

Manufacturing of Kevlar-Mg AZ31B Alloy Sandwich Composite

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Abstract –In this research manufacturing of the Kevlar-Mg AZ31B sandwich composite is done. Sandwich is prepared using Kevlar fiber and Mg AZ31B alloy. This sandwich composite is manufactured by Vacuum Assisted Resin Transfer Moulding (VARTM) method. This method uses the vacuum and pressure difference causes the bonding of fiber-metal surface using epoxy resin. In this sandwich composite Mg AZ31B alloy act as core material and Kevlar fiber as a face skin. This fiber-metal sandwich composite will have enhanced mechanical properties than core material.

Key Words: Kevlar, Mg AZ31B alloy, Sandwich composite, VARTM.

1. INTRODUCTION

In last few decades the use of various composite materials is increased tremendously. Various types of composites are present the world having different and better properties than conventionally used materials. In present era Sandwich composites are evolved as a new composite material having great strength. Typical sandwich materials always exhibit a particular fundamental pattern of two faceplates (facings), which are comparatively thin but of high strength and stiffness, enclosing a core structure. Core is relatively thick but light-weight, and possesses sufficient stiffness in the direction normal to the plane of the faceplates. The components of the sandwich material must also be bonded together, using either adhesives or mechanical fastenings, such that they can act as a composite load-bearing unit. In principle, the basic concept of a sandwich panel is that the faceplates carry the bending stresses whereas the core carries the shear stresses.

There are many methods for manufacturing the sandwich composites like hot press moulding, vacuum bagging and autoclaving, Resin Transfer moulding, Vacuum Assisted Resin Transfer Moulding, Wet Lay-up method etc. The components of the sandwich material must also be bonded together, using either adhesives or mechanical techniques. As a result, they can act as a composite load-bearing unit. The scope of the work is to develop the Kevlar – Mg AZ31B alloy sandwich composite using vacuum assisted resin transfer moulding method. In this method vacuum is created by means of vacuum pump in the vacuum bag. Due to this pressure difference is created between atmosphere and inside the vacuum bag which

is responsible for bonding of fiber to metal. Resin is blown into the material and curing is taking place by the time. VARTM process is used to make sandwich composites of different varieties and shapes. As this method produces nearly zero voids in sandwich composite, the strength of material also increases.

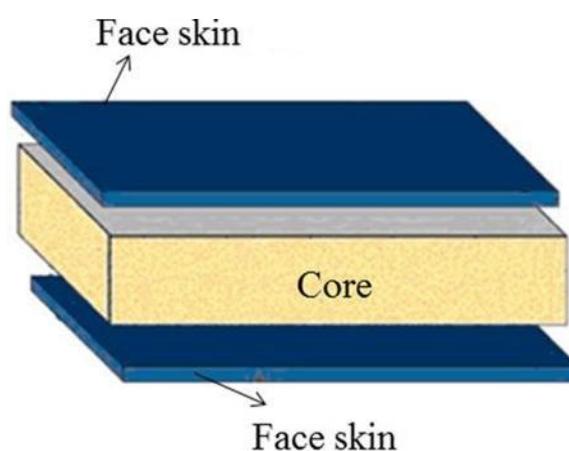


Fig-1: Schematic of sandwich composite

Kicki F. Karlsson and B. Tomas AstrGm [1] stated the different methods of manufacturing the sandwich composites. Methods such as wet lay-up, adhesive bonding, resin transfer moulding, vacuum bagging are explained with their applications and advantages. They also stated the feasibility of methods to be used for particular applications. Singh et al. [2] from their work, it is clear that the metal matrix plays a crucial role in industrial applications due to its unique properties. The unique properties of MMCs are excellent strength to weight ratio, dimensional stability, high specific stiffness. Among various type of MMCs, aluminium metal matrix is very common in various application due to low weight matrix of aluminium. They presented manufacturing techniques of metal matrix composites (MMCs). They also studied desired properties of MMCs can be achieved with the shape and type of reinforcing materials along with their physical conditions. Kuo et al. [3] they fabricated low density and high-performance Mg based laminated composites by means of sandwiching the AZ31 Mg foils with the carbon fiber/polyether ether ketone and prepared through hot pressing. They stated that, proper surface treatments of AZ31 sheet using CrO₃ base etchants are necessary in order to achieve

good interface bonding characteristics. Mg base laminated composite having low density of 1.7 Mg/m³, high modulus of 75 GPa and tensile strength of 932 MPa along the longitudinal direction. Faidzi et al. [4] in their research article they reviewed the evolution of sandwich panels based on recent work and older source and they focused on the trends concerning sandwich panel achievements and applications. The main factors that contribute to the failure phenomena experienced by sandwich panels, such as geometries of core design, different configuration of core design, the adhesive interaction effect between the bonding layers of sandwich panels and the effect of sandwich panels under high-speed impact and blast loading are considered. Rajak et al. [5] studied that fiber-reinforced polymer composite offers not only high strength to weight ratio but also have exceptional properties such as high durability, stiffness, damping property, flexural strength and resistance to corrosion, wear, impact, and fire. They said that, fiber-reinforced composite material was found to be one of the most promising and effective types of composites. Composite structures have shown improvement in strength and stiffness of material, while the reduction in weight is magnificent. Mohamed et al. [6] manufactured the glass fiber-based sandwich composite structure using vacuum assisted resin transfer moulding (VARTM) process. Then they evaluated the stiffness, load-carrying capacity and compressive strength of manufactured glass fiber sandwich composite. Also, they have performed the FEA of flexural test for validation of experimental results. Yoon et al. [7] studied the VARTM process and stated that this process is suitable for manufacturing large scale sandwich composites. They studied gravitational effect on flow during the process. Also, they considered nondimensional process parameters in terms of the resin fill time, mold angle, permeability, radius and length of injection tubes, and preform cross-sectional area for horizontal, downward, and upward injection situations. Jun Hee Song [8] manufactured the composite material using carbon nanofibers and glass fibers. This composite is made using epoxy resin with two different pore sizes of 45 and 50 micrometer. Author prepared the composites of different thicknesses ranging from 4 to 10 mm. Researcher used Vacuum Assisted Resin Transfer Moulding (VARTM) method for the preparation of composite material. In this research study author also investigated the process parameters and integrity of composites.

2. MATERIAL

In this research the sandwich composite is developed, in which Mg AZ31B alloy is sandwiched between Kevlar fiber sheets. Mg AZ31B alloy is light weight material and having good strength to weight ratio. Kevlar fiber is also a strong fiber having good mechanical strength. This sandwich is developed using Vacuum Assisted Resin Transfer Moulding method. In this method uniform atmospheric pressure is used to make

sandwich of fiber metal using resin. Epoxy resin LY556 and Hardener HY951 is used to bind Fiber and metal homogeneously to make sandwich composite. Epoxy resin is used with hardener in the ratio of 10:1. Size of plate is 300 x 300 mm.

Mg AZ31B is a wrought magnesium alloy with good room-temperature strength and ductility combined with corrosion resistance and weldability. AZ31B finds application in wide variety of uses including aircraft fuselages, cell phone and laptop cases, speaker cones and concrete tools. AZ31B can be superformed at elevated temperatures to produce a wide variety of intricate components for automotive uses. Magnesium AZ31B alloy is mixture of magnesium (the lightest structural metal) with other metals, often as aluminium, zinc, manganese, silicon, copper, iron and nickel. Magnesium AZ31B alloy means it contains Aluminium of approximately 3% and Zinc of approximately 1%. Following table shows the chemical composition of Mg AZ31B alloy.

Element	Content %
Aluminium	3.15
Zinc	0.98
Manganese	0.33
Silicon	0.009
Iron	0.002
Copper	0.008
Nickel	0.0086
Magnesium	Balance

Table -1:Chemical composition of Mg AZ31B alloy

Magnesium AZ31B alloy is available in different forms such as plate, sheet, and bar. It is an alternative to aluminium alloys as it has high strength to weight ratio. It is widely available when compared to other magnesium grades. Following figure shows the plate of Mg AZ31B alloy.



Fig-2: Magnesium AZ31B alloy

Kevlar Aramid fiber is used to make a variety of clothing, accessories, and equipment safe and cut resistant. It's lightweight and extraordinarily strong, with five times the strength of steel on an equal-weight basis. Best known for its use in ballistic and stab-resistant body armour. Aramid fibers have unique properties that set them apart from other fibers. Aramid fiber tensile strength and modulus are significantly higher than those of earlier organic fibers and fiber elongation are lower. Aramid fibers can be woven on fabric looms more easily than brittle fibers such as glass, Carbon or ceramic. They also exhibit inherent resistance to organic solvents, Fuels, lubricants and exposure to flame. Following figure shows the Kevlar fiber mat used in sandwich composite.



Fig-3: Kevlar fiber mat

Adhesives based on synthetic resins and rubbers excel in versatility and performance. Synthetics can be produced in a constant supply and at constantly uniform properties. In addition, they can be modified in many ways and are often combined to obtain the best characteristics for a particular application. When considering the effectiveness of an epoxy adhesive, it is useful to analyze the general formulation of the compounds that constitute it. Epoxies are created by polymerizing a mixture of two starting compounds, the resin and the hardener. When resin is mixed with a specified catalyst, curing is initiated. Curing is the process, by which molecular chains react at chemically active sites, resulting in an exothermic reaction. Covalent bonds between the epoxide groups of the resin and the amine groups of the hardener that arise from this combination afford for the cross linkage of the polymer, and thereby dictate the rigidity and strength of the epoxy. In this project we have used the Epoxy resin LY556 and Hardener HY951 in the ratio of 10:1 for better strength.

This resin is cured at room temperature having curing time of 24 hours. This is low viscosity resin and it is easily flow into the material to be pressurized. It is very important while preparing the resin mixture that hardener is mixed well and added in the exact proportion. If resin and hardener is not mixed well and are not in proper proportion there may not be bonding of fiber-metal structure.

3. VACUUM ASSISTED RESIN TRANSFER MOULDING (VARTM)

There are many methods for manufacturing the fiber metal sandwich composites. Many sandwich composites are prepared using autoclave and hot pressing technique. But in hot pressing technique as sandwich structure is pressed at higher temperature some fibers may withstand after curing but fiber-metal sandwich composites are not making bonding may of time. In this process after pressing the sandwich structure face skin i.e. Kevlar fiber in our case is not attached to the core material i.e. with Mg AZ31B alloy very well. After some time, fibers leave the surface of metal by absorbing moisture in the air. Therefore, voids are also generated during the preparation of sandwich composite.

VARTM is a liquid composite moulding closed mould process with a single side tool and vacuum bag where the resin is drawn through the preform using vacuum. Instead of fully enclosing with two stiff molds in a process such as resin transfer moulding, only one rigid mold and a vacuum bag are comprised in a typical VARTM setup. A resin is introduced to the mold through injection pipes and the reinforcements and core materials contained in the mold are filled with the resin via vacuum. In addition, a high permeable layer enhancing the flow along with a peel ply for making possible disposal are other critical components of the VARTM process.

Vacuum Assisted Resin Transfer moulding (VARTM) is widely used method for preparation of sandwich composites. With the use of this method anyone can make the sandwich composite from small to large size. In this method vacuum is created using vacuum bag and resin is transferred into the vacuum bag containing material to be sandwiched. Due to vacuum inside the bag uniform pressure is exerted on material and resin is absorbed by fiber and metal which ultimately resulted in sandwich composite material. With the help of this method we can make desired sandwich composite by varying mould size and shape.

Vacuum Assisted Resin Transfer Moulding (VARTM) is basically low pressure closed moulding method. This method mainly used in automotive, marine, aircraft industries. In this method firstly, metal plate is cleaned using acetone to remove dirt and foreign particles on the surface. Then material to be sandwiched is placed inside the vacuum bag. Then due to

pressure difference created, resin is blown into the vacuum bag and responsible for bonding. Following figure shows the schematic representation of VARTM process.

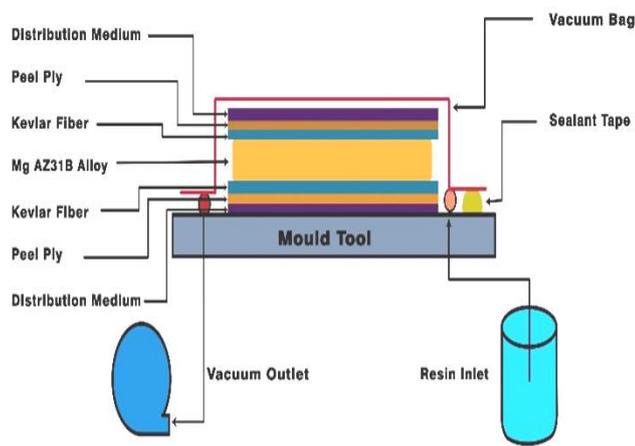


Fig-4: Schematic representation of VARTM

Components of vacuum assisted resin transfer molding:

Vacuum bag – It is attached to the upper side of mould tool and covers entire material and mould tool. It is used as upper part of moulding and maintain airtight environment throughout the process. It is generally made up of Nylon bagging film.

Sealant tape – Sealant tape used for forming a vacuum tight seal between a vacuum bag and a release treated mould surface. It is used to hold the perimeter of vacuum bag with mould tool for airtight environment. It should be resilient enough to withstand with pressure generated.

Vacuum pump – Vacuum pump moves the gas molecules inside the vacuum bag by creating high and low pressure states. It is used to pump out excess air in the vacuum bag and maintain vacuum. The pressure inside the vacuum bag is generally below the atmospheric pressure i.e. between 0 to 14 psi according to sandwich to be fabricated. In this project we maintain the pressure near about 5 psi.

Resin tank – It contains the mixture of epoxy resin and hardener in the ratio of 10:1. This resin tank is open to atmosphere. It contains the air and bubble free resin which is blown into the vacuum bag and between the fiber –metal due to pressure difference resulting in strong bonding.

Distribution medium – It is HDPE mesh used to assist the flow of resin over the material.

Peel ply – It is used on bonding surfaces to keep them clean and also provide for enhanced surface free energy when

removed.

Following figure shows the experimental setup for VARTM process for fabrication of sandwich composite.

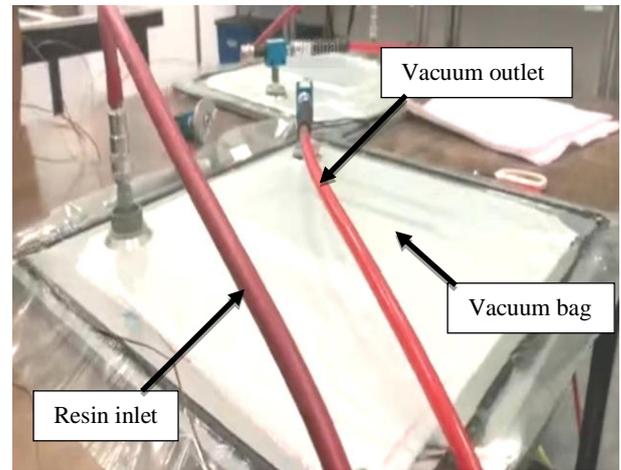


Fig-5: Experimental setup for VARTM

After preparing setup, vacuum is created using vacuum pump then due to pressure difference resin is blown into the material. Then after resin flow into the bag, it is left for curing time of nearly 16 to 18 hours is given for the bonding of fiber-metal sandwich. During curing time, it is preferable to check the setup for leak. If leakage is present during curing time, there may be chance of delamination of fiber-metal surface. Then by removing the sealant tape and vacuum bag we can remove the manufactured sandwich composite from the flat mould. These used vacuum bag, we can use further if there is no any leakage present.

Following figure shows the manufactured Kevlar-Mg AZ31B alloy sandwich composite by using VARTM process.

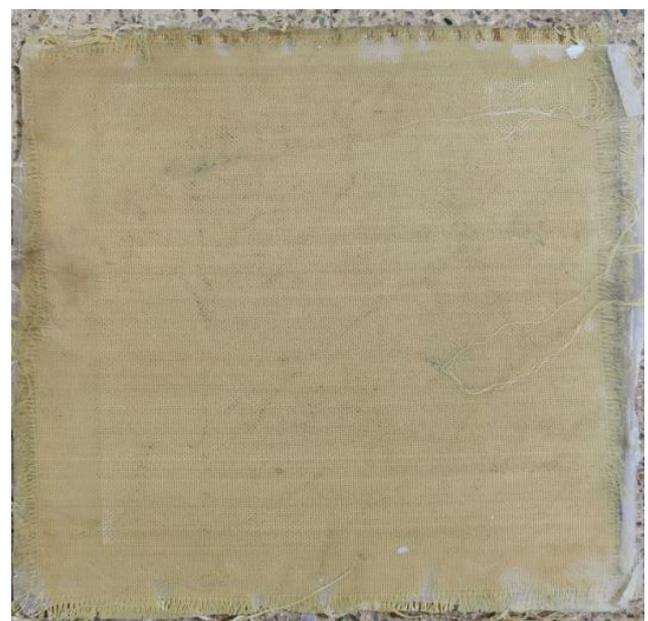


Fig-6: Kevlar-Mg AZ31B alloy Sandwich composite (Top view)

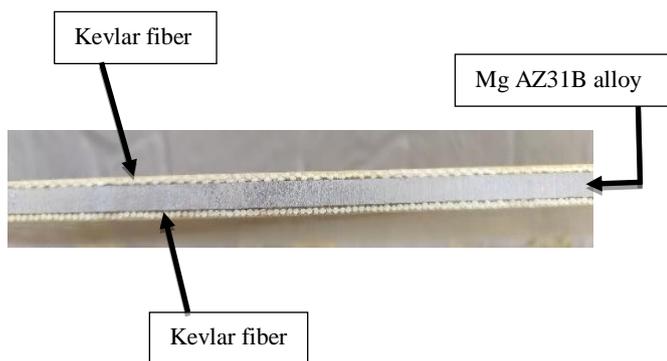


Fig-7: Kevlar-Mg AZ31B alloy Sandwich composite (Side view)

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Advantages of VARTM:

- It is cheaper and good method as it does not require the autoclave machine.
- It can be used for any size and shape components as we can make any size of vacuum bag.
- By varying mould shape, we can produce complex shape of sandwich composites.
- It gives good quality of sandwich composites because voids present in sandwich composite is nearly zero.

4. CONCLUSION

The Vacuum Assisted Resin Transfer Moulding (VARTM) method is best and cheaper method over hot pressing, wet lay-up and other open mould methods for making fiber-metal sandwich composites. As bonding is done in the vacuum it provides void free sandwich composite having good strength.

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