Design and Development of Compression Cum Extruder equipment for Fabrication of fiber Reinforced Polymer Matrix Composites for Cylindrical Parts

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Abstract- **The advances in material science and improvements in the production technologies motivates the researchers to do their studies towards Composite materials [1]. Especially for the cylindrical and spherical composite parts in various applications such as marine, oil and gas refineries, chemical industries, and other industrial applications this composite cylindrical and spherical parts plays a vital role. These applications required parts with leak-proof, higher strength, lowest possible weight, less usage of labor force and corrosive resistive properties at the lower cost. There are lot of equipment and fabrication methods are available for producing cylindrical composite parts. The methods or techniques are Pultrusion, Resin Transfer Molding (RTM) Autoclave Molding, Filament Winding Machine (FWM), compression molding, etc. These methods have some limitations like high investment cost, requires skilled operators, requirement of automated and high power drive systems, complex design and control mechanisms. In order to optimize these problems, a new equipment with lower cost and enhanced capabilities has been designed and developed for producing the cylindrical parts. In the present invention, the setup is designed in such a way that it can produce the required parts by the combination of compression and screwing of piston rod manually with the help of piston-cylinder arrangement. Thus we can avoid the usage of electrical, thermal, and other forms of expensive energies, maintenance cost also very less as compared to all techniques. In the present work, simple and low cost compression cum extruder die set-up equipment is designed and developed for the fabrication of fiber reinforced polymer matrix Composite parts.**

Keywords— ***Compression molding, Cylindrical parts, Extrusion, Composites, Matrix material.***

INTRODUCTION

The term Composite material can be defined as a combination of two or more materials that results in superior properties [2] than the distinct constituent used individually or it can also be described as a structural material that consists of two or more constituents at a macroscopic level and constituents are not soluble in each other. The two constituents are reinforcement and a matrix. However, in modern materials engineering the term usually refers to a "MATRIX" material that is reinforced with fibers. Most composites used today are at the leading edge of materials technology with performance and costs appropriate to ultra-demanding applications such as spacecraft, marine and shipbuilding applications, oil refineries, automobile industries, fluid transmission applications. In such applications cylindrical parts should be used.

Generally, in now a day's composite materials are used in the above field of applications because of their superior properties such as light weight, high specific strength, stiffness, fatigue characteristics, corrosion resistance, part consolidation, design flexibility, low thermal conductivity, and insulating capabilities.

There are lot of equipment and fabrication methods or techniques such as Pultrusion [4], Resin Transfer Molding (RTM) [5], Filament Winding Machine (FWM) [7], Autoclave Molding, compression molding [8], etc. But some are required high investment, some requires skilled operators, some techniques require automated facilities and some are having complex design and drive mechanisms. In order to overcome these above problems, a new equipment with low cost and enhanced capabilities has been designed and developed for producing the cylindrical composite parts. In the present invention, the setup is designed in such a way that it can produce the required parts by simple manually operated ability.

The setup was designed to produce required parts by the combination compression and screwing of piston rod manually in the piston-cylinder arrangement. Thus we can avoid the usage of electrical, thermal, and other forms of expensive energies there by we can reduce the cost of the products. And this new equipment doesn't need any automated facilities. Hence it was named as "Compression Mold cum Extruder die set-up apparatus". The three dimensional solid model of the Compression Mold cum Extruder set-up equipment as shown in Fig.1, and the Fig.2 shows the connection between various elements of the equipment.

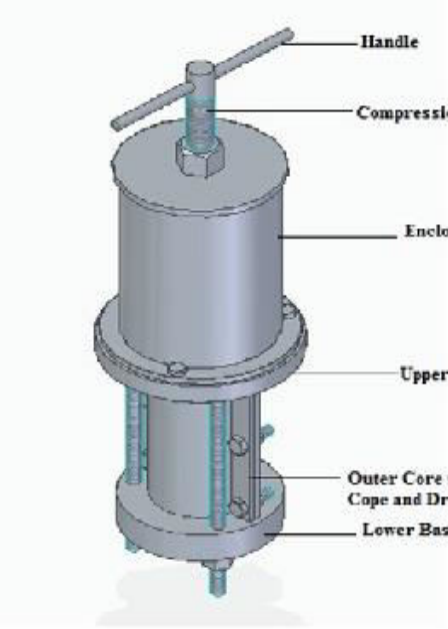

FIG.1: Three Dimensional representation of Compression Cum Extruder Die Type Equipment

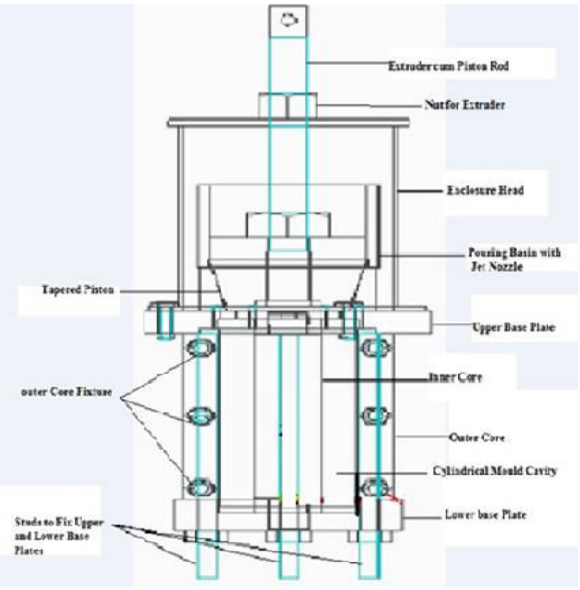

FIG. 2: Representation of connection between different elements in Compression Cum Extruder Die Type Equipment

I. EXPERIMENTAL SET-UP

A. COMPONENTS OF COMPRESSION CUM EXTRUDER DIE TYPE EQUIPMENT

The Fig. 2 shows that, the connections of different elements of newly developed compression cum extruder die type apparatus. The main parts of the equipment can be described with the help of respective schematic diagrams as below:

1. Fixture for Hollow cylinder
2. Inner core or Mandrel
3. Outer core or Cope and Drag plates
4. Pouring basin
5. Extruder cum compression Piston rod
6. Enclosure head.

1. Fixture for Hollow cylinder: The Fig.3, shows the elements of main fixture for cylinder. It contains one lower and one upper base plates of EN31 steel material with one hole on each plate of 20 mm in diameter to insert the inner core or mandrel. The lower base plate is of 125 mm in diameter and 25 mm thickness and have a facility of slotted area to place the cope and drag plates. The upper base plate of 150 mm diameter and 15 mm in thick also contains one hole at center to insert the mandrel or inner core. In addition to that there is a provision of 6 circular holes with 4 mm in diameter to entering the resin into cylindrical mold cavity. Three threaded studs of 20 mm in diameter were fixed one of its ends to the upper base plate by welding, and these studs provides the facility of increasing the length of the cylinder by increasing the lengths of the pattern i.e., cope and drag set up.

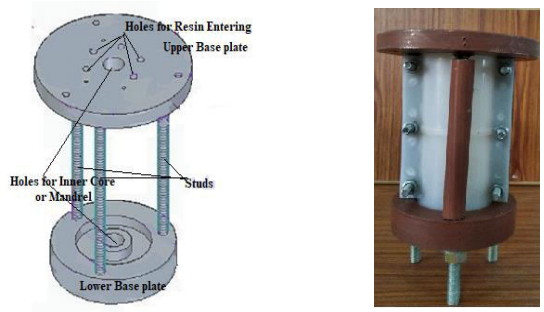

FIG. 3: Fixture for Hollow cylinder with Lower and Upper base plates of Compression Cum Extruder Die Type Equipment

2. Inner core or Mandrel: The Fig 4, shows the inner core or mandrel which is made up of Teflon material. It forms hollow portion in the cylinder of which final part to be fabricate. Two types of mandrels used in general are one is temporary and other is permanent mandrel. The temporary mandrels are made up of very low melting point materials i.e., wax, rubber and low melting polyurethane, etc. whereas permanent mandrels are made up of higher melting point temperature materials such as metals, Teflon, plastics with higher melting point, etc.

The mandrel dimensions will vary according to requirements, presently 35 mm and 50 mm diameter mandrels were is used. And at two ends are 20 mm and 25 mm in diameter, 15 mm height respectively in order to insert into both the lower and upper base plates of the main fixture of Compression Cum Extruder Die Type Equipment. The height of 135 mm inner core is used in the present apparatus and its length can also increase further if required.

FIG.4: Inner core or Mandrels of different diameters of Compression Cum Extruder Die Type Equipment

3. Outer core or Cope and Drag plates: The Fig. 5, shows the cope and drag plates of the pattern used in the present invention. These were made with Teflon material and has a higher melting point than the polymer composite which is to be fabricate. These are fixed by two rubber spaces with the help of 6 bolts and nuts in order to easy and quick removal of cylindrical composite part.

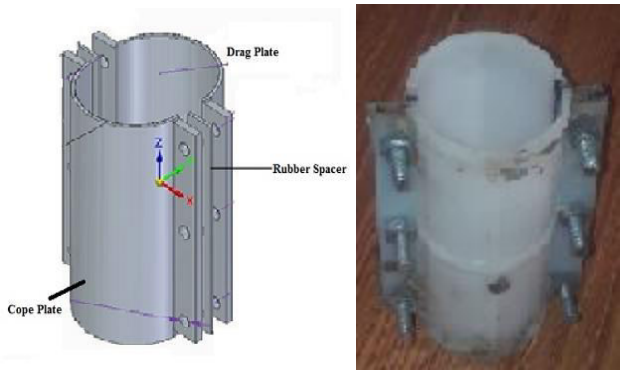

FIG. 5: Outer core or Cope and Drag plates of Compression Cum Extruder Die Type Equipment

4. Pouring basin: The Fig:6, shows the pouring basin for the polymer resin to fabricate the composite part is fixed to the upper base plate with the help of 6 screws of 4 mm in diameter. The pouring basin used in this apparatus was made with Teflon material with a provision of having a tapered portion at the bottom end in order to get jetting action of matrix (polymer resin) material which results in increase of its pressure before entering into mold cavity. We can also use the other materials like metals and plastics for the pouring based on the number of parts to be produced. The volume of pouring basin will depend upon the volume of composite part to be fabricate. The pouring basin used in the present equipment has the dimensions as of 105 mm of height with 95 mm and 85 mm as outer and inner diameters. And also, there is a 15° taper up to 40 mm from bottom end of pouring basin. This taper is mainly intended to increase the pressure of the matrix material which is to entering into the cylindrical mold cavity.

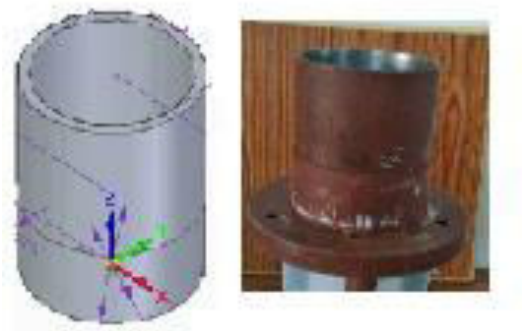

FIG. 6: Pouring basin or Cylindrical Hopper for Matrix material entering into mold cavity Compression Cum Extruder Die Type Equipment

5. Extruder cum compression Piston rod: The Fig. 7, shows the extruder cum piston rod for compressing the polymeric matrix resin into the mold cavity from cylindrical pouring basin. The piston head has up to 35 mm tapered shape made to compressive action and there is a provision of threading to the piston rod acts as an extruder, there by this equipment will works on the combined effect of extrusion and piston-cylinder compressive action.

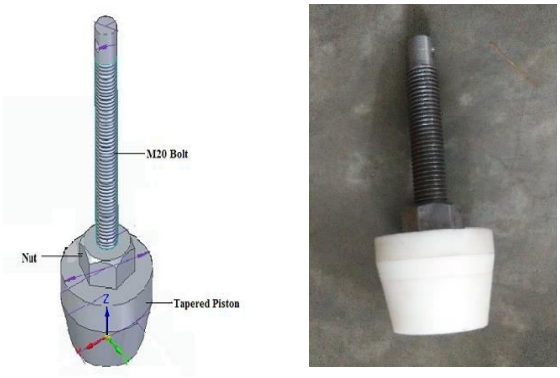

FIG. 7: Extruder cum compression Piston rod of Compression Cum Extruder Die Type Equipment

6. Enclosure head: The Fig.8: shows the enclosure head of the equipment. The enclosure head consists of two circular plates at two ends are top and bottom dead. The bottom dead plate has a diameter of 145 mm and it is welded to a 116 mm diameter hollow cylinder of height of 140 mm length hollow cylinder and a 20 mm nut was firmly welded to the top dead plate for the screwing action or extruding action.

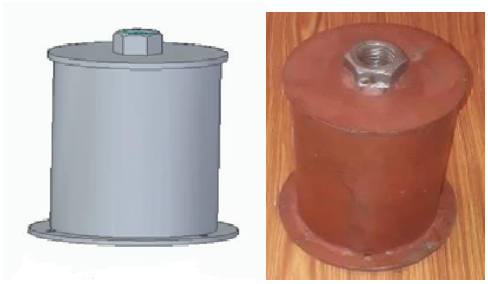

FIG. 8 Enclosure head of Compression Cum Extruder Die Type Equipment

III. FABRICATION OF CYLINDRICAL COMPOSITE PARTS BY COMPRESSION CUM EXTRUDER EQUIPMENT:

A. Preparation of Reinforcement material:

Both synthetic as well as natural fibers are used as the reinforcement material. The synthetic fibers like Nylon, Polythene, Glass fiber, Bakelite, PVC, etc. and natural fibers like Jute, Sisal, Pineapple, Bamboo, Kenaf, Luffa and Bagasse (Luffa-cylindrica or Sponge-Gourd vegetable plant fibers are used in this present work) etc. are used as the reinforcing fibers. These fibers were winded or surrounded to the inner core or mandrel as shown in Fig9.

B. Matrix materials:

Epoxy resin of Araldite (LY-556) which chemically belongs to epoxide family and vinylester resin of ester group resins are used as the matrix materials for the fabrication of required composite parts. We can also use polyester resins as the matrix materials through this Compression Cum Extruder Die Type Equipment.

C. Fabrication of Composite parts:

Apply oil or wax for the resin contacting area of parts i.e. for inner core, inner surfaces of the cope and drag parts of mold cavity, cylindrical pouring basin, lower baseplate, upper base plate and piston head portion surfaces. In case of Vinyl ester for 450 gm., 9 gm. i.e., 2% of accelerator and 2% of Catalysts were added.

Apply the pressure on the epoxy-hardener mixture by compressive and screwing action through the piston rod into cylindrical mold cavity through cylindrical pouring basin. Then now allowed the epoxy resin matrix and any type of Synthetic or Natural fiber reinforced mixture composite up to 6-10 hours according to ASTM standards for curing and hardening of required cylindrical part. Then finally, remove and clean the composite part by removing the cope and drag parts of the cylindrical outer pattern. Fig10 shows the cylindrical parts fabricated by the compression cum extruder die type equipment.

FIG. 9: Luffa-Cylindrica or Sponge Gourd vegetable fiber Stitched to Cylindrical core as reinforcing material

FIG. 10: Fabricated cylindrical Polymer Matrix Composite samples with required diameters

D. Advantages

- The equipment is capable to produce cylindrical parts with less wastage of raw material (i.e. lower resin and fiber loss).
- It is capable to operate without consuming any form of expensive energy, i.e., the equipment is operated manually with one or fewer work force.
- It is also capable to produce parts as polymer matrix as well as Metal Matrix Composites.
- The machine has capability to produce cylindrical as well as any shape of parts by simply changing its die shape.
- The design and fabrication of all elements in this machine are simple and maintenance is also very easy.

E. Limitations:

- The size and diameter of parts to be produced is limited and the volume of composite parts will affect the volume of the pouring basin.

II. CONCLUSION:

The design and development of compression cum extruder die set- up equipment for fabrication of cylindrical parts with fiber reinforced polymer matrix composites has done and the developed equipment has a capable of producing cylindrical parts with less wastage of raw material (i.e. lower resin and fiber loss), without consuming any form of expensive energy and also capable to produce parts as well as Metal Matrix Composites.

1. The equipment is capable of producing cylindrical parts of different diameters using mandrels of different sizes.
2. Different combination of fibers and resins can be used to produce cylindrical tubes and pipes.

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