Int. J. Chem. Sci.: 14(2), 2016, 1183-1196
ISSN 0972-768X
www.sadgurupublications.com

MECHANICAL CHARACTERIZATION OF POLYURETHANE PLASTICS IN VACUUM CASTING PROCESS BY USING ALUMINIUM POWDER AND GLASS FIBRE

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ABSTARCT

Polyurethane have high quality, low viscosity and odorless general purpose resin. It is used for pattern making, prototyping, product development process. This venture is undertaken to improve the mechanical properties of polyurethane. Composites are made by using polyurethane resin, aluminium powder and glass fibre in various mixing ratios. Mechanical stirrer is used to stir the composites to mix automatically. Silicon rubber mold was produced by using vacuum casting machine. These rubber molds are used to produce the test specimens in vacuum casting. Master patterns are made by ABS plastics in FDM (Fused deposition modelling) machine. The composites of various mixing ratios are tested for their mechanical properties by carrying out tensile, compression and charpy impact tests.

Key words: Polyurethane, Vacuum casting machine, Fused deposition modeling, Glass fiber, Aluminium powder.

INTRODUCTION

Polyurethane has revolutionized the quality of life in the 20th century, providing energy savings, safety, lightness, comfort and durability. Combining the skills of the designer, chemist and engineers, their unique properties can be adjusted to create valuable products varying in structure from soft furniture to tough car bumper each toller -made for a specific purpose. Polyurethane is durable product, offering many years of service. Lifetime can vary between 3 to 50 years depending on the end use.

Aluminum powder is produced by presenting pure molten aluminium metal to a compressed gas jet and converting it to fine droplets, which are then solidified and collected.

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Powders so collected are subsequently graded, depending on size, specification and application. The range of particle sizes of the product made in this way can be controlled to some extent by varying the nozzle opening, the air pressure and other factors. A wide range of particle size is available from the finest, 5 microns up to 1000 microns. This is made by dry ball milling of atomised aluminium under inert atmosphere or removal of solvent from wet-milled atomised aluminium under controlled conditions. It is generally 6-35 microns average particle size, the smaller sizes tending to be more hazardous to handle. Depending on application, some flake may be 'stabilised' by a coating to limit reactivity.

Glass fiber which is one product called "fiberglass" today, was invented in 1932-1933 by Russell Games Slayter of Owens-Corning, as a material to be used as thermal building insulation[1]. It is marketed under the trade name Fiberglass, which has become a generalized trademark. Glass fiber when used as a thermal insulating material is specially manufactured with a bonding agent to trap many small air cells, resulting in the characteristically air-filled low-density "glass wool" family of products. Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This structural material product contains little air, denser than glass wool, and is an especially good thermal insulator. Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing.

Literature review

In the last few years some works have been performed by researchers on glass fiber reinforced polyurethane (GFRP). Saint-Michel et al.[1,2] studied the mechanical properties of polyurethane foam with different densities and filler size. He investigated the thermal and mechanical properties of two types of polyurethane resin, one commercial and another derived from soybean oil, reinforced with glass fibers. Both composites displayed excellent results showing that polyurethane from soybean oil is an alternative to petrochemical resin. Wilberforce and Hashemi[3] studied the effect of fiber concentration, strain rate and weld line on mechanical properties of short glass fiber polyurethane composites. The long-term properties of polyurethane reinforced composites were investigated by Bruckmeier and Wellnitz[4] with the intention of using the composites in the automotive industry due to its lightweight, strength and damage tolerance. With several advances made in understanding the behavior of composite materials, GFRP are finding increasing use as primary load bearing structures and also in a wide range of high technology engineering applications, such as pipeline reinforcement. Since one of the main applications of such composite material is to repair and reinforce both internal and external corrosion on pipelines, the knowledge of the material behavior when the strain rate varies is crucial to execute an accurate and appropriate repair. Corroded pipelines with part-wall metal loss defects can be repaired or reinforced with a composite sleeve system. In these systems, a piping or vessel segment is reinforced by wrapping with concentric coils of composite material[5].

EXPERIMENTAL

In this study, FDM Machine used to produce master patterns. Five master patterns is made by ABS plastics and polycarbonate black Plastics. FDM begins with a software process, which processes an STL file (stereolithography file format), mathematically slicing and orienting the model for the build process. The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle, which can turn the flow on and off. There is typically a worm-drive that pushes the filament into the nozzle at a controlled rate where the nozzle is heated to melt the material. The thermoplastics are heated past their glass transition temperature and are then deposited by an extrusion head. The nozzle can be moved in both horizontal and vertical directions by a numerically controlled mechanism. The nozzle follows a tool-path controlled by a computer-aided manufacturing (CAM) software package, and the part is built from the bottom up, one layer at a time.

Although the 3-D printing technology FDM is very flexible, and it is capable of dealing with small overhangs by the support from lower layers, FDM generally has some restrictions on the slope of the overhang, and cannot produce unsupported stalactites. Myriad materials are available, such as acrylonitrile butadiene styrene ABS, polylactic acid PLA, polycarbonate PC, polyamide PA, polystyrene PS, lignin, rubber, among many others, with different trade-offs between strength and temperature properties.

Fig. 1: FDM Machine

Silicon rubber is used as mold for this process. Silicon rubber (White colour - 2 kilogram Hardener 200 g 10: 1 ratio: Mixing for Mould: Manual handling to mix the silicon rubber and hardener 10-15 min. After mixing process bubbles are created to reduce the bubbles in vacuum casting machine (air sucking time 3-5 min). Minimum 12 hrs in vacuum casting machine get solid state into mould state vacuum casting is the method used for obtaining silicone rubber molds. This method is one of the most used, interesting and spectacular applications for use of RP models to develop new products. Vacuum casting is a technique that has proved the appropriateness and efficiency in the stage of developing new products, step when prototyping of complex parts must be used for small batches (30-50 parts), for testing new product functionality and/or market testing of the new product. This manufacturing method reproduces faithfully the details of form and the quality of RP model surfaces used as a master. Materials used in the vacuum casting are different types of resins, plastics and rubber.

Fig. 2: Mechanical stirrer pouring

Experimental procedure

In this study explain on polyurethane based composite materials. The main ingredients to make a polyurethane are isocyanates and polyols. Other materials are added to help processing the polymer or to change the properties of the polymer.

Calculation for polyuerthane mixture

$$\frac{\text{Part weight}}{180} = \text{Isocynate weight}$$

$$\text{Isocynate weight x } 80 = \text{Polyol weight}$$

The shape and dimensions of an ASTM D638 (1998) Type I test specimen as shown in Fig. 5.

Fig. 3: Master patterns

Fig. 4: Mold pattern with masters

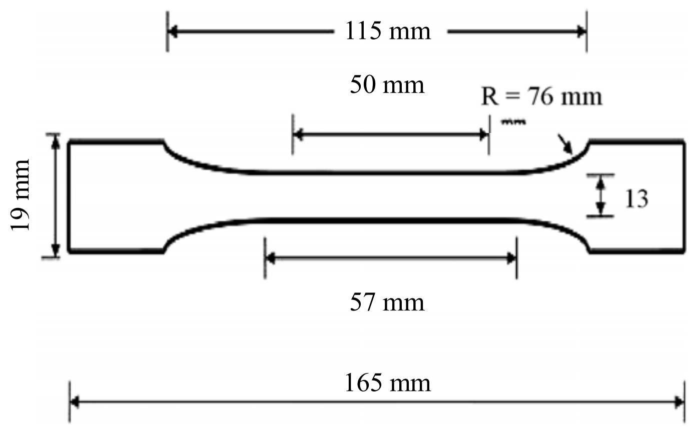

Fig. 5: Tensile test specimen measurements are in mm

Materials and methods

Polyurethane reinforced composites are widely used in various applications ranging from medical devices to automotive body panels. The success of polyurethane is due to its ability to be produced in various forms from flexible to rigid structures. In this research polyurethane pre-impregnated, glass fiber composite used to repair and reinforce internal and external corrosion on pipeline or structures is used to evaluate its performance at different temperature. Glass/Epoxy based composite slabs filled with varying concentrations of epoxy and filler materials were determined by considering the density, specific gravity and mass. Fabrication of the composites is done at room temperature by hand lay-up techniques. The required ingredients of resin, hardener, and fillers are mixed thoroughly in a basin and the mixture is subsequently stirred constantly. The glass fiber positioned manually in the open mold. Mixture so made is brushed uniformly, over the glass plies. Entrapped air is removed manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature. The prepared E-glass fiber reinforced epoxy composite

Mixing ratios

Polyurethane

Isocynate 44 g and Polyol 36 g. Take in this weight of polyurethane material into small cup mixing use by mechanical stirrer with in seven minutes stirrer time of isocynate and adding polyol in fourty five seconds. After adding the polyurethane poring into rubber molding the pouring materials (Fig. 3) are heated vacuum casting machine.

% of Weight in polyurethane

Total weight − 80 g

Isocynate weight − 44/80 = 0.55%

Polyol weight − 36/80 = 0.45%

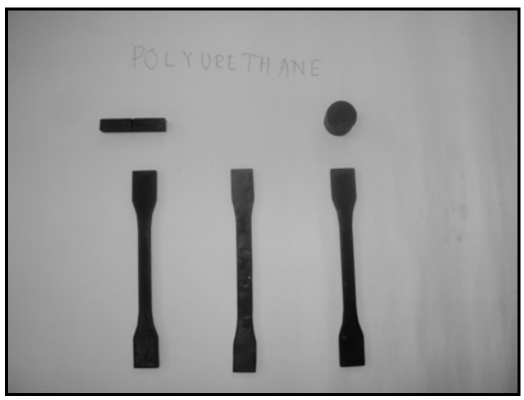

Fig. 6: Polyurethane

Polyurethane Composite-1

Polyurethane 80 grams aluminium powder 10 g and Glass fibre 10 g. Take in this weight of polyurethane material and aluminium powder into small cup mixing use by mechanical stirrer with in seven minutes stirrer time of isocynate and glass fibre adding polyol in fourty five seconds. After adding the polyurethane poring Fig. 3 into rubber molding. Finally pouring materials are heated vacuum casting machine.

% of Weight in composite

Total weight − 100 g

Polyurethane weight − 80/100 = 0.8%

Aluminium powder weight − 10/100 = 0.1%

Glass fibre weight − 10/100 = 0.1%

Polyurethane Composite-2

Polyurethane 80 g aluminium powder 5 g and Glass fibre 5 g. Take in this weight of polyurethane material and aluminium powder into small cup mixing use by mechanical stirrer g seven minutes stirrer time of isocynate and glass fibre adding polyol in fourty five seconds. After adding the polyurethane Fig. 3 into rubber molding. Finally pouring materials are heated vacuum casting machine.

% of Weight in composite

Total weight − 100 g

Polyurethane weight − 80/100 = 0.8%

Aluminium powder weight − 5/100 = 0.05%

Glass fiber weight − 5/100 = 0.05%

Polyurethane Composite-3

Polyurethane 80 g aluminium powder 2 g and glass fibre 8 g. Take in this weight of polyurethane material and aluminium powder into small cup mixing use by mechanical stirrer with in seven minutes stirrer time of isocynate and glass fibre adding polyol in fourty five seconds. After adding the polyurethane poring Fig. 3 into rubber molding. Finally pouring materials are heated vacuum casting machine.

% of Weight in composite

Total weight − 100 g

Polyurethane weight − 80/100 = 0.8%

Aluminium powder weight − 2/100 = 0.02%

Glass fibre weight − 8/100 = 0.08%

Polyurethane composite-4

Polyurethane 80 g and Glass fibre 10 g. Take in this weight of polyurethane material and aluminium powder into small cup mixing use by mechanical stirrer with in seven minutes stirrer time of isocynate and adding polyol in fourty five seconds. After adding the polyurethane poring into rubber molding. Finally pouring materials are heated vacuum casting machine.

% of Weight in composite

Total weight − 100 g

Polyurethane weight − 80/90 = 0.8%

Glass fibre weigh − 10/980 = 0.11%

Fig. 7: Composite Ratio-1

Fig. 8: Composite Ratio-2

Fig. 9: Composite Ratio-3

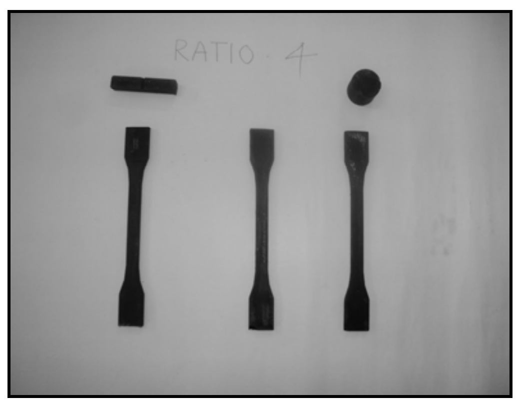

Fig. 10: Composite Ratio-4

Table 1: Material weight percentage in composite

S. No.	Materials	Composite 1	Composite 2	Composite 3	Composite 4
1	Polyurethane	Isocynate –44% Polyol – 36%	Isocynate – 44% Polyol – 36%	Isocynate – 44% Polyol – 36%	Isocynate – 44% Polyol – 36%
2	Aluminium powder	0.11%	0.055%	0.02%	–
3	Glass fibre	0.11%	0.0552%	0.088%	0.11%
4	Total weight	90 g	90 g	90 g	90 g

RESULTS AND DISCUSSION

Mechanical properties of materials: Mechanical properties of materials used in engineering design are determined by tests of small specimen according standards ASTM: American society for testing of materials

Tensile test

Tensile tests measure the force required to break a specimen and the extent to which the specimen stretches or elongates to that breaking point. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. The data is often used to specify a material, to design parts to withstand application force and as a quality control check of materials. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end user environment.

Test procedure

Specimens are placed in the grips of the Instron at a specified grip separation and pulled until failure. For ASTM D638 the test speed is determined by the material specification an extensometer is used to determine elongation and tensile modulus. The most common specimen for ASTM D638 is a Type I tensile bar. The most common specimen for ASTM D882 uses strips cut from thin sheet or film.

The following calculations can be made from tensile test results:

(i) Tensile strength (at yield and at break)

(ii) Tensile modulus

(iii) Strain

(iv) Elongation and percent elongation at yield

(v) Elongation and percent elongation at break

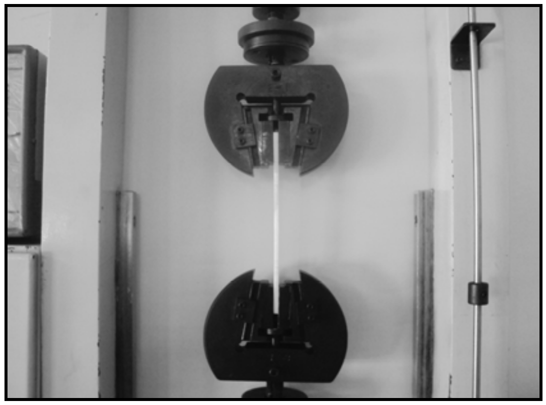

Fig. 11: Testing specimen

Polyurethane curve

Polyurethane test specimen tensile strength is 55.43 N/mm². Improve the mechanical strength of these plastics adding aluminium powder and glass fibres in various ratios. In first test only polyurethane used. Isocynate weight 0.55% Polyol weight 0.45%. After complete the tensile test take values in stress vs atrain curve is shown Table 2.

Stress vs strain graphs

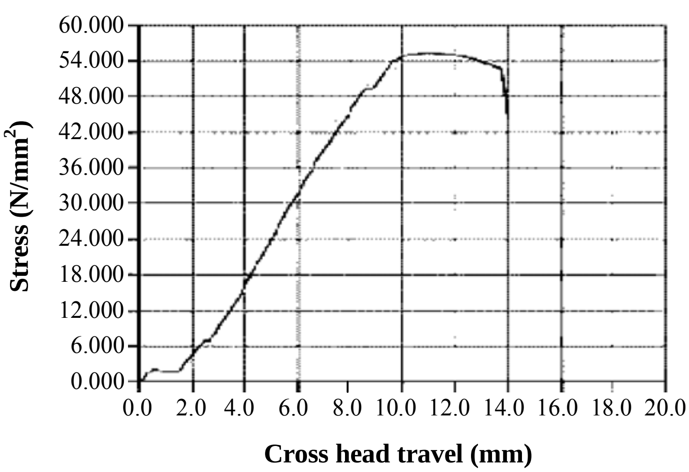

Fig. 12: Polyurethane

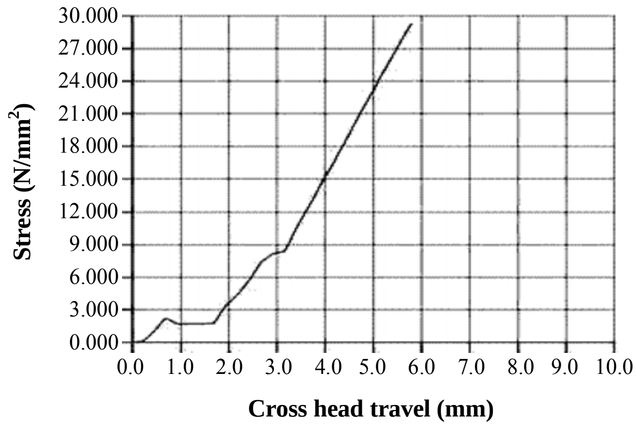

Fig. 13: Composite Ratio-1

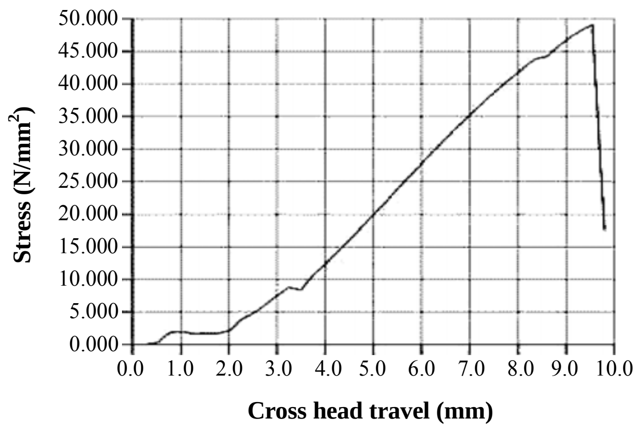

Fig. 14: Composite Ratio-2

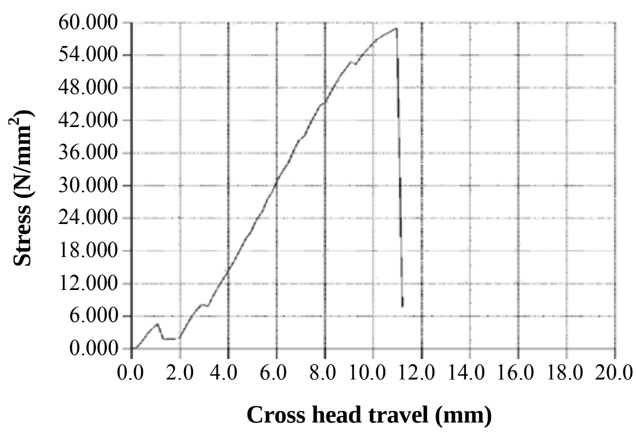

Fig. 15: Composite Ratio-3

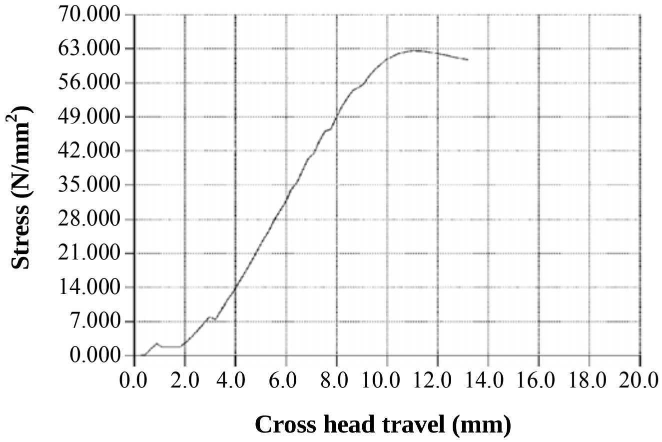

Fig. 16: Composite Ratio-4

Composite – Curve 1

In this ratios of composite materials are same weight of polyurethane Isocynate weight 0.55% polyol weight 0.45%. Adding aluminium powder is 0.11%, glass fibre 0.11%. After complete the tensile test take values in stress vs strain curve is shown Table 2. In this test can not improve the tensile strength of composite materials.

Composite – Curve 2

In this Ratios of composite materials are same weight of polyurethane isocynate weight 0.55% Polyol weight 0.45%. Adding aluminium powder is 0.055%, glass fibre 0.0552%. After complete the tensile test take values in stress vs strain curve is shown Table II. In this test can not improve the tensile strength of composite materials because above two composite materials is equal weight of aluminium powder and glass fibre.

Composite – Curve 3

In this, Ratios of composite materials are same weight of polyurethane Isocynate weight 0.55% Polyol weight 0.45%. Adding aluminium powder is 0.02%, glass fibre 0.088%.In this composite mixing small amount of aluminium powder taken. The tensile test values in stress vs strain curve are shown in Table II. In this test, there is improvement in the tensile strength of composite materials.

Composite – Curve 4

In this Ratios of composite materials are same weight of polyurethane Isocynate weight 0.55% Polyol weight 0.45%. Adding only glass 0.11% After Complete the tensile test take values in stress vs strain curve is shown Table 2. In this test, there is improvement in the tensile strength of composite ratio 4.

Table 2: Mechanical strength improvements in composite materials

S. No.	Materials	Peak load (KN)	Max C.H. travel (mm)	Tensile strength (N/mm^2)	Load at break (KN)	% Elongation
1	Polyurethane	2.217	10.83	55.43	1.793	12.63
2	Ratio-1	1.173	5.79	29.33	1.173	5.75
3	Ratio-2	1.966	9.52	49.12	0.700	20.03
4	Ratio-3	2.357	10.99	58.93	0.307	10.13
5	Ratio-4	2.504	11.03	626.60	2.428	12.01

CONCLUSION

This research will give experience and knowledge about the methods of manufacturing of Polyurethane based material. During the manufacturing process, properties of adhesives can be clearly understood. Tensile tests were performed on glass fiber reinforced polyurethane at different temperatures between room temperature and 100ºC. This study is a preliminary step to obtain a simple but effective failure criterion for composite reinforcement systems used for Air crafts and lightweight automobile component manufacturing industries.

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Accepted : 20.05.2016