A. M. Correa, and J. P. Casas-Rodríguez, "Durability study of adhesive joints used in high-speed crafts manufactured with composite materials subjected to impact fatigue," *Eng. Fract. Mech.*, vol. 225, no. September 2018, pp. 0–1, 2020, doi: 10.1016/j.engfracmech.2019.03.016.

[16] A. Gursel, "Adhesion Mechanism and Failure Modes in Adhesively Bonded Joints," *Int. Conf. Mater. Sci. Technol. Kızılcahamam/ANKARA*, no. October, pp. 108–114, 2019.