Fabrication of Silicone Bagging and Fluid Flow Analysis in Vacuum Bag Moulding Process

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Abstract:
The present research activity focused on establishing the thumb rules in the manufacturing process in way of producing high quality monolithic components, which can fulfill the needs of automotive industries and various advanced applications like in aerospace parts, wind turbine plates, car components etc. It is very important to produce sound products of monolithic nature with the technique involved in the vacuum bag fabrication and analysis of fluid flow on vacuum through the complicated reinforce network. Vacuum bagging is a clamping method that uses atmospheric pressure to hold the adhesive or resin-coated components of a lamination in place until the adhesive cures. Modern room-temperature-cure adhesives have helped to make vacuum bag laminating techniques available to the average builder by eliminating the need for much of the sophisticated and expensive equipment required for laminating in the past. The effectiveness of vacuum bagging permits the laminating of a wide range of materials.

Keywords: Design, Mould and Sample Preparation

I. Introduction:
In this process, fibre reinforcement is manually inserted into a single-sided mould, where resin is then forced through the thickness of the fibre mats using hand rollers. A primary advantage to the hand lay-up technique is its ability to fabricate very large, complex parts with a quick initial start-up. [1]. Evaluated the mechanical properties of composite materials based on two types of self-reinforced polypropylene (SRPP) and a glass fibre reinforced polypropylene are investigated under quasi-static and dynamic loading conditions. Hybrid laminates based on glass fibre-reinforced polypropylene skins and a self-reinforced polypropylene core was manufactured using a compression moulding technique [2]. Vacuum assisted resin transfer molding (VARTM) is a low-cost manufacturing process primarily used in the marine industry to make boat hulls and other large structures [3].

The composite manufacturing process has been very receptive to reusable silicone vacuum bags as a method of reducing costs when compared to the nylon film and sealant tape process. In experimental setup, the laminate prepared by the Silicone vacuum bagging process can be easily removed when compared with other moulding processes. Since this entire laminate under the close moulding process, the working environment will not be effected by the evaporating chemicals that provide the clean working environment. This manufacturing process provides the scope for producing components with intricate shapes and variable thickness. This process possess front flow velocity of resin in Silicone bag with less time to fill by using a single vacuum inlet instead of many nozzle inlets

II. Vacuum Bagging Process:
The vacuum bagging moulding process utilizes a flexible and transparent film (i.e.: fabric, nylon, rubberized sheet or plastic) in order to fully enclose and compacting the wet laminate by using atmospheric pressure. This process is also called vacuum bagging for short as it uses a vacuum and pump to extract the air from inside the vacuum bag and compress the part under atmospheric pressure in order for the compacting and hardening process to take place. Vacuum bagging is an upgrade of the wet lay-up process and is widely spread in the composite industry because of its clear benefits over this method. You will most often see the use of fiberglass, carbon fibre and resin materials being laminated together using the vacuum bag technique. The outer atmospheric pressure caused through the vacuum within the closed system will compress the laminate and excess resin is sucked out of the wet laminate into the bleeder cloth and resin catch pot.

Figure 1. Schematic diagram of Vacuum bagging process
III. Properties of Silicone Rubber:
Silicone rubber offers good resistance to extreme temperatures, being able to operate normally from −100 to 300 °C (~148 to 572 °F). Some properties such as elongation, creep, cyclic flexing, tear strength, compression set, dielectric strength (at high voltage), thermal conductivity, fire resistance and in some cases tensile strength can be at extreme temperatures far superior to organic rubbers in general, although a few of these properties are still lower than for some specialty materials. Silicone rubber is a material of choice in industry when retention of initial shape and mechanical strength are desired under heavy thermal stress or sub-zero temperatures. Organic rubber has a carbon-to-carbon backbone which can leave it susceptible to ozone, UV, heat and other ageing factors that silicone rubber can withstand well. This makes silicone rubber one of the elastomers of choice in many extreme environments. Silicone rubber is highly inert and does not react with most chemicals. Due to its inertness, it is used in many medical applications including medical implants.

IV. Procedure to prepare the mould with Aluminium plate:

Figure 3. Plywood of 400×400×10 mm³ on aluminium plate

Figure 4. Sticking a double sealed tape on the boundaries of plate

Figure 5. Placing the gasket of 10mm thickness on the other side of tape

Figure 6. Modifications for the resin flow purpose.
Cutting the 2 equal pipes of 300mm and placing on the centre of plywood for the resin flow from the valve which is placed at the intersection of both tubes and also sticking the double-sealed tape between the plywood and gasket for the resin passage as inlet and outlet purpose.

V. Procedures to prepare the Reusable Silicone Bag:

Figure 7. Mixture of both part-A and part-B silicone gel
Silicone gel part-A and part-B of brushable type by whose mixture, the silicone rubber bag can be produced by brushing it on the flat-smooth aluminium plate. Now part-B is thoroughly mixed before adding part-a as mention in the note. Both the parts are mixed together in a mug for the better reaction of silicone. The figure 7. Shows that it has to be stirred hardly to get diluted with each other.
As the mixture getting stirred, consequently the silicone releasing spray is sprayed on the plate at which the brushable platinum silicone is applied.

Silicone part-A and part-B gels are mixed together, but it should be vacuumized at 760 mm of Hg pressure. So for that, the vacuum pump is required to vacuumize the mixture. This mixture is enclosed in a transparent bucket and made a hole at the top layer from which the pressure can be sent into the transparent enclosed body. This transparent body is enclosed with silicone tape which does not allow the air inlet and outlet from the body. Now place the silicone mixture inside the transparent body and sealed with lid at the top and surrounded with silicone tape around the lid and vacuum had been sent from vacuum pump by means of tube. The figure.9 shows the process of silicone mixture Vacuumization.

After the Vacuumization of silicone part-A and part-B mixture, it is applied on the aluminium plate and brushed evenly to get a thickness of 5mm silicone bag. The thickness on the borders of gasket, plywood and tube should be maximum to avoid tearing of the bag while removing from the aluminium plate mould after getting dried of silicone mixture. After 30 minutes of curing period time, the bag becomes as shown in figures 11 and 12.

6. Procedure to prepare the laminates into the required size and shape:
In the present work composite templates are prepared as per the required dimensions. According to the required dimensions the chopped strand mat has been cut into various orientations by making use of different mechanical equipment and measuring equipments. The excess material is removed on the surface of the mould and poly vinyl alcohol viscous liquid is applied on the surface of the mould uniformly and left for drying about 15 minutes. This liquid creates an invisible film which works as impervious layer prevents sticking to the mould surface. After completion of distribution of resin on to the layers a miler film is placed to get the surface finish, while after a pressure plate is placed on the layers by that the uniform load is distributed and exact thickness occurs by the spacers. To get the required laminate it has been taken 4 hours while after remove the pressure plate and miler film and removes the laminate from the mould. The same processes have done for various orientations of sandwich composite laminates. And finally cut the laminates by using cutter machine in to a required ASTM standard dimension.

Step by step procedures for the preparation of sandwich composite laminates are shown in figures.13, 14, and 15.
Chopped strand mat or CSM is a form of reinforcement used in fiberglass. It consists of glass fibers laid randomly across each other and held together by a binder. Using chopped strand mat gives a fiberglass with isotropic in-plane material properties. Initially required dimensions marked on the mat by using ruler.

Bevel protractor is used to cut the fibre in different orientations. Bevel protractor measures the angle in which direction that was to cut.

Now finally, the resin is injected into the reusable silicone rubber bag by using vacuum pump with a pressure of 760 mm of Hg. It is injected by means of pipe which is connected to the pump at one end and to in the resin quantity at the other end. The resin is sent into the silicone bag through the inlet provided at the centre of the bag which can be seen in figure 19. Preparing the laminate of 350\times 350 \text{ mm}^2 size with 6 layers of chopped stranded mat which took of 120 seconds to fill the resin into the bag to create a laminate.
V. Calculations:
For laminate I:

Porosity:
Porosity can be calculated by using,
\[ \Phi = \frac{V_c - V_{gf}}{V_c} \times 100 \]

Therefore, \( V_c = \) Volume of cavity,
\( V_{gf} = \) Volume of glass fiber

For laminate I (30*30 cm\(^2\)),

Volume of cavity (\( V_c \)) = 40*40*0.5 = 800 cm\(^3\)

Volume of glass fiber (\( V_{gf} \))
= 30*30*6*450/1.9*100*100 cm\(^3\)
= 620.89 cm\(^3\)

Therefore, \( V_c = 800 \) cm\(^3\)
\( V_{gf} = 620.89 \) cm\(^3\)

Now, Porosity = \( \frac{V_c - V_{gf}}{V_c} \)
= 0.223

Since, the porosity value got as error that is less than 0.7 i.e., 0.223, then permeability and Reynolds number values doesn’t exist.

For laminate II:

Porosity:
Volume of cavity (\( V_c \)) = 40*40*0.5 = 800 cm\(^3\)

Volume of glass fiber (\( V_{gf} \))
= 35*35*6*450/1.9*100*100 cm\(^3\)
= 174.07 cm\(^3\)

Therefore, \( V_c = 800 \) cm\(^3\)
\( V_{gf} = 174.07 \) cm\(^3\)

Now, Porosity = \( \frac{V_c - V_{gf}}{V_c} \)
= 0.782

Permeability:
\[ K = \frac{Q \ln \left[ \frac{r_f}{r_i} \right] \times r_i^2}{\text{AXP}} \]

Therefore, \( Q = \) Discharge
\[ = V \times 3.14 \times r^2 \]

Where, \( V = \frac{d}{t} = 40/120 \)
= 0.33 cm/sec
\( Q = 0.33 \times 3.14 \times (20)^2 \)
= 414.48 cm\(^3\)/sec

Therefore, Radial Flow (\( r_i \))
\[ = \sqrt{\frac{Q \times t}{\Phi \times 3.14 \times h + r_i^2}} \]
\[ = \sqrt{\frac{414.48 \times 120}{0.782 \times 3.14 \times 0.5 + 0.3^2}} \]
= 201.274

Permeability
\[ K = \frac{Q \ln \left[ \frac{r_f}{r_i} \right] \times r_i^2}{\text{AXP}} \]

\[ = \frac{251.327 \times 4.75 \times (201.274)^2 \times \ln(201.274/0.3)}{35 \times 35 \times 533289.4} \]
= 0.211 cm\(^2\)

Reynolds number:
\[ Re = \frac{P \times V \times d}{\mu} \times 1000 \]

Where, \( P = \) Density of resin mixture
\[ = 1.2 \text{ g/cm}^3 \]
\( V = \) Velocity of resin flow
\( d = \) Diameter of the pipe
\( \mu = \) Viscosity of resin mixture
\[ Re = \frac{1.2 \times 0.2 \times 10}{4.75} \times 1000 \]
= 505.263

VI. Conclusion:
The composite manufacturing process has been very receptive to reusable silicone vacuum bags as a method of reducing costs when compared to the nylon film and sealant tape process. In experimental setup, the laminate prepared by the Silicone vacuum bagging process can be easily removed when compared with other moulding processes. Since this entire laminate under the close moulding process, the working environment will not be effected by the evaporating chemicals
that provide the clean working environment. This manufacturing process provides the scope for producing components with intricate shapes and variable thickness. Since the clamping force is not at all required, the manufacturing process becomes user-friendly and usage of bolts and nuts for clamping can be avoided. This process possesses front flow velocity of resin in Silicone bag with less time to fill by using a single vacuum inlet instead of many nozzle inlets.

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