Fabrication of Pneumatic Compression Molding Machine for FRP Composites

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Abstract - *This paper deals with the development of pneumatically operated compression molding machine for polymer composites. The main aim of fabricating this machine is to prepare the fiber reinforced polymer composite samples for testing purpose. Researchers working on composites for research work they require the samples of composites with different composition for the purpose of testing. For that this machine is useful for the researchers and also for the manufacturer to produce small sized less complicated plastic components. In this machine temperature of specimen dies can be controlled automatically by using sensors and by using FRL (filter, regulator and lubricator) unit, the pressure can be controlled. The low density, high strength and high stiffness to weight ratio, fiber reinforced composite materials are manufactured by this machine are low cost.*

In this research work, the tensile strength of test specimen of Epoxy without Fiber, Epoxy with carbon fiber, and Epoxy with coconut fiber are tested and compared.

***Key Words*: Carbon fiber, Epoxy Resin, Fiber reinforced Composite, Compression Moulding, and Test Specimen**

1. INTRODUCTION

Compression moulding process is done in two steps, preheating and pressurizing. Compression molding is a one of the well known oldest technique used to develop variety of composite products. Because of its ability to develop variety of composite products, the process is versatile. It is a closed die moulding with high pressure application. This process is suitable for small to medium size parts.

In industries, different types of moulding machines are used; Semi-automatic and Automatic The hydraulic machine can be used in some applications where there is a requirement of high pressure or high load for manufacturing the components, these high capacity molding machines cannot be installed in small scale industries, because the cost of the high capacity hydraulic molding machine are too expensive for the preparation of small sized composite products and also a skilled operator is required to operate these high capacity hydraulic machine. To overcome these problems it is a need to develop low cost pneumatically operated molding machine. This machine is useful in small scale industries for the production of FRP composites. The initial cost of machine is low and the maintenance cost is minimal.

Compression molding machine is used to prepare the FRP composite samples for testing purpose. In this process, the molding material, generally preheated by using heater after filling in a heated mold cavity. The mold is closed with the help of a top force, by using hydraulic cylinder and pressure is applied to force the material into contact with all mold areas. Heat and pressure is maintained until the molding material has cured.

Compression molding is a method suitable for molding complex, high-strength fiber reinforcements. It is one of the lowest cost molding methods compared with transfer molding and injection molding;

2. METHOD

Compression molding is a technique to develop variety of composite products. In this method, as shown in figure 1, two matched metal dies are used to fabricate composite product by the application of compressive force. In this, lower or bottom plate is stationary while upper plate is movable. Reinforce element (Carbon Fiber) and matrix (Epoxy) are placed in the lower die. Heat and pressure is applied as per the requirement of composite for a definite period of time. Due to application of pressure and heat, the material placed in a dies/moulds flows and acquires the shape of the mold cavity. Curing of the composite may carried out either at room temperature or at some elevated temperature. After curing, mold is ejected and composite product is extracted by dismantling split die for further processing.

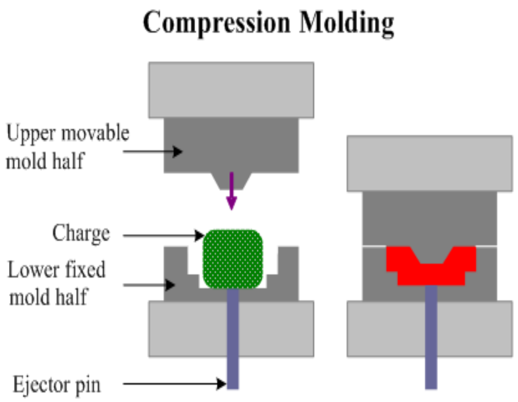

Fig -1: Compression molding Process

3.MATERIALS

A composite material is made by combining two or more dissimilar materials. Combining a fiber with a polymeric matrix produces a composite material with higher stiffness and strength and other useful properties.

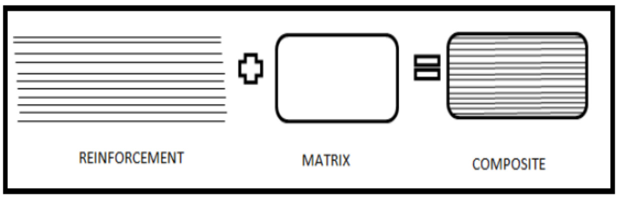

Fig -2 Composite constituents

Thermosetting materials are commonly used in compression molding technique. In a composite material polymer is used as a thermosetting material and fiber material is as a reinforced material.

Hardener and mould releasing agent is used to cure the specimen in less time and to remove the specimen easily from mould cavity respectively.

Also silica powder may be added for hardening of the test specimen.

Table-1. Raw materials used in compression molding process

Matrix	**Thermosetting:** Epoxy, polyester, polyvinyl ester, phenolic resin, Unsaturated polyester, polyurethane resin, Urea formaldehyde. **Thermoplastic**: polypropylene (PP), polyethylene (PE), nylon, polycarbonate (PC), polyvinyl chloride (PVC), cellulose acetate, polyetherether ketone (PEEK), Acrylonitrile-butadiene-styrene (ABS), polystyrene (PS) biodegradable polymers such as poly lactic acid (PLA), poly vinyl alcohol (PVA), soy based plastic, starch based polymers etc.
Reinforcement	Glass fiber, carbon fiber, aramid fiber, natural plant fibers (sisal, banana, nettle, hemp, flax etc.) (all these fibers may be in the form of unidirectional mat, bidirectional (woven) mat, stitched into a fabric form, mat of randomly oriented fibers, short fibers, chopped fibers)

4. MATERIAL SELECTION

4.1-Epoxy Resins [Bryan Harris]

Epoxy resins have played a vital role in polymer matrix materials because of their superior mechanical and adhesive properties. They have been used widely as a matrix to hold the high-performance fiber reinforcement together in composite materials, as well as structural adhesives. It is almost totally transparent when cured. Epoxy Resins are thermosetting resins, which cure by internally generated heat. Epoxy systems consist of two parts, resin and hardener. When mixed together, the resin and hardener activate, causing a chemical reaction, which cures (hardens) the material. Epoxy resins are regarded as compounds which contain more than one epoxy group, capable of being converted to cured (thermoset) form with the help of hardener curing agents. The main features of these resins are that they maintain their properties at high temperatures and possess high heat deflection temperature (HDT) and high glass transition temperature (T). The presence of a phenolic backbone provides short-term thermal stability coupled with chemical versatility of epoxide group and also it has led to their manifold newer applications.

4.2 characteristics of epoxy resins

1. Ability to be cured rapidly or slowly.
2. Ability to be processed by a variety of techniques.
3. Ability to accept a wide range of fillers and pigments.
4. Absence of volatile matter during cure.
5. Excellent adhesion on almost all substrates.
6. Excellent toughness.
7. Excellent chemical properties.
8. Good electrical properties Low shrinkage and therefore, better dimensional stability.

4.3-Carbon Fibers [Dr. J. Fazlur Rahman et al.]

Glass fibers suffer from low elastic stiffness (of course, possess excellent strength characteristics) and limited char strength (relatively low melting point) for ablative applications. This necessitated the use of carbon fibers in place of glass fibers for ablative and structural applications. By oxidizing and paralysing a highly drawn polyacrylonitrile (PAN), and subsequently hot-stretching it, it is possible to convert it to a carbon filament. Depending on processing conditions, a wide range of mechanical properties (controlled by structural variation) can be obtained, and fibers can therefore be chosen from this range so as to give the desired composite properties. Carbon fibers have strength and modulus vastly superior to glass fibers. Although, they are at present much more costly, they will undoubtedly lead to further development of composite materials for more exciting applications. In view of their superior heat stability, carbon fibers can be used for reinforcing ceramics, metals, and plastics, giving engineers and technologists a completely new range of materials. (Harris, 1999)

5. CONSTRUCTION AND WORKING [Eranna. H]

Components required:

1. Pneumatic cylinder
2. Heating elements
3. FLR unit
4. 5/3 Direction control valve .
5. Flow control valves
6. Die
7. Packing materials: carbon fiber and epoxy material

Once the composite material is placed in shell type lower die, the upper die is closed on lower die by means of air cylinder which is controlled by 5/3 direction control valve. The required pressure is applied by using FRL unit which is provided with a pressure gauge. The heating coils are used to heat the dies or mould. By using temperature sensors, temperature is automatically controlled. Flow control valves are used to control the flow rate of air.

6. DEVELOPMENT OF PNEUMATIC MOLDING MACHINE

CAD MODEL

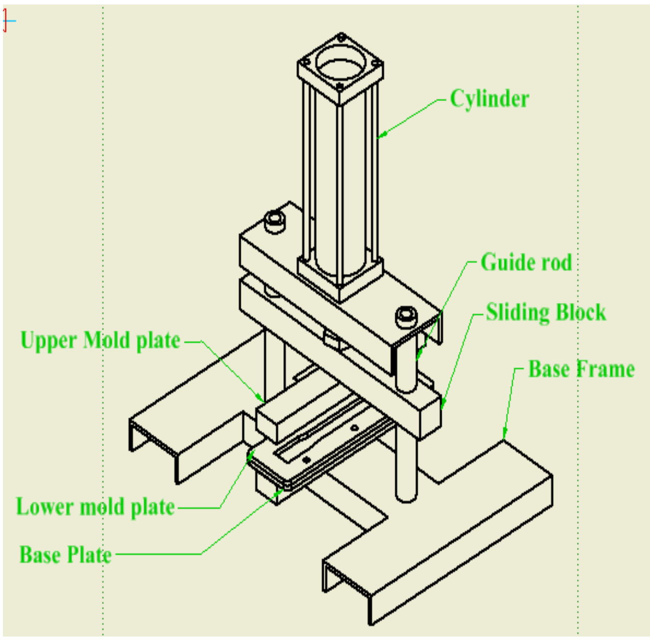

Fig- 3 Cad Model

7. DESIGN OF PARTS [Eranna. H]

7.1 Double Acting Cylinder - output Stroke

The force exerted by a double acting pneumatic cylinder can be expressed as,
F = P A
F= p π d2/4 -------- (1)
Where,
F= force exerted (N)
p = gauge pressure (N/m^2, Pa)
A = full bore area (m^2)
d = full bore piston diameter (m)

Double Acting Cylinder - Input Stroke .

The force exerted by pneumatic cylinder can be expressed as

$F = p \pi (d_1^2 - d_2^2) / 4$ (2)

Where,
d1 = full bore piston diameter (m)
d2 = piston rod diameter (m)

7.2 FORCE CALCULATIONS:

Pressure of the cylinder = 3 bar =0.3 N/mm^2
Diameter of the cylinder = 25mm
Diameter of the piston rod = 10mm

Calculation – double Acting Piston outstroke:

The force exerted by a single acting pneumatic cylinder with 5 bar and full bore diameter of 25 mm (0.1 m) can be calculated as

$F = p (\pi d^2 / 4)$
$= 0.5 \times 490.87$
$= 245.43$

Calculation - Double Acting Piston in-stroke:

The force exerted from a single acting pneumatic cylinder with 5 bar full bore diameter of 25 mm (0.025 m) and rod diameter 10 mm (0.01
m) Can be calculated as

$F = p \pi (d_1^2 - d_2^2) / 4$
$= 0.5 \times (25^2 - 10^2) / 4$
$= 65.62$ N

7.3 Die

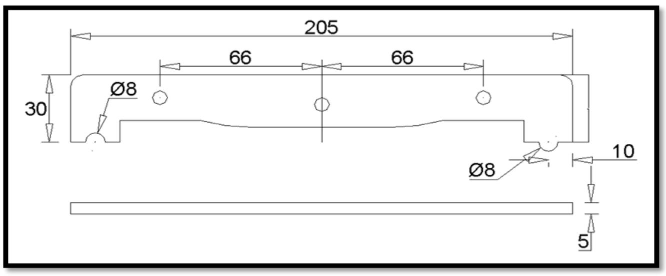

Fig-4 Die for tensile testing

7.4 Base plate

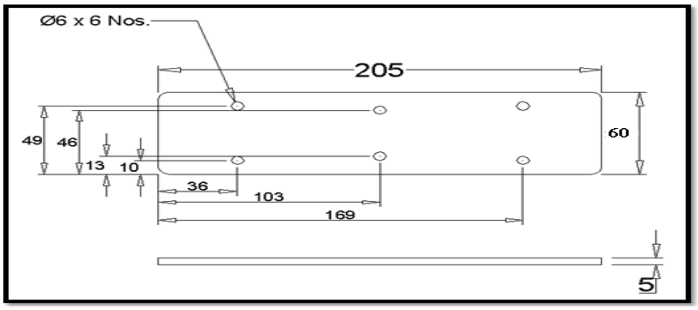

Fig-5 Base Plate

7.5 Grid Rod

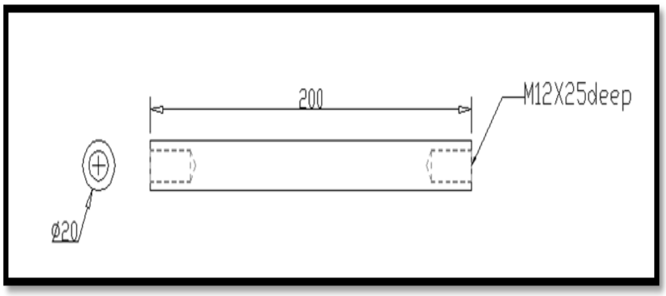

Fig-6 Grid Rod

7.6 Base frame

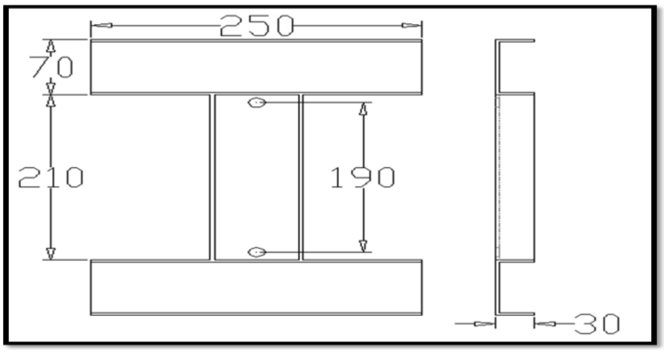

Fig-7 Base Frame

8. Working of Compression Moulding Machine

In compression molding, uses a specific amount of material (uncured resin and fibers) placed into the cavity of a matched mold in the open position. The mold is closed by bringing the male and female halves together, and pressure is applied to squeeze the composite material so it uniformly fills the mold cavity. While under pressure the material is heated so that it cures. The heat and pressure is maintained by heating element and air until the plastic material is cured. The cylinder is used for vertical upward and downward motion of the plunger exerts the pressure on composite material to be molded. The direction control valve is used to control the movement of the cylinder. The heat is applied by mounting heating elements on upper and lower die. Epoxy and reinforce material is placed in an open and heated mold cavity. The mold is closed and the pressure is applied to force the material to fill up the entire mold cavity. Once the material is cured it is removed from the mold for finishing and testing.

The molding process can require high pressures, and so the molds are mounted in large presses. The presses allow rapid mold cycles and high-volume production therefore; this process is widely used in the automotive industry and in other industries where high volumes of small-to-moderate-sized parts are manufactured. The squeezing of the material results in low void contents in the finished parts.

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Fig-8 Fabrication of Machine setup

9. Result and Discussion

9.1. Preparation of FRP Composite

Testing samples were prepared in dumb-bell shapes and these dimensions are 165x19x 5mm3 based on the ASTM D 638 standards.

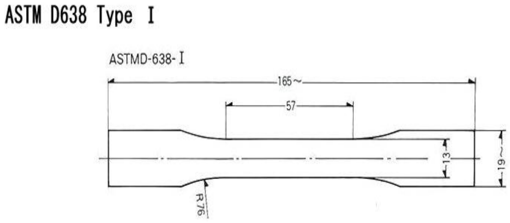

Fig-9 Size of Specimen

Table 2-Specimen 1: Epoxy + Carbon fiber

Description	Raw Materials	Proportion(gm)
Matrix	Epoxy resin	15
Hardener	Epoxy Hardener-509	15
Reinforcing agent	Carbon Fiber	5
Mold releasing agent	Polyvinyl alcohol (PVA) / Wax	0.2

Fig-10 Carbon fiber Specimen

Table3-Specimen 2: epoxy + Coconut fiber

Description	Raw Materials	Proportion(gm)
Matrix	Epoxy resin	15
Hardener	Epoxy Hardener-509	15
Reinforcing agent	coconut Fiber	5
Mold releasing agent	Polyvinyl alcohol (PVA) / Wax	0.2

Fig-11 Coconut fiber Specimen

The fig shows the fiber reinforced composite prepared by using pneumatically operated compression molding machine under the pressure of 2 MPa and at the temperature of 70^0 C.

The material is kept under pressure of 2MPa for 1 hour and heated under the temperature of 70^0 C for 1 hour.

Fig-12 Epoxy + Carbon Fiber Test Specimen

Fig-13 Epoxy + Coconut Fiber Test Specimen

9.2 Testing of Prepared FRP Laminate

Thermoset FRP laminate has been prepared by using developed pneumatically operated compression molding machine. The tensile test has been carried out by using Universal testing machine as per ASTM D638 standard.

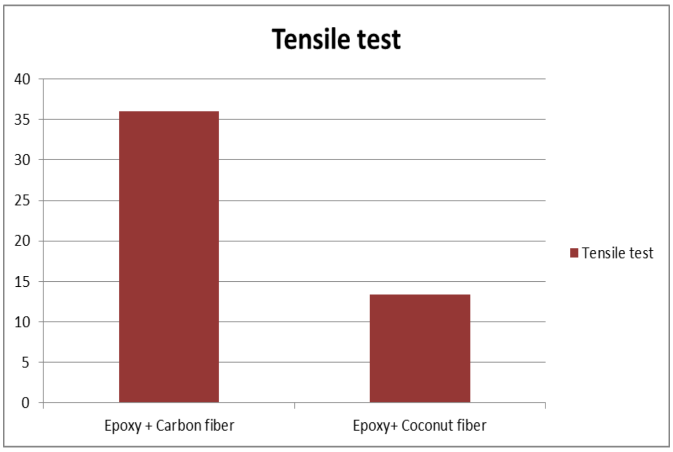

Chart -1: Tensile test

Tensile Strength for Epoxy and Carbon Fiber is found to be 36 N/mm^2

Tensile Strength for Epoxy and Coconut1 Fiber is found to be 13N/mm^2

10. CONCLUSIONS

1. The tensile strength of the developed FRP composites are tested as per ASTM standard D-638.

2. The tensile strength of the developed FRP composites is in line with the result obtained by the other researchers.

3. FRP composite can be produced without air voids.

4. This machine can be used by the researchers for preparing FRP composites.

5 .The pressures can be varied from 1bar to 6 bars.

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