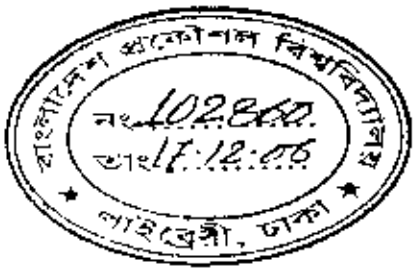
MECHANICAL PROPERTIES OF LOW DENSITY POLYETHYLENE AND ITS COMPOSITE

MD. NAZIM UDDIN



DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DHAKA-1000, BANGLADESH

CERTIFICATE

The thesis titled "Mechanical Properties of Low Density Polyethylene and its Composite" submitted by Md. Nazim Uddin, Student No. 100008006, Session October,2000 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Engineering in Industrial and Production Engineering (IPE) in April,2006.

BOARD OF EXAMINERS

Dr. A. K. M. Masud — **Chairman**
Assistant Professor,
Department of Industrial and
Production Engineering, BUET.
(Supervisor)

Dr. M. Ahsan Akhter Hasin — **Member**
Professor,
Department of Industrial and
Production Engineering, BUET.

Dr. Abdullahil Azeem — **Member**
Assistant Professor,
Department of Industrial and

DECLARATION

This is to certify that this work has been done by me and it was not submitted elsewhere for the award of any degree or diploma except for publication.

Md. Nazim Uddin

DEDICATED

TO

MY PARENTS

ACKNOWLEDGEMENT

First and foremost, the author would like to express his heartfelt gratitude and profound indebtness to his project supervisor **Dr. A.K.M. Masud**, Assistant Professor, Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka for his continuous guidance, full fledge support, valuable advice, keen supervision, numerous helpful snggestions and overall encouragement from the inception to the completion of this research work. The author deeply appreciates the time and effort he took to provide the valuable critiques, which often extended beyond the normal working hour, His never-ending inspiration in this work is beyond simple thanks giving.

The author wishes to take the opportunity to reuder respect and convey special thanks to his thesis committee members **Dr. Ahsan Akhter Hasin,** Professor, Department of Industrial and Production Engineering, BUET and **Dr. Abdullahil Azeem,** Assistant Professor, Department of Industrial and Production Engineering, BUET for their encouragement and useful suggestions.

Finally, no words can express the contribution of the author's parents on him. Their constant blessings, great sacrifice and moral support throughout his study were the backbone behind the success of the author in his study.

ABSTRACT

An experimental investigation of mechanical properties of the Low Density Polyethylene (LDPE) and its jute fiber-reinforced polymeric composite are presented on the basis of the results of the tensile test. In this case hand injection molding machine was used to manufacture the specimens. The long jute rope is twisting form of many long fibers together which is called as roving. At first, long roving jute are straightly set in the longitudinal direction of the mold along the length of the specimen. Then LDPE is supplied in the form of pellets in to the heating chamber. The LDPE is heated to form the liquid within minutes. The hot molten LDPE is forced to inject under pressure into the cold mold through the nozzle. The pressure is released after few seconds. Then the mold is setout and the shaped specimen removed from the mold immediately. No Chemical reaction occurs during the molting process. After that the length, width and thickness of each specimen measured with a suitable micrometer at several points. The specimen tested under tensile load by the universal testing machine. According to the results, it is discussed and analyzed that the mechanical properties like, max displacement, max stress, break load, break displacement, break stress, energy absorption capacity and young modulus are increased in the composite material in comparison with that of the Low Density Polyethylene resin matrix. By analyzing for present work further research and development, according to the needs in extension of this work.

TABLE OF CONTENTS

CHAPTER 04: TENSILE STRENGTH.

CHAPTER 05: ENERGY ABSORPTION.

CHAPTER 06: YOUNG'S MODULUS.

CHAPTER 07: SUMMERY OF THE TEST RESULT.

APPENDIX

CHAPTER 01

INTRODUCTION

1.1 General Introduction.

Plastic have become a universal material for everything from thruway bags to wings for combat aircraft. Plastics are cheap, lightweight, strong, often attractive, and can be synthesized with a wide rauge of properties.

Plastics have become major design materials of the 21st century and they are increasingly shaping the objects we use and rely on every day. Compared to the long established technologies of wood, metal, glass and ceramics, the plastics industry is a late arrival, but it now enjoys a well documented history and design in plastics has evolved its own distinctive indnstrial aesthetic. Traditionally associated with shiny, rounded shapes and gaudy colors, objects made of plastic now have more refined forms, sharper edges and softer, friendlier finishes. Where once synthetic materials were considered inferior.

Plastics have an ever widening range of uses in both the industrial and consumer sectors. In industry, advanced plastics and composites are everywhere replacing metal components in processes from food prodnction to nnclear reprocessing. Plastics have revolutionized the sports goods, houschold appliance and electronics industries, and tissue compatible plastics, notably carbon fiber and PTFE, have made a great impact on the design of medical equipment and prostheses.

Plastics are the materials of past, present and future generations. In addressing all the superior attributes of plastics, it is equally important to discuss some of the difficulties associated with the material. Plastics are very weak and can take very small load. They are easy to break. So plastics continue to be improved.

"Polyethylene (PE), sometimes known as "polythene" was discovered in 1933 by the Reginald Gibson and Eric Fawcett at the British industrial giant Imperial Chemical Industries (ICI). PEs are cheap, flexible, durable, and chemically resistant. This material evolved into several forms, "Low Density Polyethylene (LDPE)", and 'High Density Polyethylene (LDPE).

The packing industry is a leading user of plastics. Much LDPE (low density polyethylene) is marketed in rolls of cling film as those used for plastic waste bags and containers, i.e., milk, water and juice containers, grocery bags, toys, liquid detergent bottles. Copolymer LDPE, pigmented with a variety of colorants, is nsed for packaging toiletries, detergents and similar products.

Composite materials involve a system where reinforcing material (usually fibers made of glass or carbon) added to a plastic resin matrix. Resin is reinforced with fiber or other fillers, to overcome the fatigue failure, to resist a corrosive environment, to improve the physically and mechanical properties and to develop energy absorption capacity of the composite. Composite have strength and stability comparable to that of metals but generally with weight.

Plastic composites have been in use for long due to their lightweight, high specific strength and improved performance nnder stringent physical, chemical and environmental conditions. The use of composites in all products - from sporting goods to bridge to satellites - is increasing. The essence of plastic composite materials technology is the ability to put strong stiff fibers or other fillers in resin, in the right place, in the right orientation with right volume fraction.

With the range of inherent characteristics of polymeric material and the possible modifications from fillers, reinforcement, and additives, the chemical and engineering potential of plastics and elastomers is limitless.

The individual materials that make up composites are called constituents. Most composites have two constituent materials: a binder or matrix, and a reinforcement. The reinforcement is usually much stronger and stiffer that the

matrix, and gives the composite its good properties. Reinforcements basically come in three forms: particulate, discontinuous fiber, and continuous fiber.

Fiber-matrix interfacial properties are very important in the mechanical properties of the composite. Fiber-reinforcement composites transmit the external load from the matrix to the fiber through the interface between the fiber and the matrix. To improve the mechanical properties filler materials are used for reinforcement to make composite materials.

Continuous fibers are used in most high performance components. If long fiber is used to make composite then the fracture of the composite would need more energy and thus the energy absorption would be increased. With the increase in the energy absorption capacity the resistance to deformation would be increased.

Comparing to other types of composites natural fiber composites enjoy excellent potential as wood substitutes in building industry in view of their low cost, easy availability, saving in energy and pollution free production. Pavithran et at al [14] found that higher cellulose content and lower micro fibril angle resulted in higher work of fracture in impact testing. In order to improve upon the laboratory indnstry linkages towards application development & commercialization, the Advanced Composites Mission launched the projects on jute composites such as 'Jute-Coir Composites Boards, 'Jute-glass composite components for railway coaches', 'Thermoplastic composites based synthetic wood' and others. Jute is an attractive natural fiber for nse as reinforcement in composite because of its low cost, renewable nature and much lower energy requirement for processing.

The jute composites may be used in everyday applications such as lampshades, paperweights, helmets, shower and bath units. They are also nsed for covers of electrical appliances, pipes, post boxes roof tiles, grain storage silos, panels for partition & false ceilings, bio gas containers etc.

1.2 Objectives of the Present Work.

The main objective of the present work is to make a thorough and systemic experimental investigation of the mechanical properties like max load, max displacement, max stress, break load, break displacement, break stress, energy absorption, young's modulns and major characteristics of Low Density polyethylene and its composite made by jute fiber.In the study and dissertation the mechanical properties of Low Density Polyethylene and its composite made by jute fiber is compared on the basis of the results of the tensile test performed. According to the results, it is analyzed that the mechanical properties like displacement, max stress, break load, break displacement, break stress, Young's modules and energy absorption capacity is increased in the jute fiber composite matrix in comparison with that of the Low Density Polyethylene resin matrix.

1.3 Methodology.

(1) Design and mannfacture of LDPE specimens and its composite.

(2) Collecting information about the manufactured specimens.

(3) Measuring the dimensions of the specimens.

(4) Testing the properties of the specimens using universal testing machine and collecting data.

(5) Plotting the experimental data as graphical representation.

(6) Analyzing load displacement and stress-strain diagram.

(7) Comparing the energy absorption capacity of the specimens.

(8) Comparing the Young's modulus the specimens.

(9) Graphical representation of theoretical and experimental mechanical properties with 3σ-distribution.

1.4 Literature Review

Considerable works have been done on jute fiber reinforced polymeric composites. A report from the National Institute of Research on Jute and Allied Fiber Technology (NIRJAFT), Calcutta reveals that, usually for molded jute composites with polyester resin the resin intake can be maximum up to 40% Both hot press molding and hand lay-up technique can be used for its fabrication. In the latter process, the resin the up may go up to 300-400% on the basis of jute fiber used which is not economical. Also, it is seen that some pre-processing of jute/treatment of fiber is required so that the interface problem could be solved. Generally, when unsaturated polyester resin in used with glass fiber, the ratio maintained is 2.5:1. Whereas. for resin with jute the ratio maintained is 3.5- 4.1. However, increase in temperature increases the productivity. Even with unsaturated polyester resin, hot condition impregnation is nsnally done for higher productivity. Pavithran et al [14] found that higher cellulose content and lower micro fibril angle resnlted in higher work of fracture in impact testing.

Ina recent US patent [25] by Plummer et al., the project innovation relates to a natural fiber composite for fabrication of structural components such as rails, sills, tracks, stops and non-structural members such as grid, cove, bead etc. for residential & commercial architecture. The composite material, extruded in the form of pellets, comprises thermoplastic matrix (polyester, polyvinyl alcohol, PBT, nylon, spandex etc.) and short/long fiber reinforcements. A variety of fibers has been tried out by the inventor. A large array of natural fiber such as jnte, flax, hemp, ramie, cotton, palm leaf, coir etc, can be used. The composite material is palletized and the pellets are further extruded of injection molded as per the desired shapes/profiles.

Medoff et al. In US patent [26] of 1999 describes a process of fabricating composites with thermoplastic matrix and cellulosic or lingo-cellulosic fibers. The invention relates to texturizing the waste cellulosic or lingo-cellulosic fibers by shearing them using a rotary cutter. The fibers (2-5% by weight) are then.

Compounded with a mixture of thermoplastics (PE, PC, PVC, polyesters etc) as available from discarded containers. The resultant composite has been found to be strong, lightweight and inexpensive.

The European patent [27] granted to Neuhold et al. describes the process of fabricating a low density insulating board made from natural fibers. The natural fibers are opened up into single fibers which are then wetted with a natural (starch, protein etc) or synthetic thermo set resin and further compressed by rollers & cured in oven into desired shape with a density of 30-100 Kgs/m^3.

The development of a door module for motor vehicle has been described by Neuhauser et in the European patent [28]. The module comprises an internal lining component, which accommodates a side air bag & gas generator. The internal lining component is made of plastics or PU foam with synthetic or natural fiber reinforcing inserts.

In a European patent [29] by Ulrich Josef from Denmark had described a composite interior lining for vehicle. The inner cladding material for a vehicle consists of a natural fibre (jute, flax or sisal) based thermoplastic composite; the decorative layer is made of leather or synthetic leather (wool or cotton fibers with polyurethane) component. The intermediate layer is made of PP or PE foam or non woven PET/PP as sheet or rolled material.

The process for making a multi layer composite body comprising a thermoplastic layer and layers of natural fiber bonded to thermoplastic resin was patented in US by a German Company [30]. The composite body has at least one reinforcing layer made of an open cell fabric of melting fibers penetrated on one or both sides of the melting thermoplastic materials. The composite body has excellent mechanical properties particularly bending stress & impact resistance. A US patent [31] granted to a US company describes the method for fabricating wet-laid non-woven webs using jute fiber as reinforcement. Composites of the un pulped fiber webs with cellulosic and spun bonded sheets find applications as thrmoformed trim products for vehicle interiors.

A US patent [32] granted to a German company describes the process of fabricating a biodegradable composite. This involves using a thermoplastic starch and a hydrophobic biologically degradable polymer reinforced with natural fibers such as ramie, cotton etc. In a US patent [33], The Mead Corporation Dayton, Ohio, USA described the use of jute mesh as the intermediate reinforcing material for a corrugated container such as bulk storage bins. The reinforcing material may be placed in between the outer & inner of two-faced corrugated board construction.

The process of molding thermoset composite reinforced with natural fibers was patented [34] by a German company in 1993. The inventors used a resin mixture comprising unsaturated polyester with styrene and acrylic acid esters. The process invoice impregnating the natural fiber with the aforesaid resin formulation and hot pressing it to a desired shape.

Pradom Ltd, London, UK in its patent [35] described an innovative approach to electrical pre-treatment of reinforcing fibers for their application in composite. The treatment involves coating the fiber with a conductive or semi-conductive material and then subjecting it to an electric field with a DC supply (50-150,000 V) or AC (10,000 - 30,000 V; frequency : 50 - 1000 Hz).

A US patent [36]. De Groot Automotives Netherlands describes the process of fabricating a sheet material. The sheet comprises polyurethane resin reinforced with binder free natural fibers such as jute, flax, hemp, coir, ramie, cotton etc. possibly combined with polypropylene, polyethylene and/or glass fiber.

The preferred natural fiber is jute in the form of needled jute felt. The application lies in fabricating a sandwich panel with two outer walls made of jute composite sheets.

The Marlo Company Inc., Newton, Connecticut, USA in their patent [37] describe a packing material comprising glass in combination with organic fiber such as sintered poly-tetra-fluro-ethylene (TFE) with or without imp regnant.

A preferred imp regnant could be a lubricant with a binder. The process also talks of substitution of sintered TFE fiber by natural and other fibers.

In their application dating back to 1974, M/s. Care Inc., N.Y, USA patented [38] double wall reinforced & insulating building panel with a combination of glass & jute composites. The panels comprise of an inner skin of woven jute layers saturated in polyester resin and an outer skin of woven jute with an exterior coating of chopped glass fiber both impregnated with polyester resin. The intermediate layer bonding inner & outer skin is made of corrugated woven jute composite. the panel is of lightweight and has durability even in extreme temperature conditions

CHAPTER 02

MATERIALS USED FOR EXPERIMENTAL INVESTIGATION

2.1 Materials Used.

The packing industry is a leading nser of plastics. Much LDPE (low density polyethylene) is marketed in rolls of cling film as those used for plastic waste bags and containers, i.e., milk, water and juice containers, grocery bags, toys, liquid detergent bottles. Copolymer LDPE, pigmented with a variety of colorants, is used for packaging toiletries, detergents and similar products.

Low Density Polyethylene was used to produce the specimen matrix. Jute fiber was employed as the filler material for reinforcement. The Present work, which is a very beginning one concerning reinforcement of jnte fiber in LDPE resin matrix, is lack of investigating on the various features & properties of jute fiber and commercially used LDPE. Further work may include the necessary properties through investigation and from other sources, as well as the structural features and micro mechanics of the composite.

2.2 Low Density Polyethylene (LDPE).

Low Density Polyethylene (LDPE) is naturally milky white in appearance. It is a crystalline plastic which means polymers arranged in a regular order. LDPE is a relatively straight chain structure. The chemical nature of a LDPE is defined by the monomer that makes up the chain of the polymer. It is a polyolefin, its monomer unit is ethane (formerly called ethylene). It appears in crystalline structure, which is produced by addition polymerization process. Addition

Addition polymerization is comprised of three basic steps, initiation, propagation, and termination. During the initiation phase of the polymerization of polyethylene, the double bonds in the ethylene "mers" break and begin to bond together. A catalyst or promoter may be necessary to begin or speed up the reaction. The second phase, propagation, involves the continued addition of monomers into chains.

The final step is termination. During all monomers may be used, causing the reaction to cease. A polymerization reaction can cease by quenching the reaction. Similar to quenching someone's thirst, water can be used to quickly cool a reaction. Very simply, addition polymerization describes the process of "mers" joining by each one adding on to the end of the last "mer". A simple visual of the process is paper clips joined together to form a long chain.

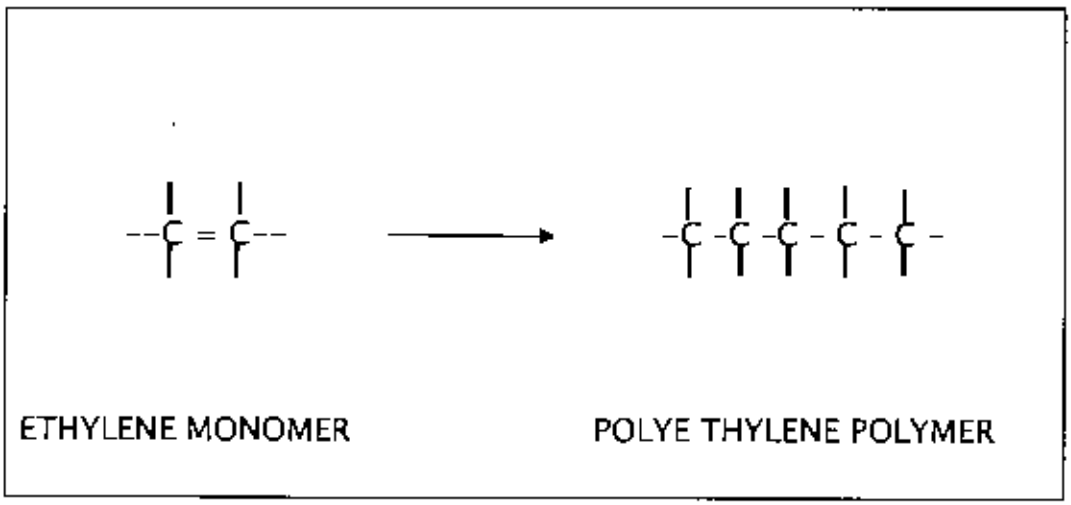


Fig. 2(a) Chain structures of ethylene monomer and polyethylene polymer.

LDPE is a thermoplastic material, which, once formed, can be heated and reformed over and over again. This property allows for easy processing and facilitates recycling. It is a rugged material. which is easy to mould, has a high resistance to impact and is not affected by most chemicals. LDPE objects are products of the injection molding process.

LDPE is flexible, translucent/waxy, weatherproof, easy to process by most methods, low cost, melt process able, have good toughness and stiffness, permeability to gas, food corrosion, abrasion, and chemical resistance, and lightweight.

The properties of LDPE depends upon the chemical system used, cure condition, specification of cure agent, cure schedule (rate and amount of hardener appropriate to the resin, temperature, duration and control of curing processes), perfection of operation and length and quality of the linking network.

In Bangladesh, LDPE is imported from Korea, India, Thailand, Australia, Japan, Saidiarabia and Indonesia. Here Polyethylene is an important packaging material used when exporting ready made garments and other exported items. REB using washer, anchor lock, meter board and electric spool which are locally made with plastics. In the kitchens there are bowls, small sieves, jars, mugs, spoons, basket, bucket, thermo flask, water tank, chairs, stools, hangers. The beverage companies are facilitated by introducing the PET bottles replacing the glass bottles. Smaller companies ontsource the PET bottles from the manufacturers, while some larger companies have setup their own PET bottle manufacturing plant. The cosmetic industries use blow molded bottles for talcum powder, shampoo, laminated tube for toothpaste. Bangladesh Biman is facilitated by the local plastic indnstry by buying from the onetime use crockery items like coffee cnp, tray etc for their catering service. Other than these ballpoint pen is manufactured hy plastics and it is used in various place. The LDPE material used in this work is of Injection type, Grade, HMA 016, imported from Saudi Arab. It is commercially used in our local market.

2.3 Jute Fiber.

Polymeric composites reinforced by glass fibers have been replacing metals in a variety of applications in mechanical and civil engineering in the past years. esides the conventional fiber composites there is a growing interest in plant fiber composites.

The scope for using jute fibers in place of the traditional glass fibers in different forms partly or fully as reinforcing agents in composites stems from the higher specific modulus and lower specific gravity of jute (~40 Pa and 1.29 respectively) compared with those of glass (~30 GPa and 2.5 respectively).

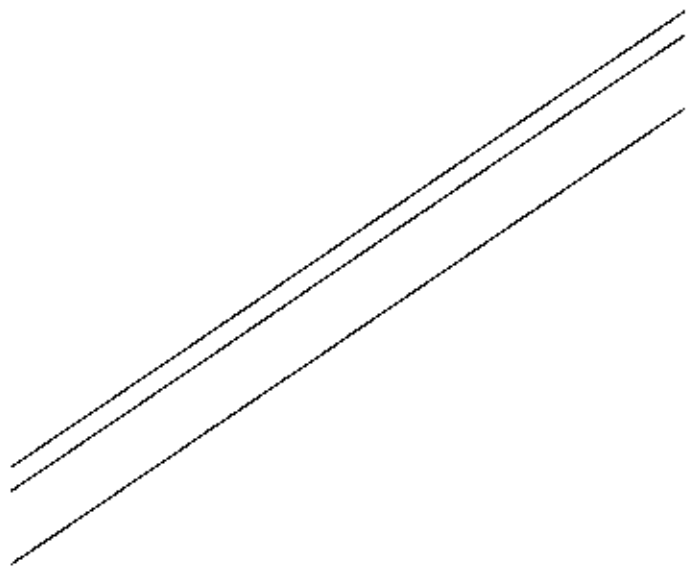


Fig : 2(b) Jute Fiber Roving used in our Project.

The following table shows a comparison of selected physical and mechanical properties of some synthetic and natural (plant) fibers. The properties of jute fiber, used in this project work were not represented in the following table. It was due to the lack of authorized data about the properties of our used jute fiber. The necessary investigation about jute fiber as a reinforcing one with its composite can be done in further extension of this project.

Table 2.1

Typical Properties of Some Synthetic and Natural Fibers.

Fiber Type	Density (Mg m^{-3})	Young's modulus (GN m^{-2})	Tensile strength (MN m^{-2})	Failure strain (%)
Synthetic fibers				
E-glass	2.56	76	2000	2.6
High strength carbon	1.75	230	3400	3.4
Kevlar™ (aramid)	1.45	130	3000	2.3
Boron	2.6	400	4000	1
Natural fibers				
Flax	1.4-1.5	50-70	500-900	1.3-3.3
Hemp	1.48	30-60	310-750	2-4
Jute	1.4	20-55	200-450	2-3
Sisal	1.45	9-22	80-840	3-14
Cotton	1.5	6-10	300-600	6-8

Although the tensile strength and Young's modules of jute are lower than those of glass fibers, the specific modulus of jute fiber is superior to that of glass and on a modulus per cost basis, jute is far superior. The specific strength per unit cost of jute, too, approaches that of glass. Therefore, where high strength is not a priority, there jute fiber can be a very potential candidate in making of composites, especially for partial replacement of high cost glass fibers without entailing the introduction of new techniques of composite fabrication. As such, commercial exploitation of jute composites for non structural applications promises excellent potential.

Rated fibers for jute have three principal chemical constituents, namely, a cellulose, hemi cellulose and lignin. In addition, they contain minor constituents such as fats and waxes, inorganic (mineral) matter, nitrogenous matter and traces

of pigments like bi-carotene and xanthophylls. As is synthetic fiber composites, the mechanical properties of the final product depend on the individual properties of the matrix, fiber and the nature of the interface between the two. Where the fiber is an agricultural one, it is possible to tailor the end properties of the composite by selection of fibers with a given chemical or morphological composition. Several studies of fiber composition and morphology have found that cellulose content and micro fibril angle tend to control the mechanical properties of cellulosic fibers.

A composite has three entities that are susceptible to failure the reinforcement, the matrix and the interface. The failure of one can initiate failure of the others, and the actual process that takes place in any particular case is determined by the stress required to activate each individual mechanism. The mechanism activated by the lowest stress will normally govern composite failure.

Thus, in order to increase the potential application area of jute fibers as reinforcement in composites, it is necessary to concentrate more on three major aspects (a) fiber modification (b) resin matrix (c) coupling agents.
Jute is available in continuous forms such as yarn, mat, roving, tapes etc. In our project, roving type jute fiber was used for making the LDPE composite specimens. The following picture shows the jute fiber roving used as reinforcement.

2.3.1 Fiber Size and Length.

The mean diameter of fibers used in reinforced plastics is usually less than 0.01mm. Jute Fiber Roving (twisted strand of fibers) used in our Project. The diameter of roving fiber consider as 1mm. The roving fibers are very strong and stiff in tension. The reason is that the molecules in the fibers are oriented in the longitudinal direction, and their cross sections are so small that the probability is low that any defects exist in the fiber.

CHAPTER 03

FABRICATION AND TEST OF THE SPECIMENS

3.1 Design of the Specimen.

A schematic diagram of the LDPE specimen matrix with necessary dimensions is shown in figure 3.2. The specimen is 271 mm ling and 27 mm wide. The neck/mid portion is 18 mm wide having a gauge length of 88 mm. The thickness of the specimen is 4.10 mm.

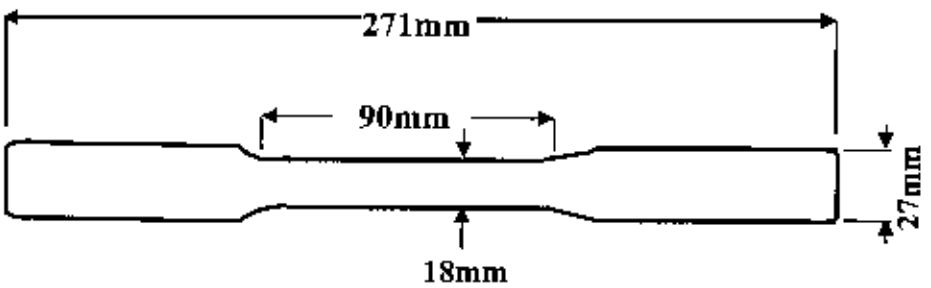


Fig 3.1 (a). Top View.

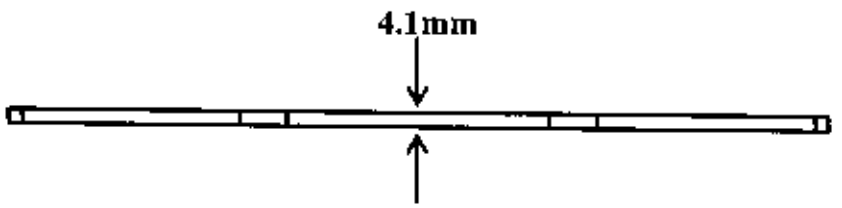


Fig 3.1 (b). Front View.

Fig : 3.1 Different View of the LDPE Specimen Matrix.

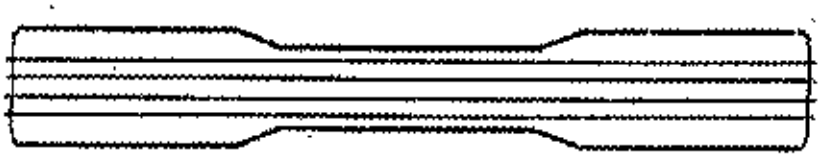


Fig 3.1(c) LDPE Composite Specimen Reinforced by Jute Fibers.

Figure 3.1(c) represents the schematic diagram of the LDPE composite specimen reinforced by jute fibers and shows how jute roving is set in the die (mold)

3.2 Manufacture of the LDPE Specimens.

The manufacture of plastic and plastic products involves procuring the raw materials, synthesizing the basic polymer, compounding the polymer into a material useful for fabrication, and molding or shaping the plastic into its final form. Injection molding process was used to fabricate the specimen. In this case hand Injection molding machine was used to manufacture the specimens. Machine capacity is 01 ounce. The variations, in small content, in the dimensions of the specimens are due to the manual operation of the machine. The material, after heated, is injected into the mold by manually rotating the wheel. In this machine at first the die is set in the position (A). Low Density Polyethylene is supplied in the form of pellets.

The pellets are gravity fed through the cylinder throat into the cylinder/heating chamber (B). The cylinder is where all the real work is done and it's essentially an electric coil spiraled outside of the cylinder. The electric coil gives heat to the material inside the heating chamber when connected to the power source.

Then the LDPE is heated to form the liquid within minutes. The manual rotating wheel (C) is used to compress, and convey the material under pressure.

As the wheel rotates, it gives the pressure to the liquid form of LDPE to get poured to the mold. The tip of the cylinder is called the "nozzle". Hot, molten LDPE is forced to inject under pressure into the cold mold through the nozzle. Then the die is set out and the shaped material is removed from the mold immediately after the part cooled and solidified. No chemical reaction occurs during the molding process. Forty specimens of LDPE matrix of required dimensions have been manufactured for the tensile test.

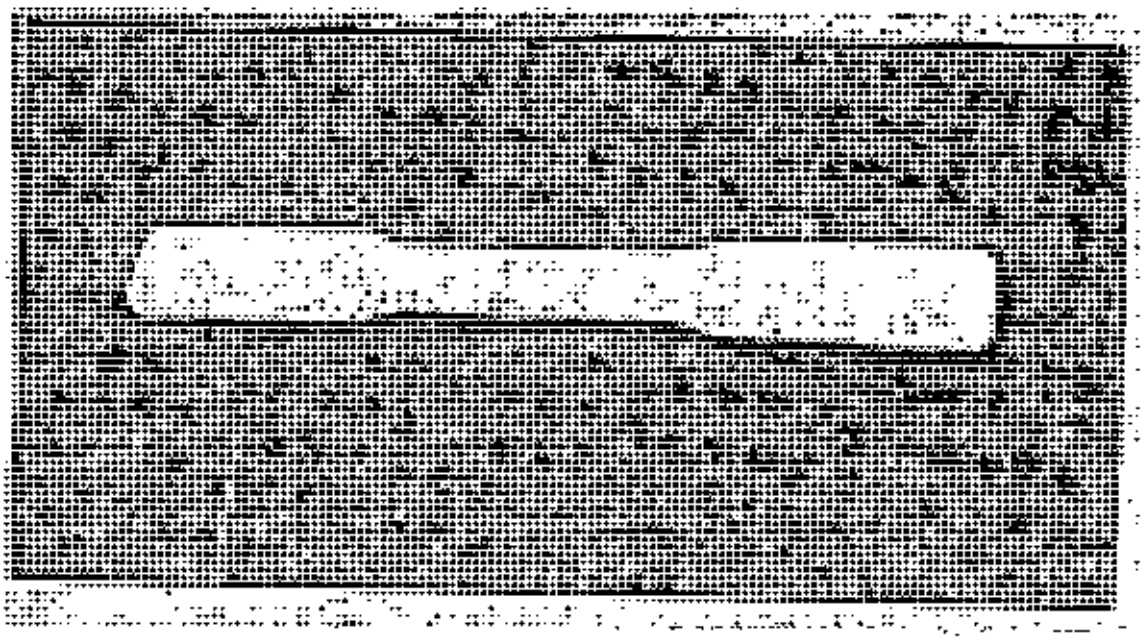


Fig : 3.2 The Manufactured LDPE Specimen Matrix.

Figure 3.2 shows the picture of LDPE specimen matrix after remove from the mold. All the LDPE specimen are similar to each other in dimension.

3.3 Manufacture of the LDPE Composite Specimens.

Long jute ropes are straightly set in the longitudinal direction of the die along the length of the specimen, as shown earlier in the figure 3.2. Then LDPE is compressed and injected manually by the hand injection molding machine. The numbers of jute ropes set in various specimens are 5.

However, the number and set up of jute roving were same and identical for all the specimens, 5 roving were set either straight, among which, it was observed after manufacture, one or two roving were torn out in some cases. The torn out pieces were not counted. The word 'long jute ropes' is explained herewith. Rope is the twisting form of many long fibers together. It can, rather, be called as roving, which is the slightly twisted strand of fibers. Roving used here are approximately of 01 mm in normal condition (slight twist), less than 01 mm in twisted condition.

Fig 3.3 The Manufactured LDPE Composite Specimen.

The picture of jute roving was shown earlier in Figure 2(b). Figure 3.3 shows the picture of a manufactured composite specimen.

3.4 Test to Investigate the Mechanical Properties of the Specimens.

Tensile test was carried out to determine the mechanical properties of the specimens under uniaxial tensile loading and to understand the mechanisms of deformation and the mode of failure. Tensile test method is designed to produce tensile property data for the control and specifications of plastic materials.

These data are also useful for qualitative characterization and the research & development. Tensile properties may provide useful data for plastics engineering design purposes. By gripping the ends of a thin, dog bone shaped specimen with a pair of crosshead grips and pulling at a constant speed, mechanical properties can be determined. Ten specimens of LDPE resin matrix and true specimens of LDPE composite matrix were tested. Due to very busy schedule of the concerned teacher of the lab, only these limited no of specimens were tested.

3.4.1 Dimensions of LDPE Specimens.

The width and thickness of each specimen tested were measured with a suitable micrometer at several points along their narrow sections. The effective representative dimensions of the test specimens, which have been tested are shown in table 3.1.

Table 3.1

Dimensions of Composite Specimens

Specimen No	Length of the specimen (mm)	Gauge Length of Neck (mm)	Gauge width of Neck (mm)	Thickness (mm)			Average Thickness (mm)
A 01	271	87.5	18.20	4.06	4.10	4.10	4.10
A 02	271	90.0	18.24	4.15	4.10	4.10	4.10
A 03	271	87.5	18.30	4.12	4.10	4.10	4.10
A 04	272	87.8	18.10	4.10	4.10	4.10	4.10
A 05	273	87.7	18.20	4.16	3.99	4.17	4.10
A 06	272	87.9	18.06	4.14	4.15	4.05	4.11
A 07	274	87.2	18.01	3.99	4.10	3.99	4.02
A 08	274	87.8	18.17	4.12	3.99	4.20	4.10
A 09	271	87.4	18.20	4.05	4.12	4.15	4.11
A 10	274	87.2	18.33	4.15	3.99	3.99	4.04
Mean	270.77	88.7	18.2				4.08

Table 3.1 shows that the average thickness is not always the same. The actual theoretical thickness of the designed specimen is 4.10 mm. As the process was done manually, the injection pressure may not be always the same, exact required amount of material may not be poured and the material may not removed from the mold at the exact time, before it cooled and solidified. So the average thickness varies.Here in all the specimens, the gauge length remains the same, it is 271 mm (major). Width is also same, it is 18 mm (neck).

3.4.2 Dimensions of Composite Specimens.

The effective dimensions of the composite specimens tested with comments on the embedding criteria of the jute ropes in the LDPE specimens, as observed after manufacturing, are shown in table 3.2 bellow.

Table 3.2

Dimensions of Composite Specimens.

Specimen No	No of fibers	Length of the specimen (mm)	Gauge Length of Neck (mm)	Gauge width of Neck (mm)	Thickness (mm)			Average Thickness (mm)
B01	5	274	92	18.2	4.4	4.4	4.2	4.33
B02	5	275	91	18.5	4.08	4.15	4.10	4.11
B03	5	275	90.5	18.1	4.35	4.30	4.32	4.32
B04	5	274	91.5	18.2	4.15	4.10	4.20	4.15
B05	5	274	91	18.2	4.20	4.40	4.40	4.33
B06	5	274	90.6	18.4	4.40	4.30	4.30	4.30
B07	5	274	92	18.3	4.30	4.40	4.10	4.28
B08	5	276	91	18.5	4.30	4.20	4.10	4.20
B09	5	275	92	18.1	4.20	4.10	4.30	4.25
B10	5	276	91	18.2	4.35	4.25	4.40	4.33
Mean		274.70	91.2	18.2				4.26

Table 3.2 also shows an increase in average thickness. The possible causes for the variation in dimensions have been discussed earlier, while observing LDPE specimens. Here also the gauge length and the width are same as in the LDPE specimens. The pieces of jute roving have not been found well embedded in LDPE. due to the pressure of liquid material while pouring into the mold, long jute ropes have floated on the surface of the specimens and consequently partially embedded.

3.5 Set-up and Operating Condition.

Each specimen was loaded into the grips of the testing machine, taking care to align the long axis of the specimen and the automated testing program initiated. The material, thickness, and width of each specimen was testing carefully recorded. Major dimensions are outlined in table 3.1 and table 3.2 above.

Close attention was paid to the specimen, noting the different stages of deformation. The response of the load and the displacement was measured and recorded. This was later put into Excel in a computer to obtain plots of load vs. displacement and stress vs. strain.

3.6 Failure.

Figure 3.5 represents a LDPE specimen matrix after failure. The specimen in the figure shows the failure. All the specimens showed little elastic and brittle failure, as observed. Brittle fracture occurred with little necking and plastic deformation. As the load is increased, the specimen begins at some level of stress, to undergo permanent plastic deformation. This stress level is known as 'Yield stress' of the material. Beyond this limit, the material shows elastic behavior. The maximum tensile stress is the 'Ultimate tensile strength'. The tensile stress at the fracture is known as 'breaking stress'.

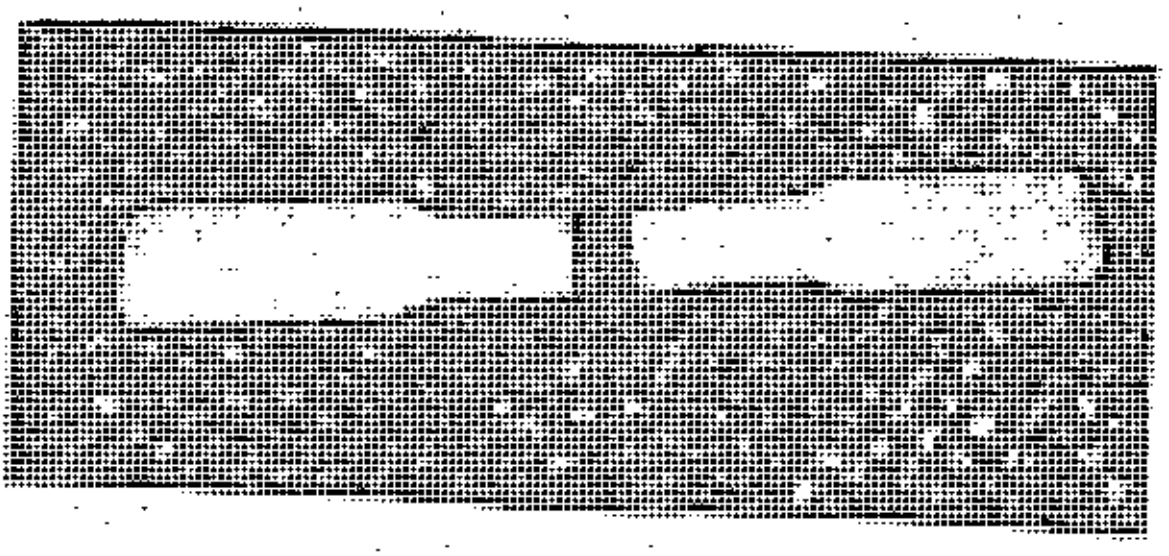


Fig 3.5 A LDPE Specimen Matrix After Failure.

CHAPTER 04

TENSILE STRENGTH

4.1 Tensile Test Result.

Table 4.1(a) and Table 4.2(b) represent the summaries of tensile test results of LDPE and composite specimens respectively showing the maximum load, displacement at maximum load, maximum stress, break load, break displacement and break stress.

Table 4.1(a)

Tensile Test Results of the LDPE Specimens

Specimen No	Max Load (kN)	Displacement at Max Load (mm)	Break Load (kN)	Break Displacement (mm)	Stress at max load (MPa)
A 01	0.628	8	0.569	12	8.415
A 02	0.628	8	0.579	13	8.397
A 03	0.647	8	0.549	13	8.623
A 04	0.647	10	0.559	14	8.719
A 05	0.608	9	0.520	14	8.147
A 06	0.633	8	0.569	12	8.531
A 07	0.638	8	0.540	13	8.812
A 08	0.643	9	0.589	13	8.664
A 09	0.633	10	0.569	14	8.462
A 10	0.628	8	0.559	11	8.480
Mean	0.633	8.6	0.560	11.5	8.525

Table 4.1(b)

Tensile Test Results of the Composite Specimens

Specimen No	Max Load (kN)	Displacement at Max Load (mm)	Break Load (kN)	Break Displacement (mm)	Stress at max load (MPa)
B 01	0.942	9	0.853	16	11.953
B 02	0.952	11	0.834	14	12.520
B 03	0.952	8	0.863	15	12.175
B 04	0.963	11	0.814	16	12.749
B 05	0.932	9	0.853	14	11.826
B 06	0.941	10	0.844	13	11.893
B 07	0.973	12	0.765	16	12.422
B 08	0.951	10	0.834	16	11.239
B 09	0.893	9	0.775	12	11.608
B 10	0.982	8	0.824	13	12.460
Mean	0.940	9.7	0.826	14.5	12.185

4.2. Load Displacement and Stress Strain Diagrams.

The load vs. displacement and stress vs. strain diagrams for all of LDPE specimens are shown in Anx A and The load vs. displacement and stress vs. strain diagrams for all of Composite specimens are shown in Anx B of this book.

4.3. Theoretical Stress.

The theoretical stress can be calculated considering the volume of jute-fibers in each composite specimen. The fiber load fraction can be increased by increasing the fiber volume fraction, which in turn increase the composite load. In general, the fiber failure strain is lower than the matrix failure strain. Assuming all the cylindrical fibers are uniformly distributed throughout the matrix and fibers have the same strength, the tensile rupture of fibers will precipitate a tensile rupture in the composite. Thus the longitudinal tensile strength of a unidirectional continuous fiber composite can be estimated. [24]The basic assumptions in this equation are as follows:

1. The jute-fibers are uniformly distributed throughout the LDPE matrix.

2. Perfect bonding exists between jute-fibers and matrix.

3. The matrix is free of voids.

4. Applied loads are either parallel to the fiber direction.

5. The lamina is initially in a stress-free state (i.e. no residual stresses are present).

6. Both jute-fibers and LDPE-matrix behave as linearly elastic materials.

4.3.1 Calculation of Volume Fraction.

We embed 05 nos of cylindrical jute fibers in to each specimen. The total tensile force P applied on the composite specimen is shared by the fibers and matrix. So that,

$$P_c = P_f + P_m$$

$$\Rightarrow A_c\sigma_c = A_f\sigma_f + A_m\sigma_m$$

$$\Rightarrow \sigma_c = \sigma_f v_f + \sigma_m (1 - v_f) \quad \ldots\ \ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (4a)$$

Where, V_f = Volume fraction.

σ_c = Theoretical tensile strength of the composite.

σ_f = Average tensile strength of the jute-fiber

= 200 MPa. (from Table 2.1)

σ_m = Average tensile strength of the matrix

= 8.525MPa. (from table 4.1a)

Here, $v_f = \frac{Total Volume of fibers}{Volume of Matrix}$

We used 05 nos of cylindrical fibers with dia of 1mm and in length of 87 mm in each composite specimen.

Hence, Total Volume of cylindrical fibers = $N \pi r^2 l$ ... ... (4b)

Where, l = length of fiber = 87mm.

r = Radius of cylindrical fiber = 0.5mm.

N = No of fibers = 05

Hence for the specimen B01, $V_f = \frac{5x(0.5)2\pi x87}{18.2x4.33x87}$

= 0.0498

As same of above we calculate the volume fraction by the equation (4a) and theoretical stress by the equation (4b) of each composite specimen and write down on the following table.

Table 4.4

Volume fraction of Composite Specimen.

Specimen No	Gauge Width of Neck (mm)	Average Thickness	No of Fibers	Volume fraction V_f	Theoretical Stress (MPa)
B01	18.2	4.33	5	0.0498	18.06
B02	18.5	4.11	5	0.0516	18.41
B03	18.1	4.32	5	0.0502	18.14
B04	18.2	4.15	5	0.0520	18.48
B05	18.2	4.33	5	0.0498	18.06
B06	18.4	4.30	5	0.0496	18.02
B07	18.3	4.28	5	0.0501	18.11
B08	18.5	4.20	5	0.0505	18.19
B09	18.1	4.25	5	0.0511	18.30
B10	18.2	4.33	5	0.0498	18.06
Average value				0.0504	18.26

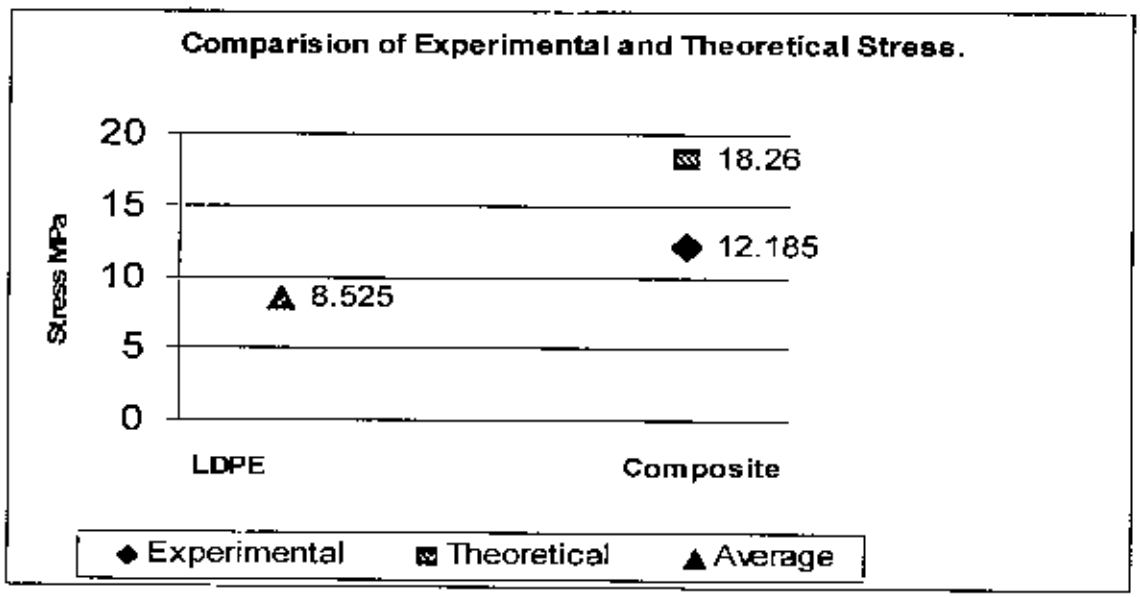


Fig 4.3 Comparison of theoretical and Experimental Stress.

4.4 Statistical analysis Actual Process Spread, 3-sigma for tensile stress.

Table 4.5(a) and 4.5(b) represents the values of actual process spread tensile stress, sigma (σ), for LDPE and its composite.

The equation for calculating sigma is given by

$$\text{Sigma, } \sigma = \sqrt{[\ \{\sum (X-\overline{X})^2\}\ ]}/N$$

Where,

X = Corresponding value of the specimen

$\overline{X}$ = Mean value

No of samples, N = 10 for LDPE and for composite.

Table 4.5(a)

3σ of tensile Stress for LDPE

Specimen No	Stress at Max Load (MPa)X	$X-\overline{X}$	$(X-\overline{X})^2$
A01	8.415	-0.110	0.0121
A02	8.397	0.128	0.0164
A03	8.623	0.098	0.0096
A04	8.719	0.197	0.009409
A05	8.147	-0.378	0.0388
A06	8.531.	0.006	0.1429
A07	8.812	0.287	0.0824
A08	8.664	0.139	0.0193
A09	8.462	-0.063	0.003969
A10	8.480	-0.045	0.0020
Mean, $\overline{X}$ = 8.525		$\sum (X-\overline{X})^2 = 0.3275$	
N= 10		σ = 0.18097	
		3σ = 0.5429	

Table 4.5(b)

3σ of tensile Stress for Composite

Specimen No	Stress at Max Load (MPa) X	$X-\overline{X}$	$(X-\overline{X})^2$
B01	11.953	-0.232	0.0538
B02	12.520	0.335	0.11223
B03	12.175	-0.010	0.00011
B04	12.749	0.564	0.3181
B05	11.826	-0.359	0.1289
B06	11.893	0.292	0.0853
B07	12.422	-0.237	0.0562
B08	11.239	0.054	0.00292
B09	11.608	0.577	0.3329
B10	12.460	-0.275	0.0756
Mean, $\overline{X}$ = 12.185		$\sum (X-\overline{X})^2$ = 1.16608	
N= 10		σ = 0.3414	
		3σ = 1.0244	

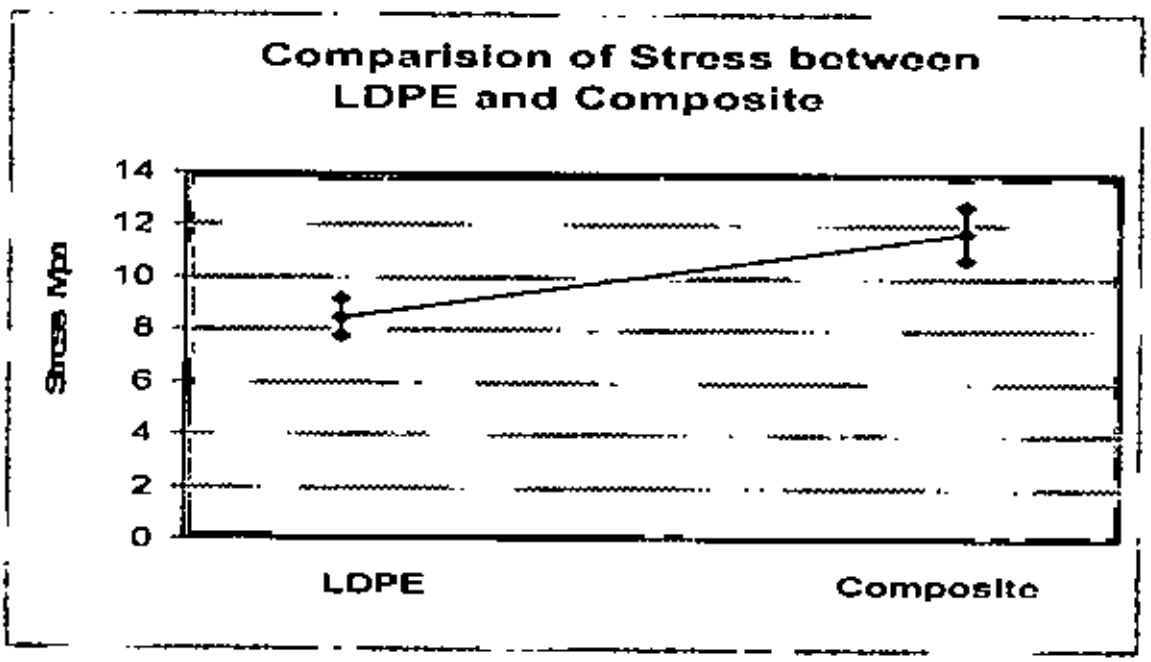


Fig. 4.4. Comparison of stress form LDPE and Composite

With a range limited by the maximum and minimum values of the experimental findings, considering it to be the allowable width/range, it will be mathematically checked that how experimental process spread. For both the LDPE and composite specimens, designated by A and B respectively, sigma will be calculated and according graphical representations are shown. Thus easier and simpler look will be get to compare between LDPE and its composite over the tensile stress.
The table will list the values of sigma and thus the actual process spread of both LDPE and composite.

4.6 Discussion .

The tensile test results was represented in the table 4.1(a) and 4.1(b). It was observed that the max, load, max displacement, max stress, break load, break displacement, break were increased in the composite specimens than that of the LDPE specimens.The tensile stress and strain were calculated by using the test results. Stress (MPa) was determined by dividing load (kN) by cross sectional area and strain (mm/mm) was determined by dividing displacement (mm) by the gauge length of neck of the specimen (mm).

The values of the tensile loads were plotted against the values of the corresponding displacements with the ordinate representing the load and the abscissa representing the displacement. Displacement is the distance the crosshead travels. Similarly the values of tensile stress were also plotted as ordinates against the corresponding values of tensile strain as abscissas. The load displacement curve and the tensile stress strain curve were approximately linear.It was observed that the jute ropes were not uniformly reinforced to a significant level due to manual operation. But, embedding of jute fibers in B 02 and B 04 was better than that in B 09. In case of B 09, at the ropes were slightly embedded, almost float to the surface due to the pressure of liquid LDPE while making composite specimen. But in case of B 02 and B 04, two and three pieces of ropes, respectively, were embedded well into LDPE. Hence gave a better sustain.

CHAPTER 05

ENERGY ABSORPTION

5.1 Definition of Energy.

Energy is defined as the ability or capacity to perform work. The amount of work done by any object is stored in the body as potential energy. Work depends upon the force and the force varies in proportion to the resistance encountered. Energy can neither be created not destroyed the resistive forces acting along within the object create internal deformations and produce an equivalent amount of internal work. If an equivalent amonnt of work were not developed, nnrestrained motion or instability would result. The dynamic form of energy produces stresses of much greater magnitude npon impact than those produced by the same weight applied gradually. The kinetic energy of the load at impact is equivalent to the total internal energy developed inside the object to resist the external one.

A load gradually applied to an elastic body would create a gradual increase in deformation, which attains its maximum value at the time of full load (capable to hold by the specimen) application. The product of the average load applied or the transferred to the body and the deformation produced by the full load is the measure of external energy put into the body. The value of the externally applied energy is measured as the areas under the load displacement curve. As a result of the externally applied force, energy is developed internally as the resisting forces. The internal energy developed is equal to the average force or couple times its maximum internal deformation. The internal or resisting forces must be equal to the external force.

5.2 Energy Absorbed by the Specimens.

The energy absorbed by the specimens of LDPE and its Composite reinforced by jute fiber was calculated from the area under the curve of the tensile load with respect to the displacement. The area was calculated by the triangle equation as following Fig.5.1 We calculated the area of all the specimen from corresponding Load-Displacement diagram shown in Anx A and Anx B and write down on the following table 5.2(a) and 5.2(b).

5.2.1 Calculation of energy absorption.

The energy absorption, E= Work done before breaking during tensile test.

= Area under the load displacement curve.

Energy = Approximate area calculated under the curve.

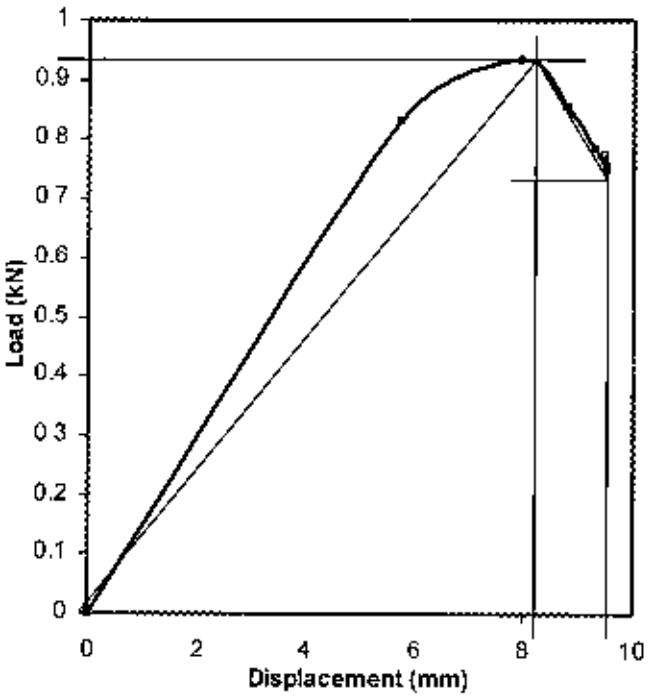


Fig. 5.1. Energy absorption by the Specimen (A09)

Table5.2(a)

Energy absorption by LDPE specimens

Specimen No	Max Load (kN)	Displacement at Max Load (mm)	Break Load (kN)	Break Displacement (mm)	Energy absorption (joule)
A 01	0.628	8	0.569	12	4.90
A 02	0.628	8	0.579	13	5.53
A 03	0.647	8	0.549	13	5.58
A 04	0.647	10	0.559	14	5.65
A 05	0.608	9	0.520	14	5.56
A 06	0.633	8	0.569	12	4.94
A 07	0.638	8	0.540	13	5.49
A 08	0.643	9	0.589	13	5.36
A 09	0.633	10	0.569	14	5.56
A 10	0.628	8	0.559	11	4.29

Table5.2(b)

Energy absorption by Composite specimens.

Specimen No	Max Load (kN)	Displacement at Max Load (mm)	Break Load (kN)	Break Displacement (mm)	Energy absorption (joule)
B 01	0.942	9	0.853	16	8.73
B 02	0.952	11	0.834	14	7.92
B 03	0.952	8	0.863	15	9.85
B 04	0.963	11	0.814	16	9.12
B 05	0.932	9	0.853	14	9.46
B 06	0.941	10	0.844	13	7.24
B 07	0.973	12	0.765	16	8.89
B 08	0.951	10	0.834	16	9.75
B 09	0.893	9	0.775	12	6.45
B 10	0.982	8	0.824	13	8.05

5.3 Statistical analysis Actual Process Spread, 3-sigma for Energy absorption.

Table 5.3 represents the values of actual process spread. sigma (σ), for LDPE and its composite.

The equation for calculating sigma is given by

$$\text{Sigma, } \sigma = \sqrt{[\ \{\Sigma(\mathbf{X}-\overline{\mathbf{X}})^2\}\ ]}/N$$

Where, $\mathbf{X}$ = Corresponding value of the specimen

$\overline{\mathbf{X}}$ = Mean value

N = No of samples = 10 for LDPE and for composite.

Table 5.3(a)

3σ of Energy absorption by LDPE specimens.

Specimen No	Energy absorption (Joule) X	$\mathbf{X}-\overline{\mathbf{X}}$	$(\mathbf{X}-\overline{\mathbf{X}})^2$
A01	4.90	-0.380	0.144
A02	5.53	0.250	0.0625
A03	5.58	0.300	0.090
A04	5.65	0.370	0.1369
A05	5.56	0.280	0.0784
A06	4.94	-0.340	0.1156
A07	5.49	0.210	0.0441
A08	5.36	0.080	0.0064
A09	5.56	0.280	0.0784
A10	4.29	-0.990	0.9801
Mean $\overline{\mathbf{X}}$ = 5.28		$\Sigma(\mathbf{X}-\overline{\mathbf{X}})^2$ = 1.7364	
N = 10		**σ = 0.417**	
		3σ = 1.25	

Table 5.3(b)

3σ of Energy absorption by Composite specimens.

Specimen No	Energy absorption (Joule) X	$X-\overline{X}$	$(X-\overline{X})^2$
B01	8.73	0.170	0.0289
B02	7.92	-0.640	0.4096
B03	9.85	1.290	1.664
B04	9.12	0.560	0.3136
B05	9.46	0.900	0.810
B06	7.24	-1.320	1.742
B07	8.89	0.330	0.109
B08	9.75	1.190	1.416
B09	6.45	-2.110	4.450
B10	8.05	-0.510	0.260
Mean $\overline{X}$ =8.56		$\sum(X-\overline{X})^2$ =11.2031	
N = 10		σ = 1.0584	
		3σ = 3.175	

5.4 Discussion.

The total area under the load-displacement diagram represents total energy of the LDPE resin matrix and the composite. Here, the composite reinforced with jute fiber shoes increase in strength as well as increase in the amount of energy absorption. The gradual increase in tensile load would be withstood by the combined resistive action by the fiber and the matrix. The applied load would be distributed among the individual fibers at the fracture plane. The reinforcement of the matrix made by the jute fiber mainly depends upon the content of the fiber in the plane along which fracture would occur.

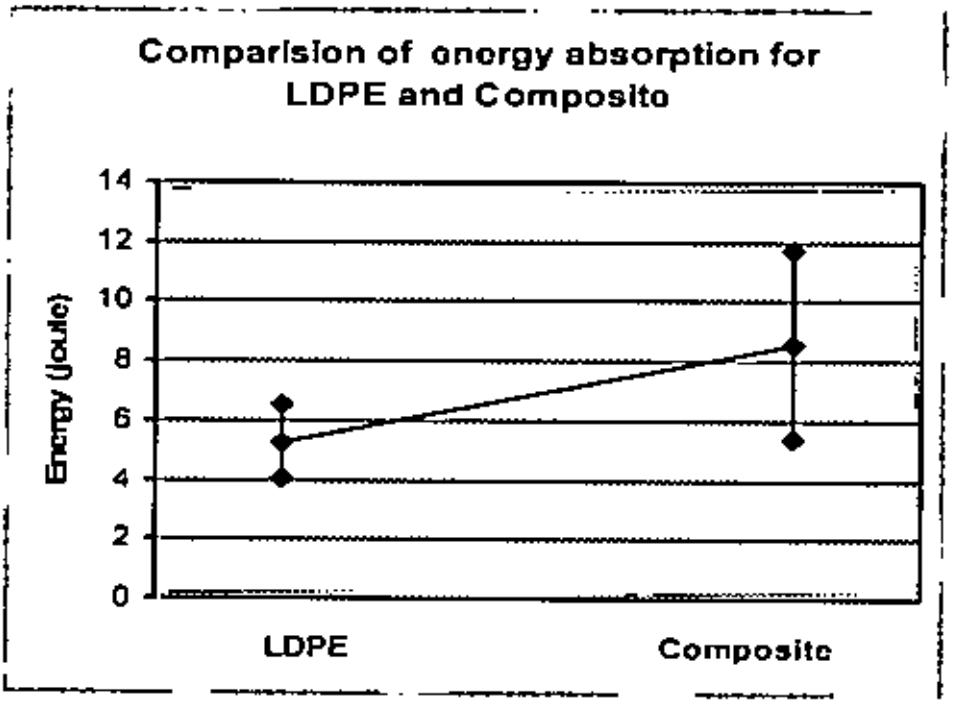


Fig 5.2. 3σ- limit of Energy absorption

The energy absorbed by a composite depends upon the intrinsic properties of the resin and the matrix as well as the interfacial properties of the fiber/matrix. But fiber orientation plays a crucial role in the inter-relation between the fiber and the matrix. It was assumed that crack may appear but hesitate to propagate.

Because the crack change its direction when meets any fiber on the way and the force along the loading direction would have move contribution than that of inclined fibers. It was considered that the tensile force would be along the neutral axis of the specimen. Strength of the composite increased with the number of fiber in a particular plane and the orientation of the fiber. The fiber would have enough interfacial shear loads between the fiber and the matrix in the composite. So to overcome the value more force would have to apply and as a result the energy absorbed in the fracture would be greater than that of the normal resin specimen.

The energy absorption increases with the increase in the number of fibers and fiber orientation. The matrix in the composite has a constant contribution in the energy absorption of the composite. The fiber-reinforced composites acquire sufficient internal energy due to the fiber to resist the applied energy and at this load the matrix fails but the interfacial shear between the fiber and the matrix provides adequate energy to resist the applied load.

These facts clearly justify the reasons why the composite materials absorbed more energy than that of the LDPE in our project. Energy absorption increases with fiber reinforcement and content of the fibers. So it can be concluded that the composite specimens reinforced with jute fiber shows better energy absorption capacity and performance than that of the normal specimen made by the same materials without fiber reinforcement.

CHAPTER 06

YOUNG'S MODULUS

6.1 Definition of Young's modulus.

Young's modulus is taken as the ratio of the some definite stress to the strain corresponding to that stress. it states that up to certain limit, the stress is proportional to strain. The limit up to which Hooke's Law is obeyed is called the limit of proportionality. Mathematically, Hooke's law is,

Stress α Strain

i.e. Stress = A constant of proportionality x Strain

Under direct stresses and strains, the constant of proportionality is known as elastic modulus or Young's modulus and denoted by Y.

Thus Young's modulus, $Y = \frac{Stress}{Strain}$ ... . (6a)

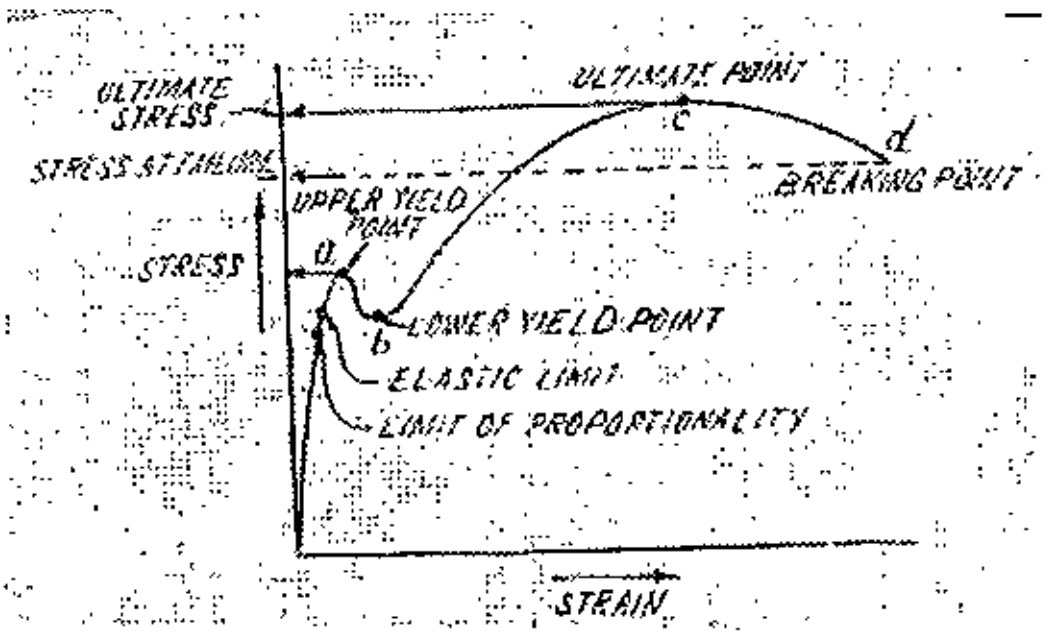


Fig. 6.1. Typical Stress-strain curve.

6.2. Young's Modulus of Specimens.

When the specimen was subjected to the gradually increasing axial load, the stresses and strains can be found out number of loading conditions and a curve is plotted up to the point at which the specimen fails, giving what is known as stress-strain curve, such curves differ in shape for various causes. All the stress-strain curves shown iu the aux A and anx B.

6.3 Calculation of Young's modulus.

We calculate the theoretical young's modulus by the equation (6c) where the volume fraction from the table 4.4 and strain is calculated from the equation (6b) and write down against each specimeu in the table 6.1(b) bellow.

$$\text{Strain} = \frac{Displacement}{length} \quad \ldots\ldots\ \ldots\ \ldots\ \ldots\ \ldots \quad (6b)$$

After that using the equation (6a) we calculate the Young's modulus from the stress and strain for each specimen.

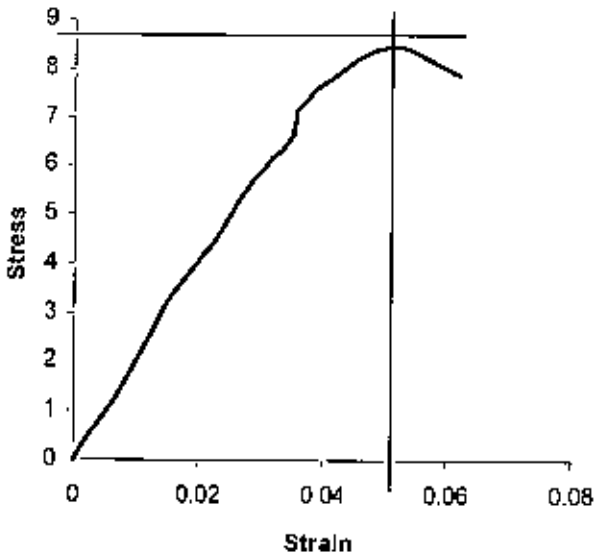


Fig. 6.2. Stress-strain curve of a specimen.

6.3.1 Theoretical Young's Modulus.

The theoretical young's modulus can be calculated considering the volume of jute-fibers in each composite specimen. The fiber load fraction can be increased by increasing the fiber volume fraction, which in turn increase the composite load. In general, the fiber failure strain is lower than the matrix failure strain. Assuming all the cylindrical fibers are uniformly distributed throughout the matrix. The total tensile force applied on the composite specimen is shared by the fibers and matrix. So that,

$$Y_c = Y_f v_f + Y_m (1 - v_f) \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (6c)$$

Where, v_f = Volume fraction.

Y_c = Theoretical young's modulus of the composite.

Y_f = Average young's modulus of the jute-fiber

= 20 GPa. (from Table 2.1)

Y_m = Average young's modulus of the matrix

= 87.16MPa. (from table 6.1a)

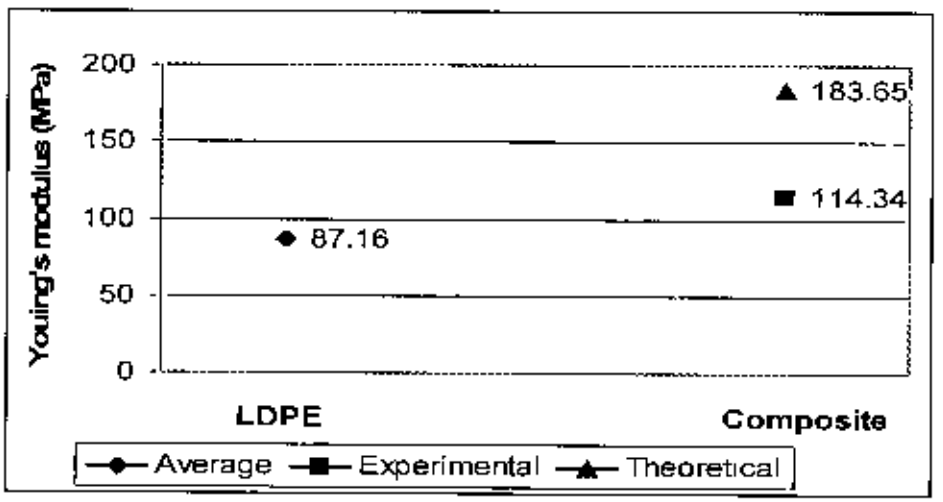


Fig. 6.4 Showing comparison of Young's modulus.

Table 6.1(a)

Young's Modulus of LDPE specimens.

Specimen No	Gauge Length of Neck (mm)	Stress at max load (MPa)	Displacement at Max Load (mm)	Young's modulus (MPa)
A01	87.5	8.415	8	92.04
A02	90.0	8.397	8	94.46
A03	87.5	8.623	8	94.31
A04	87.8	8.719	10	76.55
A05	87.7	8.147	9	79.39
A06	87.9	8.531	8	87.90
A07	87.2	8.812	8	96.05
A08	87.8	8.664	9	84.52
A09	87.4	8.462	10	73.95
A10	87.2	8.480	8	92.43

Table 6.1(b)

Young's Modulus of Composite specimens

Speci-men No	Gauge Length of Neck (mm)	Stress at max load (MPa)	Displacement at Max Load (mm)	Young's modulus (MPa)	Theoretical Young's modulus (MPa)
B01	92	11.953	9	122.19	182.42
B02	91	12.520	11	103.57	185.86
B03	90.5	12.175	8	137.73	186.62
B04	91.5	12.749	11	106.05	182.42
B05	91	11.826	9	108.22	182.03
B06	90.6	11.893	10	107.75	183.12
B07	92	12.422	12	95.24	182.99
B08	91	11.239	10	102.27	183.75
B09	92	11.608	9	118.65	184.91
B10	91	12.460	8	141.73	182.42
Average value =				114.34	183.65

6.4 Statistical analysis Actual Process Spread, 3-sigma for theoretical Young's Modulus.

Table 6.4 represents the values of actual process spread, sigma (σ). for LDPE and its composite.

The equation for calculating standard deviation sigma is given by

Sigma, $\sigma = \sqrt{[\{\sum(X-\overline{X})^2\}]/N}$ for a normal distribution.

Where, **X** = Corresponding value of the specimen

$\overline{X}$ = Mean value

N = Sample size = 10 for LDPE and for composite.

Table 6.4(a)

for 3σ Spread of LDPE specimen.

Specimen No	Young's modulus (MPa) X	$X-\overline{X}$	$(X-\overline{X})^2$
A01	92.04	9.38	87.98
A02	94.46	4.83	23.33
A03	94.31	8.49	72.08
A04	76.55	10.07	101.04
A05	79.39	-19.39	375.9
A06	87.90	-4.39	19.27
A07	96.05	10.48	109.83
A08	84.52	-12.08	145.9
A09	73.95	-6.84	46.78
A10	92.43	-9.13	83.35
Mean, $\overline{X}$ = **87.16**		$\sum (X-\overline{X})^2$ = 1065.47	
N=10		σ = 10.32	
		3σ = 30.96	

Table 6.4(b)

for 3σ Spread of Composite Specimen.

Specimen No	Experimental Young's modulus (MPa)X	$X - \overline{X}$	$(X-\overline{X})^2$
B01	122.19	7.85	61.6
B02	103.57	-10.77	115.99
B03	137.73	23.39	547.09
B04	106.05	-8.29	68.72
B05	108.22	-6.12	37.45
B06	107.75	-6.59	43.42
B07	95.24	-19.10	364.81
B08	102.27	-12.07	145.68
B09	118.65	4.31	18.57
B10	141.73	27.39	750.21
Mean $\overline{X}$ = 114.34		$\sum (X-\overline{X})^2 = 2153.54$	
N=10		$\sigma = 14.67$	
		$3\sigma = 44.02$	

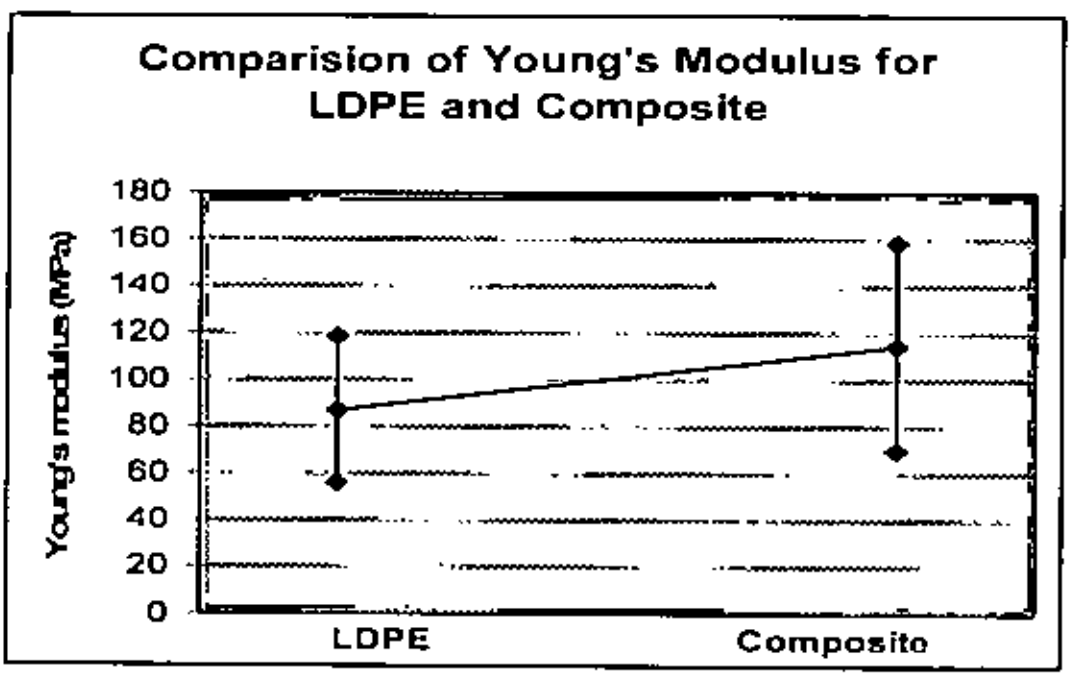


Fig. 6.3 3σ- limit of Young's modulus.

A range limited by the maximum and minimum values of the experimental young's modulus, considering it to be the allowable width/range, it will be mathematically checked that how experimental process spread. For both the LDPE and composite specimens, designated by A and B respectively, sigma will be calculated and according graphical representations are shown. Thus easier and simpler look will be get to compare between LDPE and its composite over the Young's modulus. The table will list the values of sigma and thus the actual process spread of both LDPE and composite.

CHAPTER 07

SUMMERY OF THE TEST RESULT

7.1 Linear comparison.

Now a table can be formulated for linear comparison of the summary of results obtained from the tensile test. Table 7.1 lists the linear compare of the mean values of both the specimens LDPE (A) and its composite (B) for four parameters, with average direct increase and percentile increase.

Table 7.1

Linear Comparison of LDPE with its Composite

Mechanical properties	LDPE (A)	Composite (B)	Direct Increase	Increase %
Break Load (kN)	0.560	0.826	0.266	47.5
Stress at max load (MPa)	8.525	12.185	3.66	42.9
Energy absorption (joule)	5.28	8.56	3.28	62.12
Young's modulus (MPa)	87.16	114.34	27.18	31.18

Table 7.1 allows a closer look and confirms that LDPE composite specimen (B) gives a higher value of all the parameters, than that of the LDPE (A). Percentile increase is calculated against value of specimen A, i.e., % increases, in all the six parameters, of the

composite with respect to that of the LDPE. Average direct increase shows a linear increase in the values of specimen B, for all the parameters, over that of specimen A. Maximum and break load show an increase over 45%, also the stresses are nearer to that. Increases in maximum and breaking displacement have also come significant. So far, has been found that composite shows better performance as it is expected.

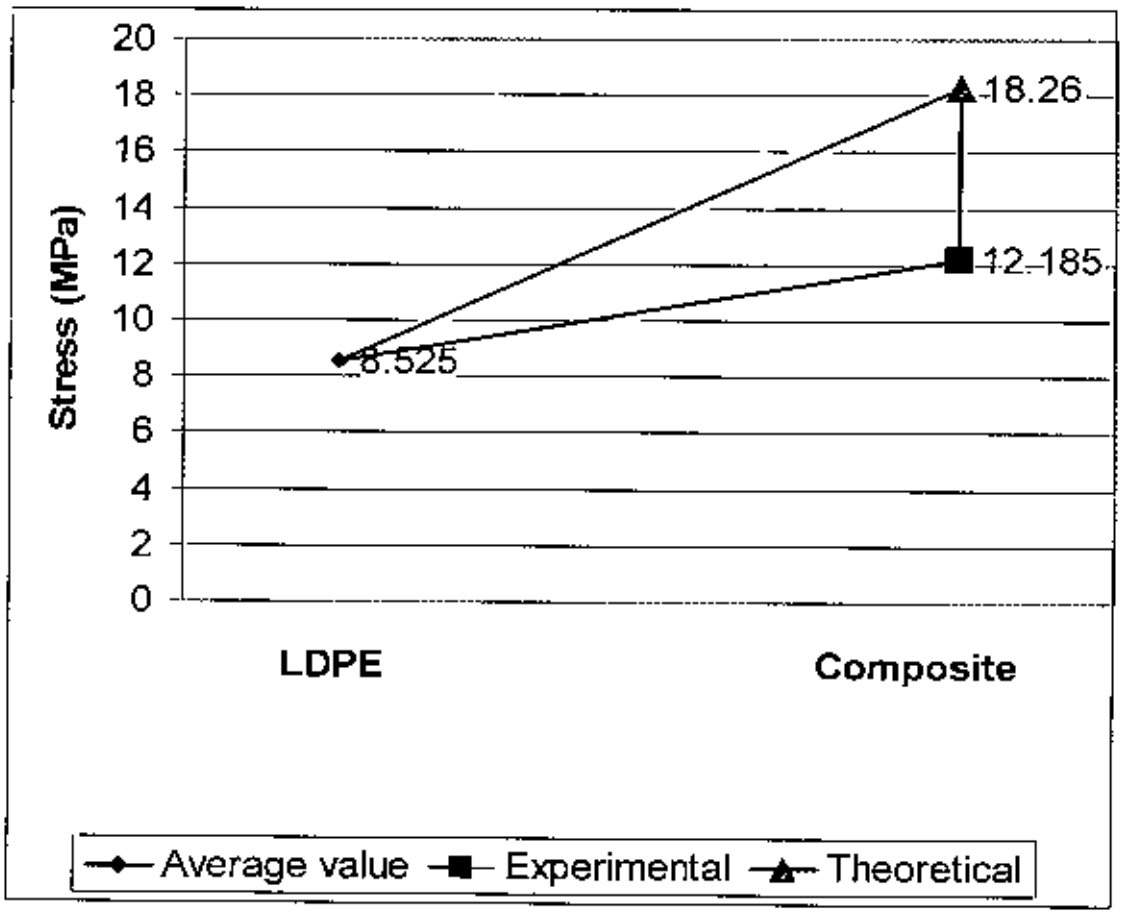


Fig. 7.1 Showing comparison of tensile stress.

7.2 Discussion.

The mechanical properties are extremely important and useful in choosing a material for a particular application. Depending upon the results of the tests, mechanical properties were established and also discussed for further research and

improvement. Tensile test was carried out for different Low Density Polyethylene specimens and its composite specimens reinforced by jute fiber.

The tensile test results was represented in the table 4.1(a) and 4.1(b). Linear comparison was done in table 7.1 It was observed that the max, load, max displacement, max stress, break load, break displacement, break were increased in the composite specimens than that of the LDPE specimens.

There might be some variation in the pressure, temperature and pouring rate, so there might be some change in the properties and the fiber orientation were not maintained exactly as desired for the same reason.

The tensile stress and strain were calculated by using the test results. Stress (MPa) was determined by dividing load (kN) by cross sectional area and strain (mm/mm) was determined by dividing displacement (mm) by the gauge length of neck of the specimen (mm).

The values of the tensile loads were plotted against the values of the corresponding displacements with the ordinate representing the load and the abscissa representing the displacement. Displacement is the distance the crosshead travels. Similarly the values of tensile stress were also plotted as ordinates against the corresponding values of tensile strain as abscissas. The load displacement curve and the tensile stress strain curve were approximately linear.

Figure 3.3 show the typical failure process of Low Density Polyethylene resin matrix and its composite reinforced by jute fiber under tensile loading. All the curves are almost identical to that of the typical ones. In the load displacement diagram of all the LDPE specimens and the composite specimens were found that the load increased gradually in a approximately linear rate with the displacement, up to a certain point, i.e., peak load, and after that the load dropped fastly and necking is accrued and suddenly fractured. So the specimens showed a brittle like fracture behavior. The appearance of the specimens showed that they were

divided into two portions just exceeding the peak load,. Thus after failure, the specimens would have no displacement with respect to load.

Figure 4.7(b) for specimen B 04 show that after the load reaches its peak value then there is a zigzag decline. The easy explanation, the curve is divided into five segments. At load level of segment 1, the load was within the proportional limit up to a fixed point, then the curve started to deviate from linearity and increase up to the peak load in segment 1. At load level of segment 2 to 4, beyond the peak load, the load shows a zigzag decline with the displacement. From load level of segments 4 to 5 the load remains constant with increasing displacement. After then fracture occurs. Here initiation of micro crack was observed in the in the middle portion of the gauge length. Plastic deformation (micro yielding) occurred in the matrix and the crack started to broaden and the specimen started to fracture macroscopically without dividing into two portions. The cause behind this behavior is the reinforcement and embedding criteria of jute fibers.
It was observed that the jute ropes were not uniformly reinforced to a significant level due to manual operation. But, embedding of jute fibers in B 02 and B 04 was better than that in B 09. In case of B 09, at the ropes were slightly embedded, almost float to the surface due to the pressure of liquid LDPE while making composite specimen. But in case of B 02 and B 04, two and three pieces of ropes, respectively, were embedded well into LDPE. Hence gave a better sustain.

Figure 4.6 (b) of specimen B 02 also shows that after attaining the peak load, the load decreases gradually with the displacement. Thus it can be considered identical, in fracture behavior, to that of B 04. This behavior shows no significant plastic deformation may occur, but ductile fracture is characterized by plastic formation.

The decreasing criterion, after the maximum sustain, of the load displacement curves of the both specimens, B 02 and B 04, argues that though, crack is

generated immediately after the peak load value, the rate of crack propagation time is much slower than that of LDPE specimen.

And this is due to the reinforcement of jute fibers. Hence show a more sustain rather breaking. And the cause of decline is that the specimen has already started cracking.But the composite materials have better sustain capacity than LDPE specimens, because of the fibers. A composite specimen does not fracture totally until all the pieces of jute ropes break. As soon as they reach the maximum sustain, LDPE specimens break within the generation of creak, killing any further time. Hence it is clear that composite material show better mechanical properties than that of the LDPE. During the tensile test of all the composite specimens with increasing load, it was observed that fibers continued to break randomly at various locations in the lamina. Thus broken fibers acted as a bridge between the two faces of matrix crack.

CHAPTER 08

CONCLUSION AND RECOMMENDATION

In this project the mechanical properties of Low Density Polyethylene resin matrix and its composite reinforced by jute fiber was considered and analyzed. The experimental results obtained from the tensile test of LDPE matrix and its jute fiber-reinforced polymeric composite was compared graphically. It is observed that the results of composite specimens are higher than that of the normal resin matrix. Energy was obtained from the load-displacement curve. A statistical analysis was also done corresponding to max tensile tress, energy absorption and young's modulus to identify the process spread, three-sigma distribution. Thus required load/stress can be specified while making any product and thereby an optimum utilization is possible.

By analyzing this work it can be stated that composite material shows better mechanical properties and takes more energy that of the normal resin matrix.

The present work is an initiation, to know the mechanical properties of Low Density Polyethylene resin and its composite reinforced by jute fiber. By analyzing for present work further research and development initiatives can be taken for further improvement, according to the needs in extension of this work. Composite properties are best in the direction of the fibers. The most efficient composites have most of their fibers oriented in the primary load direction, and just enough fibers oriented in the other directions to carry secondary loads and hold the structure together. It may be improved by using two directional fiber in proper embed in the resin matrix in future work.

REFERNCES

1. P J Roe and M P Ansell, Material Science, 20 (1985), 4015.

2. Philip Yam, Plastic Get Wired, Scientific American, July 1995, 82:87.

3. John Emsley, Molecules At An Exhibition, Oxford University Press, 1998.

4. Irvin I, Rubin, Handbook of Plastics Materials & Technology.

5. Tim Beardsley, Disappearing Act, Scientific American, November 1988.

6. Garmer A. Olsen, Elements of Mechanics of Materials, Fourth Edition, PP 547.

7. A. G Winfiel, Plastic & Rubber Institute, 14 (1979), 23-24.

8. George C Danl, Robert M. Rein-Hardt, Text Res. Journal, 25, (1955), 246.

9. G. S. Learmonth, Fillers for Plastics, edited by W C Wake (Lindon, 1971), 81.

10. A. N Shah and S. C Lakkad, Fiber Science Tech, 15 (1981) 41.

11. Hull, D. and Clyne, T. W. (1996), An Introduction to Composite Materials, Cambridge University Press, Cambridge, UK, pp 9-32.

12. A. R. Bunsell, Fiber reinforcement for composite materials, Composite Materials Series, Vol. 2 Elsevier, (1988), pp 249.

13. P K Mallik, Fiber-reinforced Composites, Marcel Dekker Inc. New York, (1999), pp 91-110.

14. C Pavitheran, P S Mukherjee, M. Brahmakurmar and A D. Damodaran, 'Impact properties of natural fiber composites', J. Material Science Fillers, 6 (1987), 882-884.

15. Ivens, J, Bos H. and Verpoest, I. (1997). The Applicability of Natural Fibers as Reinforcement for Polymer Composites. In: Renewable Byproducts : Industrial Outlets and Research for the 21st Century. June 24-25, 1997, EC-

symposium at the International Agricultural Center (IAC), Wageningen, The Netherlands.

16. Rheinlander, J. T, "Quantitative Non-Destructive Characterisation (NDC) of plant fiver composites", 9th Annual Symposium on Non-Destructive Characterization of materials, Sydney (Australia) Jnne, July 1999.

17. N R Bose and K K Phani, Jute Material Science, 22 (1987), 1929-1933).

18. P Ghosh and P. K Ganguly, Jntc Fibre-Reinforced Polyester Resin Composite: Effect of Different Types and Degree of Chemical Modification of Jute on performance of the Composite: Plastic, Rubber and Composite Processing and application 20 (1993), 171.

19. Mohanty, A. K. and Misra, M., "Studies on Jute composite - a literature review", Polymer Plastics Technology and Engineering, 34 (5) pp. 729-792, 1995.

20. Lilholt, H. & Bjerre, A. B., "Composites based on jute-fibers and polypropylene matrix, their fabrication and characterization", in Proceeding of the 18th Risc International Symposium on Materials Science : Polymeric Composites - Expanding the limits, Rise National Laboratory, Denmark, 1997, pp. 411-423.

21. R K Basak, B. C Mitra, M Sarkar, 'Studies on Jutc-Reinforced Composites: its limitations and some solution through Chemical modifications: J. Applied Polymer Science 67, (6), (1998) 0021-8995.

22. P. J Roe and M. P Ansell, Jute reinforced Polyester Composites : J Material Science 20 (1985) 4015-U 120.

23. M. K Sridhar, G Basavarappa, S G Kasturi & N Balasubramanian ' Mechnical Properties of Jutc/Polyester Composites : Indian Journal of Technology, 22 (1984), 213-215.

24. An Introduction to Composite Materials. by Derek Hull.

25. ASTM Standards, vol. 08.01, D 631-98 (1999).

26. US Patent 5985429, November 1999.

27. US Patent 5973035, October 1999.

28. European Patent DE4391557, March 1999.

29. European Patent EP0872383, October 1998.

30. US Patent 9836900, A1, 1998.

31. US Patent 9831626, A1, 1998.

32. US Patent 5663216, 1997.

33. US Patent 5285957, 1994.

34. US Patent 5231121, 1993.

35. US Patent 5218012, 1993.

36. US Patent 5037690, 1991.

37. US Patent 4559862, 1995.

38. US Patent 3819466, 1974.

Appendix-A

Load Displacement diagram of LDPE Specimen

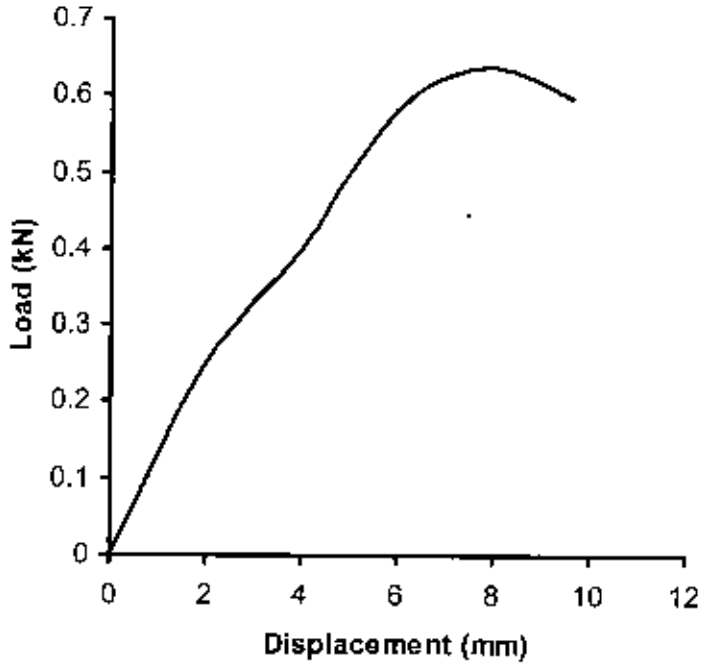


Fig. 4.1(a). Load Displacement Diagram of the LDPE Specimen A01.

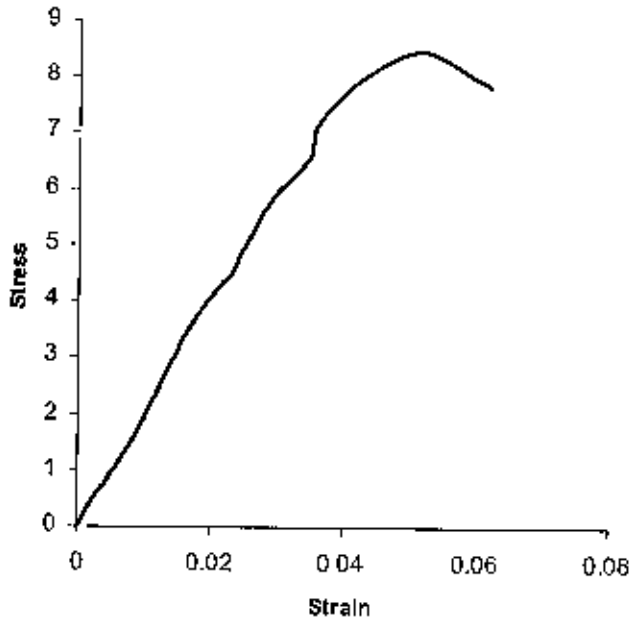


Fig. 4.1(b). Tensile Stress Strain Diagram of the LDPE Specimen A01

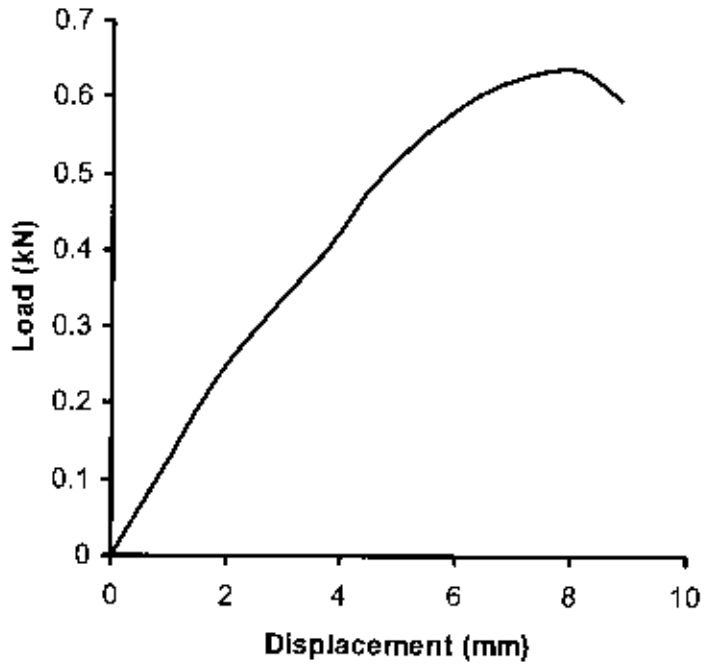


Fig. 4.2(a). Load-Displacement Diagram of the LDPE Specimen A02

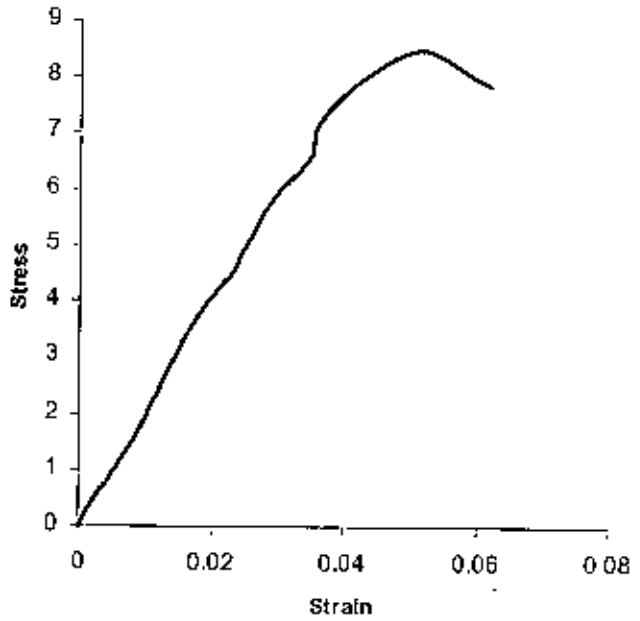


Fig. 4.2(b). Tensile Stress Strain Diagram of the LDPE Specimen A02

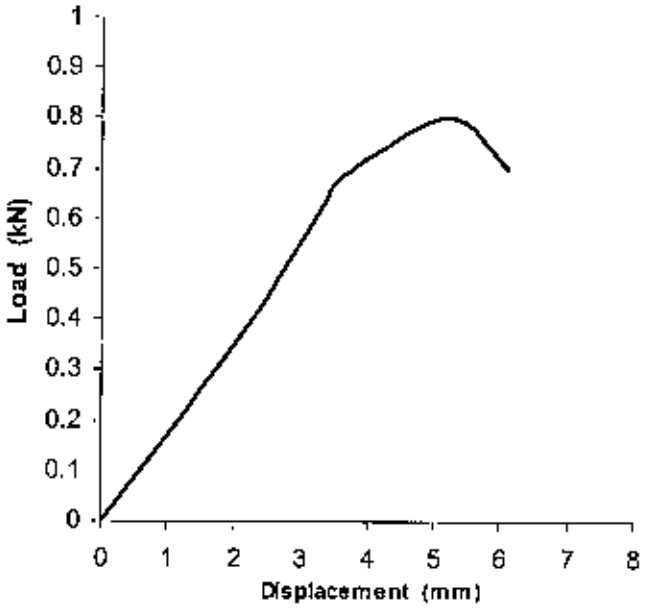


Fig. 4.3(a). Load-Displacement Diagram of the LDPE Specimen A03

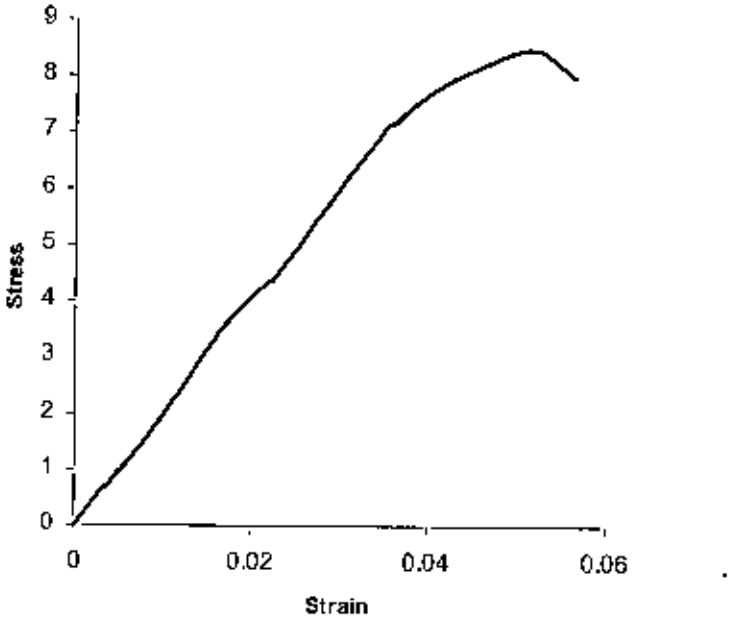


Fig. 4.3(b). Tensile Stress Strain Diagram of the LDPE Specimen A03

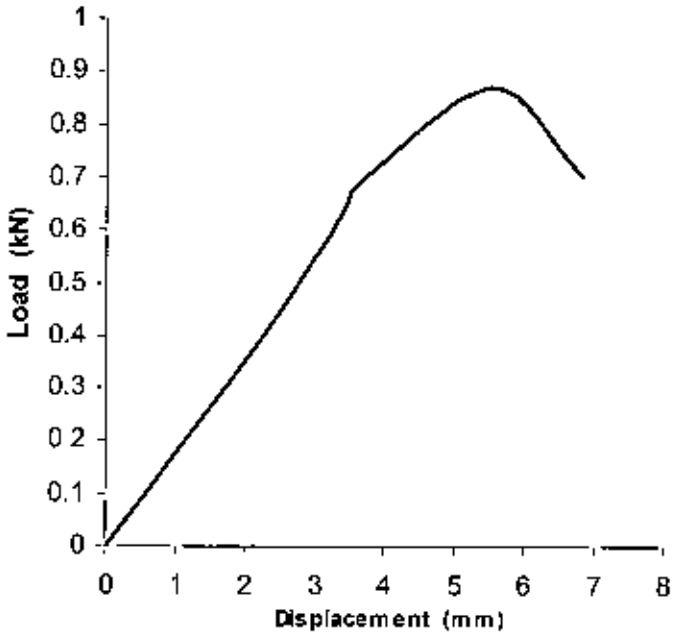


Fig. 4.4(a). Load-Displacement Diagram of the LDPE Specimen A04

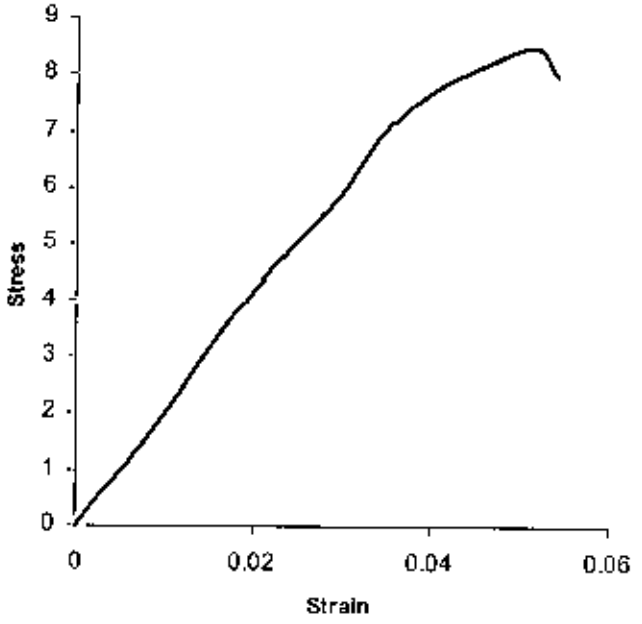


Fig. 4.4(b). Tensile Stress Strain Diagram of the LDPE Specimen A04

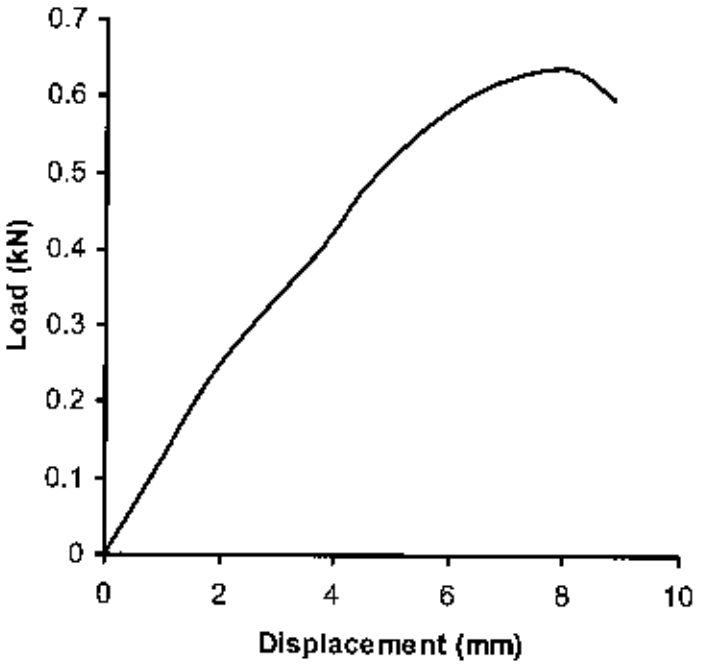


Fig. 4.5(a). Load Displacement Diagram of the LDPE Specimen A05

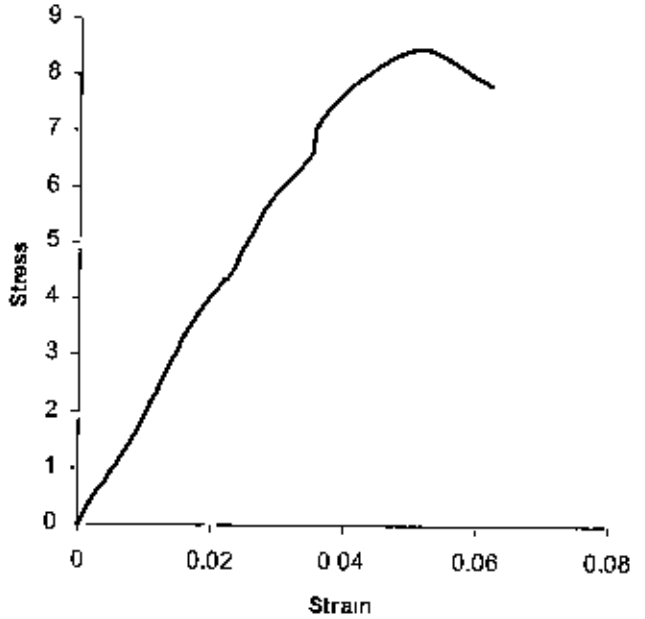


Fig. 4.5(b). Tensile Stress Strain Diagram of the LDPE Specimen A05

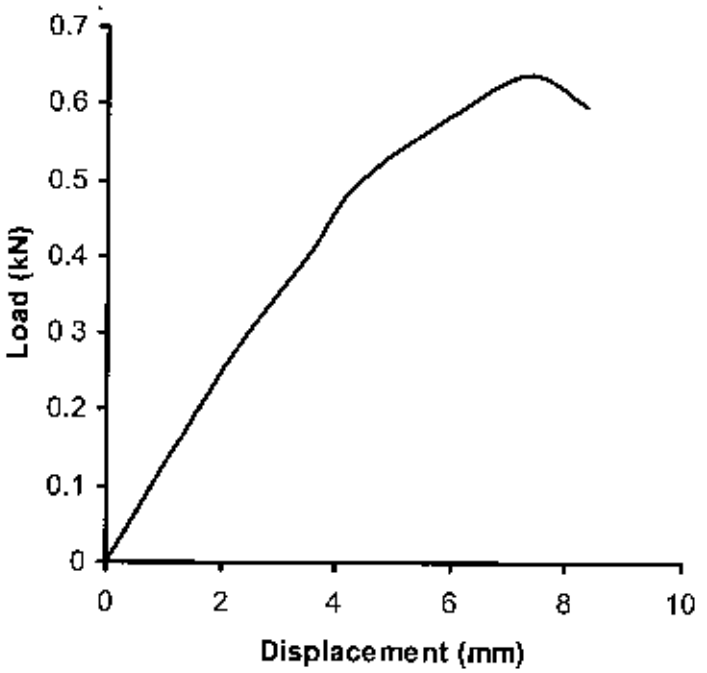


Fig. 4.6(a). Load Displacement Diagram of the LDPE Specimen A06

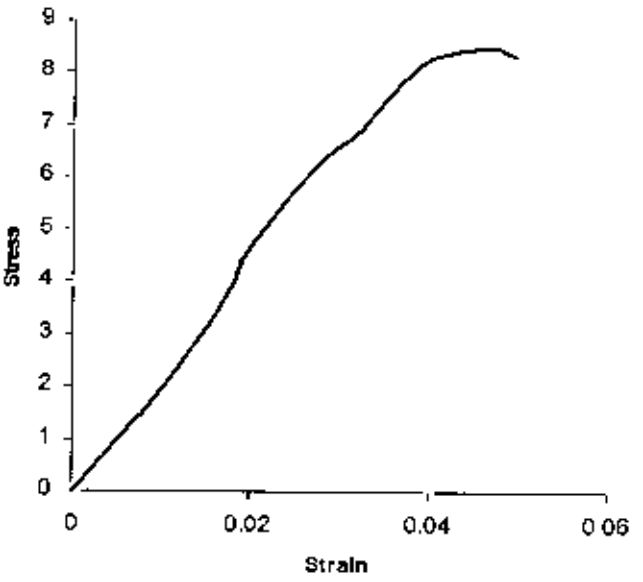


Fig. 4.6(b). Tensile Stress Strain Diagram of the LDPE Specimen A06

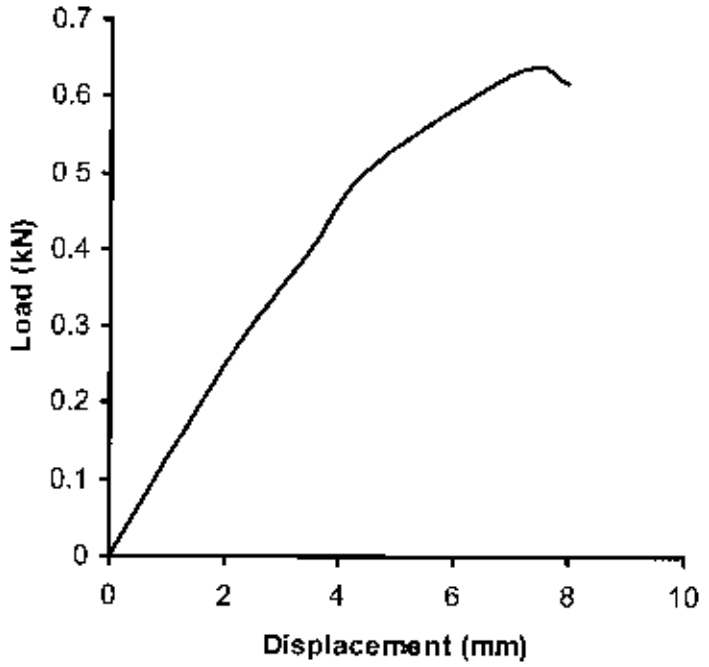


Fig. 4.7(a). Load Displacement Diagram of the LDPE Specimen A07

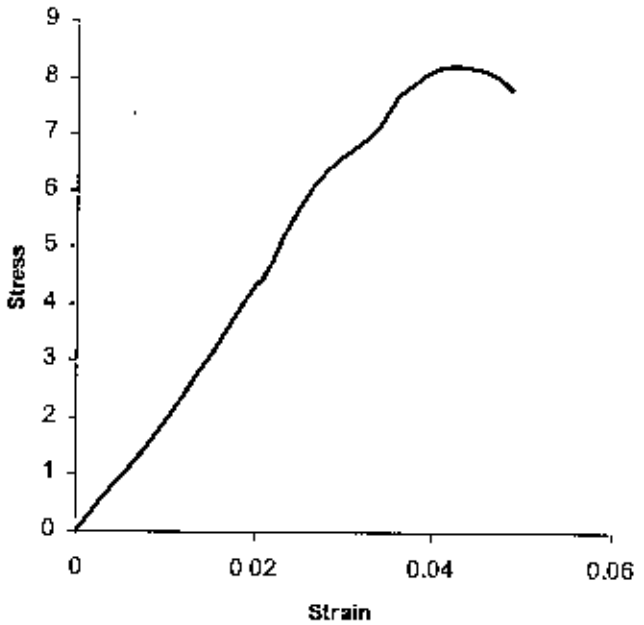


Fig. 4.7(b). Tensile Stress Strain Diagram of the LDPE Specimen A07

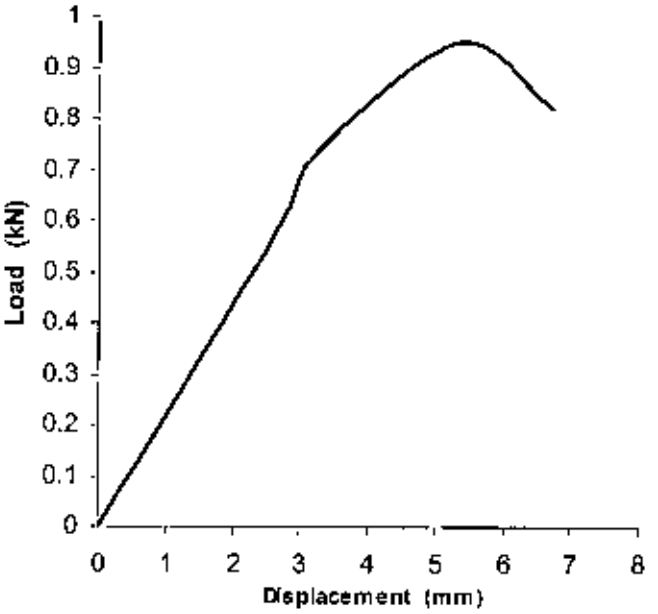


Fig. 4.8(a). Load Displacement Diagram of the LDPE Specimen A08

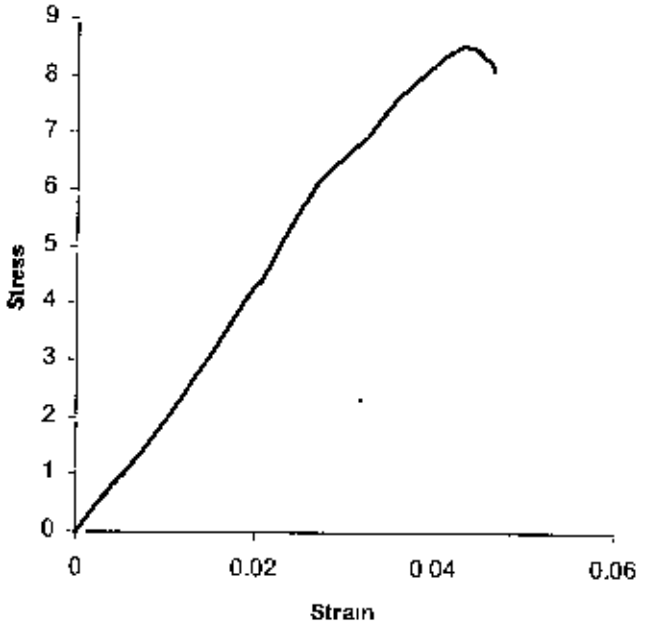


Fig. 4.8(b). Tensile Stress Strain Diagram of the LDPE Specimen A08

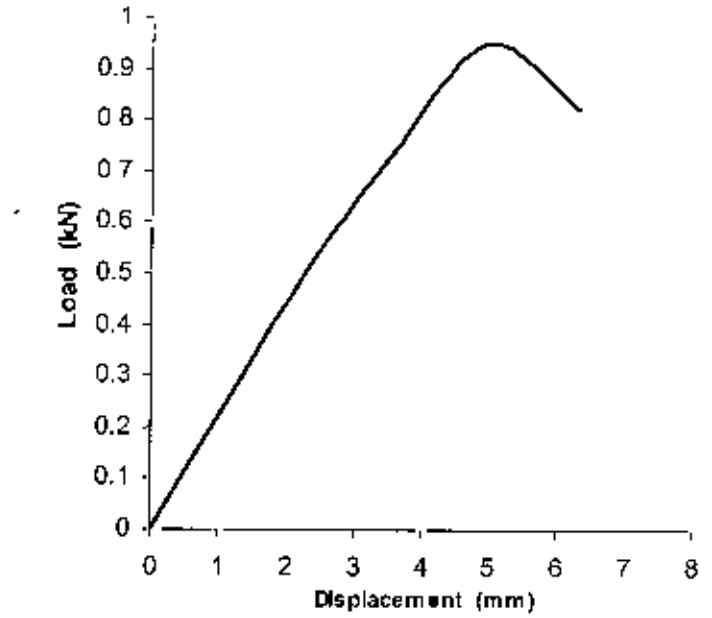


Fig. 4.9(a). Load Displacement Diagram of the LDPE Specimen A09

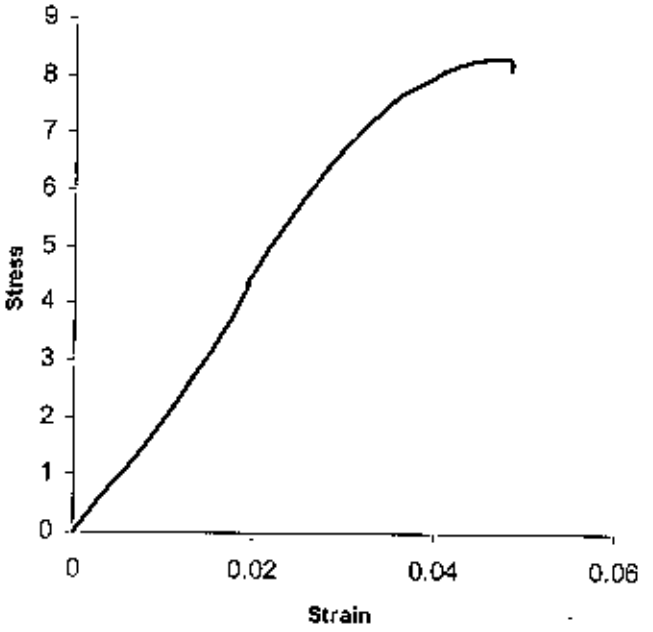


Fig. 4.9(b). Tensile Stress Strain Diagram of the LDPE Specimen A09

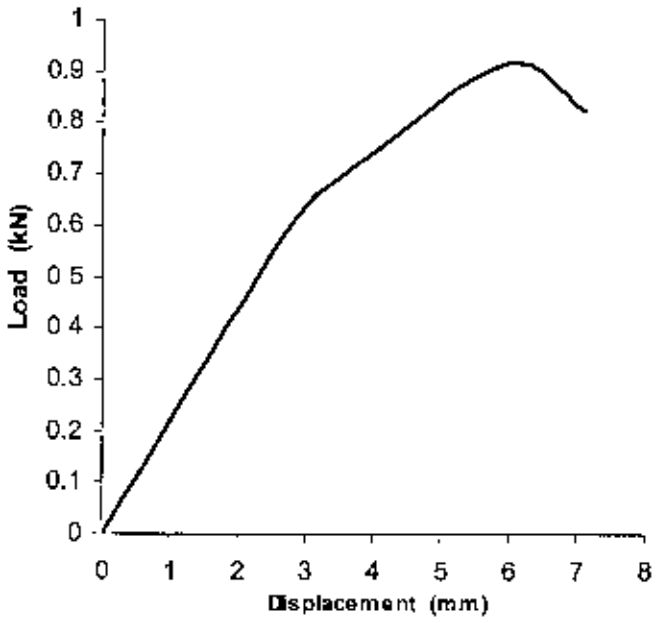


Fig. 4.10(a). Load Displacement Diagram of the LDPE Specimen A10

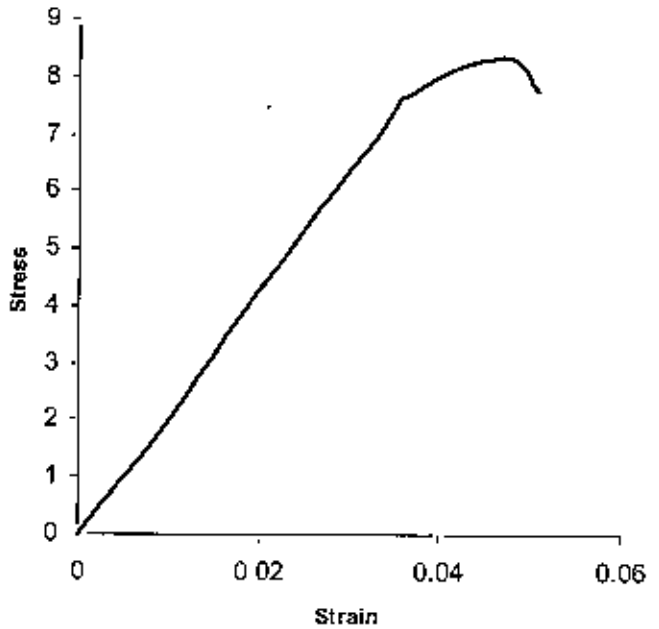


Fig. 4.10(b). Tensile Stress Strain Diagram of the LDPE Specimen A10

Appendix- B.

Load Displacement diagram of Composite Specimen

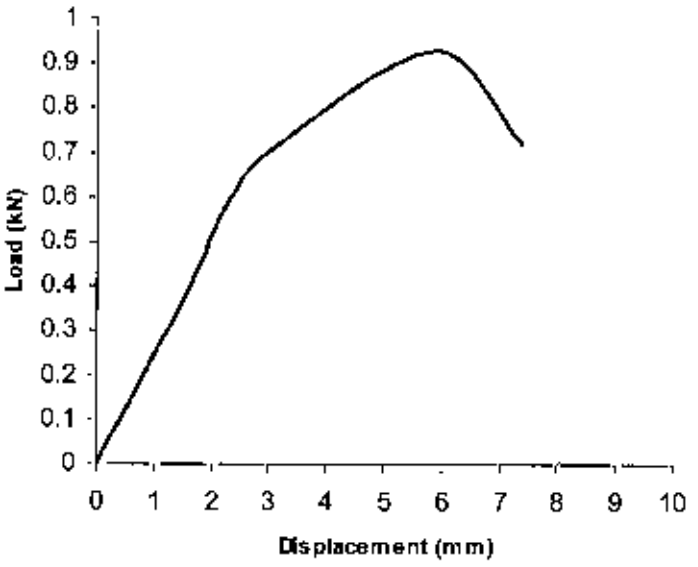


Fig. 5.1(a). Load-Displacement Diagram of the Composite Specimen B01

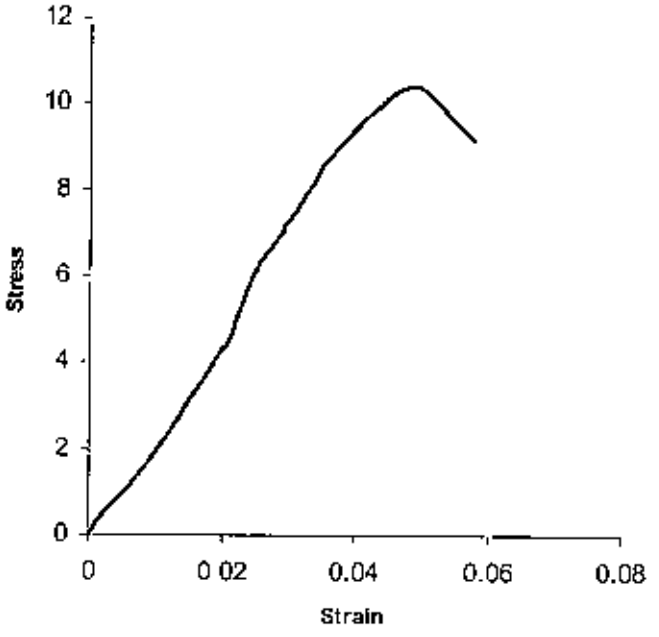


Fig. 5.1(b). Tensile Stress-Strain Diagram of the Composite Specimen B01

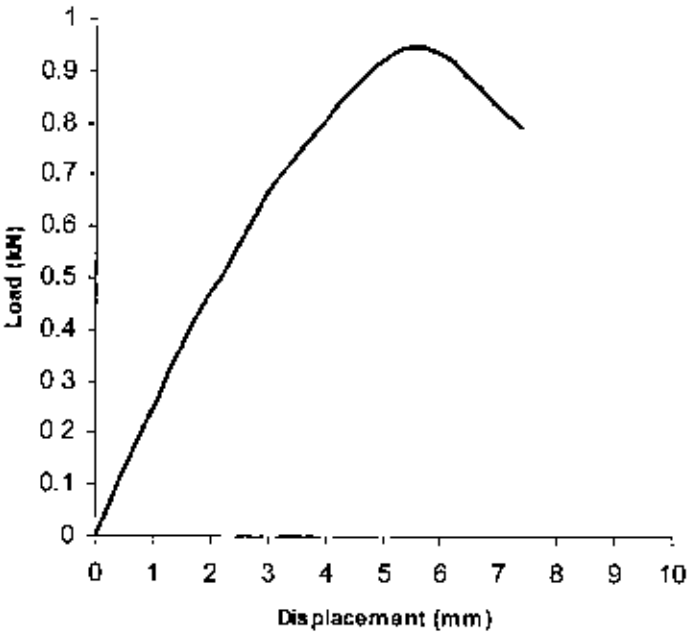


Fig. 5.3(a). Load-Displacement Diagram of the Composite Specimen B03

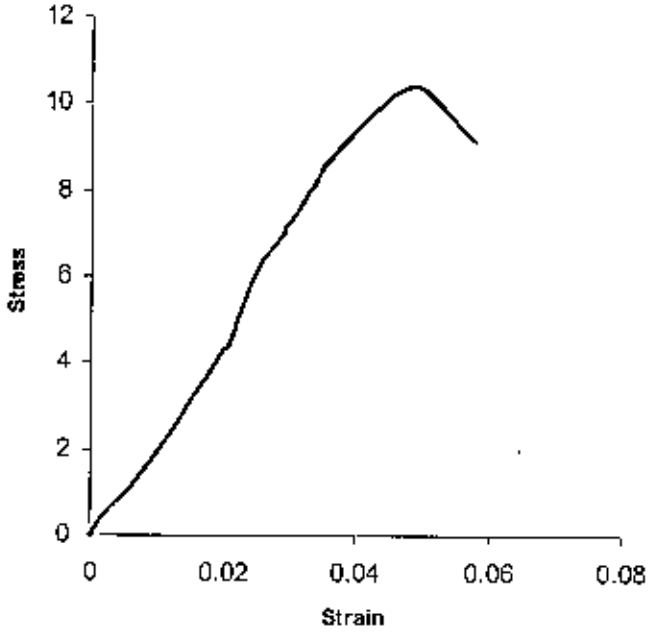


Fig. 5.3(b). Tensile Stress-Strain Diagram of the Composite Specimen B03

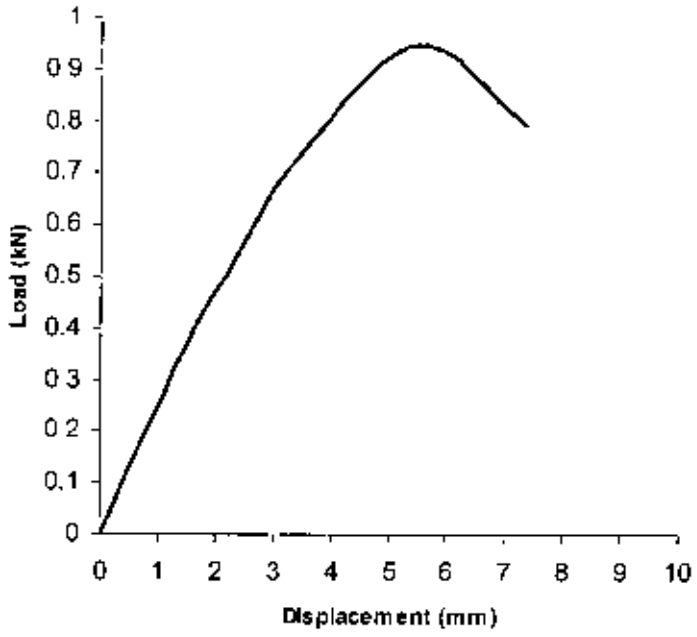


Fig. 5.2(a). Load-Displacement Diagram of the Composite Specimen B02

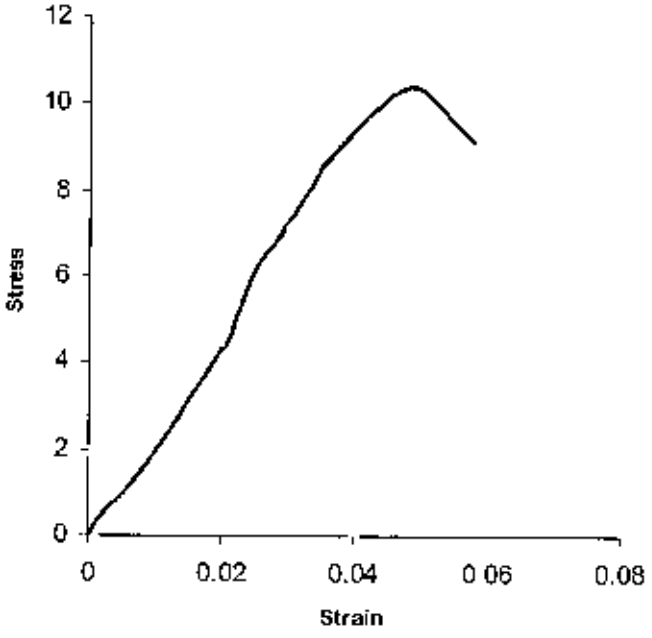


Fig. 5.2(b). Tensile Stress-Strain Diagram of the Composite Specimen B02

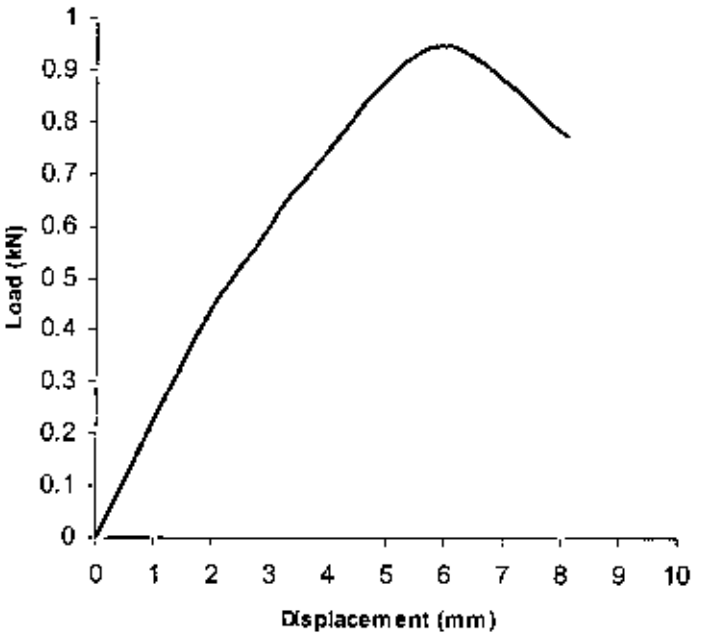


Fig. 5.4(a). Load-Displacement Diagram of the Composite Specimen B04

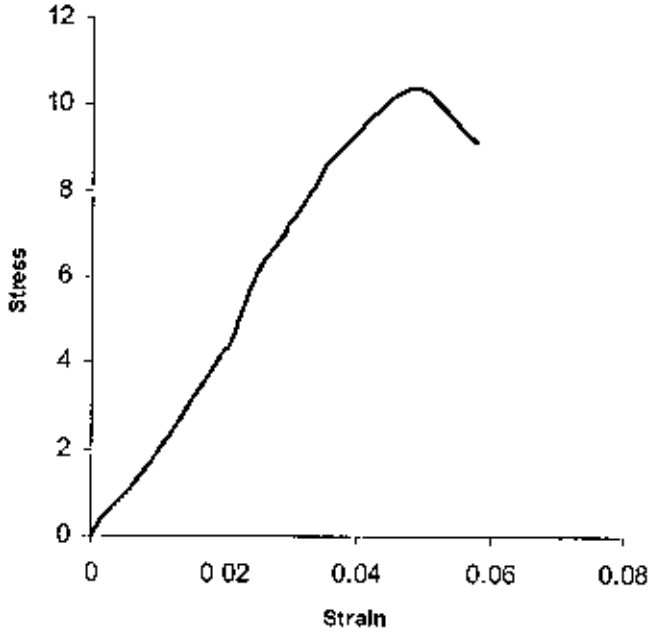


Fig. 5.4(b). Tensile Stress-Strain Diagram of the Composite Specimen B04

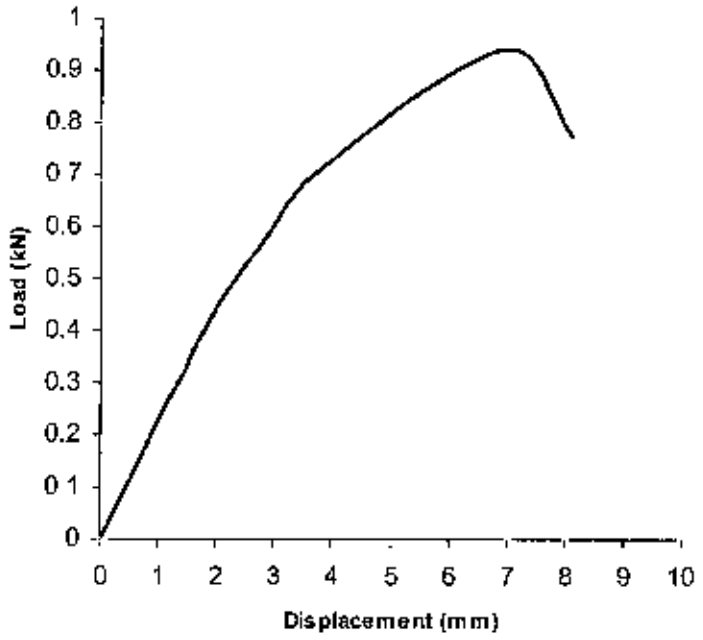


Fig. 5.5(a). Load-Displacement Diagram of the Composite Specimen B05

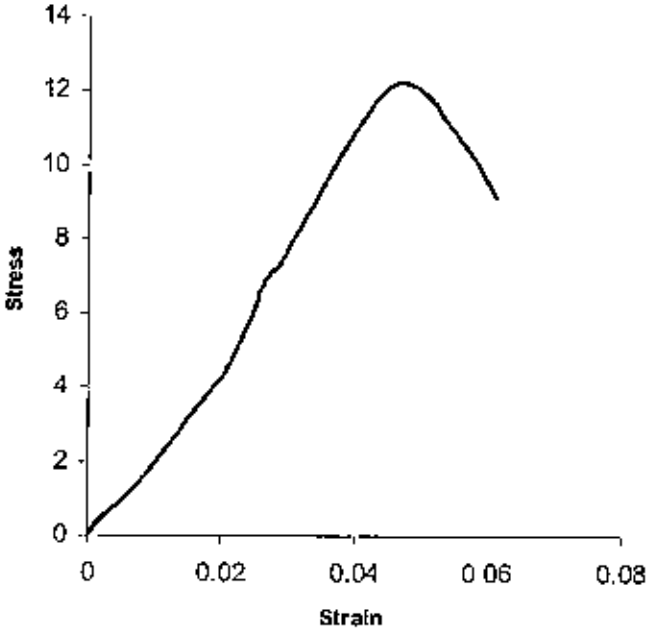


Fig. 5.5(b). Tensile Stress-Strain Diagram of the Composite Specimen B05

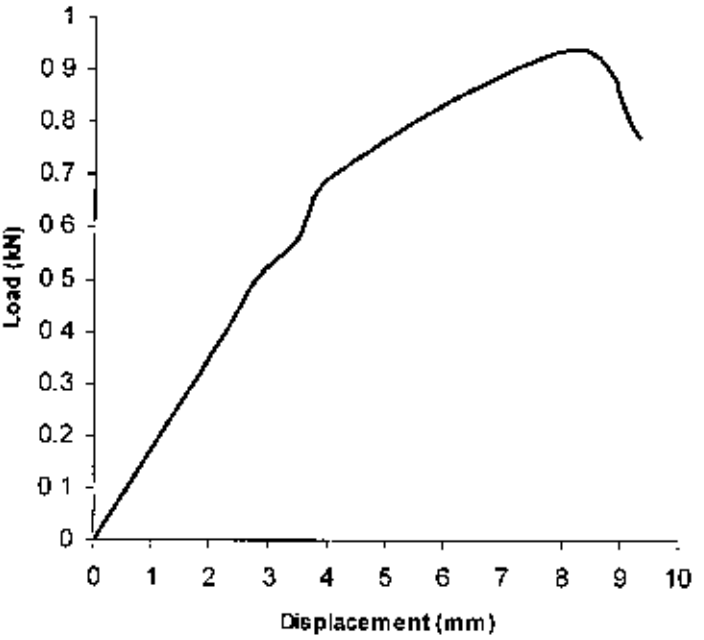


Fig. 5.6(a). Load-Displacement Diagram of the Composite Specimen B06

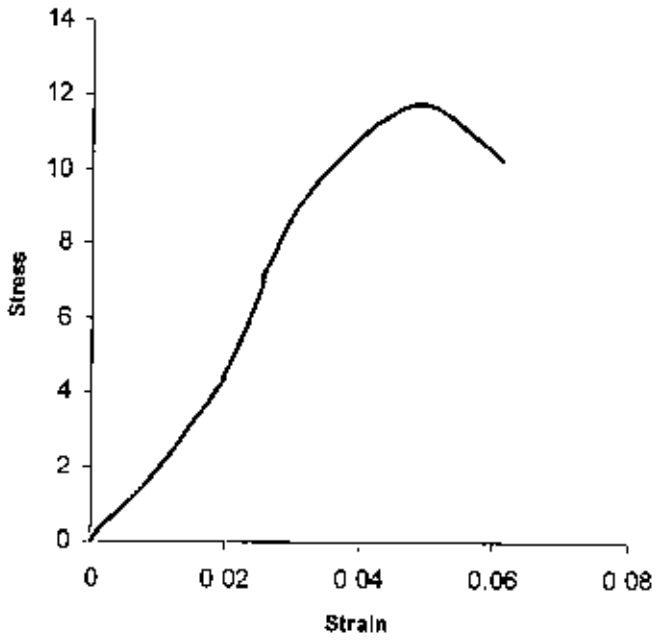


Fig. 5.6(b). Tensile Stress-Strain Diagram of the Composite Specimen B06

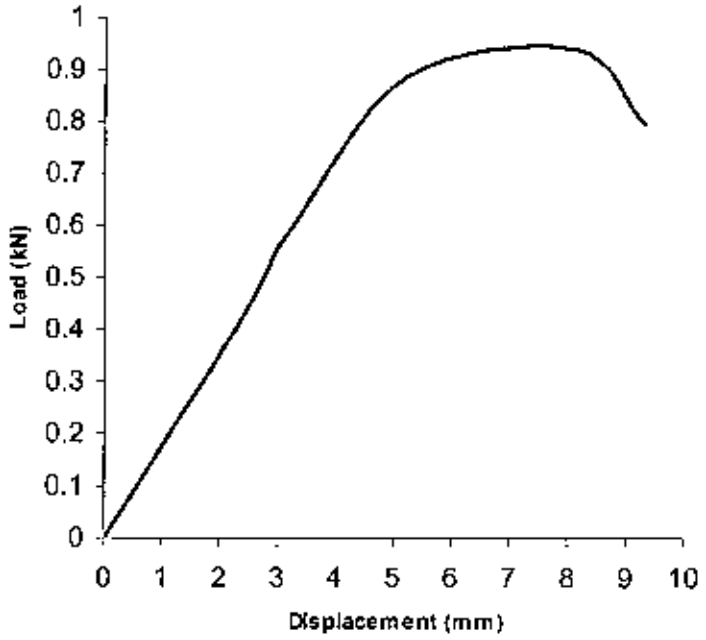


Fig. 5.7(a). Load-Displacement Diagram of the Composite Specimen B07

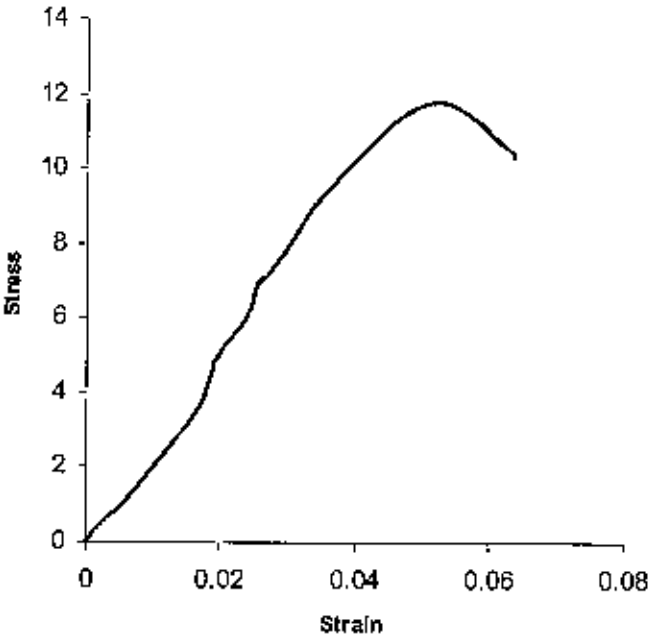


Fig. 5.7(b). Tensile Stress-Strain Diagram of the Composite Specimen B07

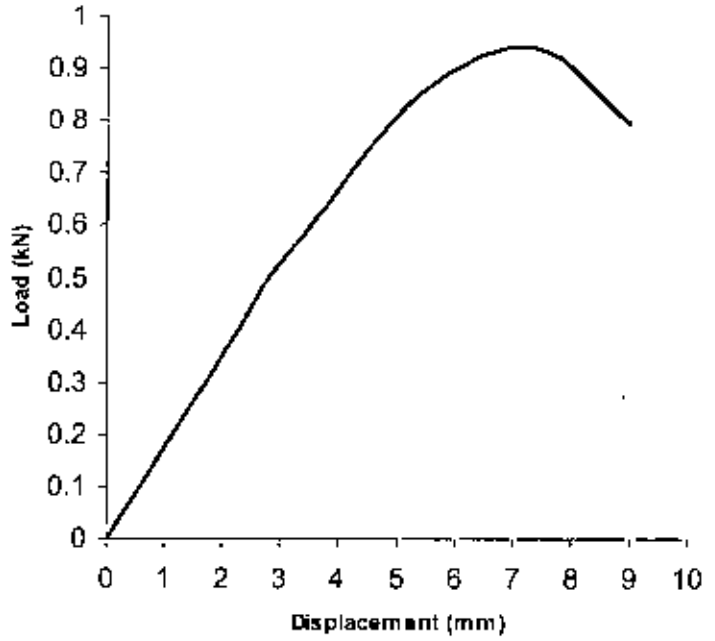


Fig. 5.8(a). Load-Displacement Diagram of the Composite Specimen B08

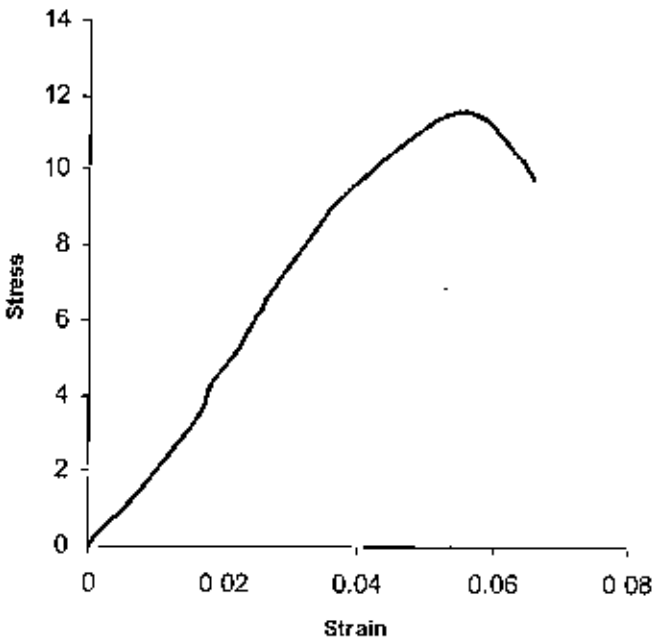


Fig. 5.8(b). Tensile Stress-Strain Diagram of the Composite Specimen B08

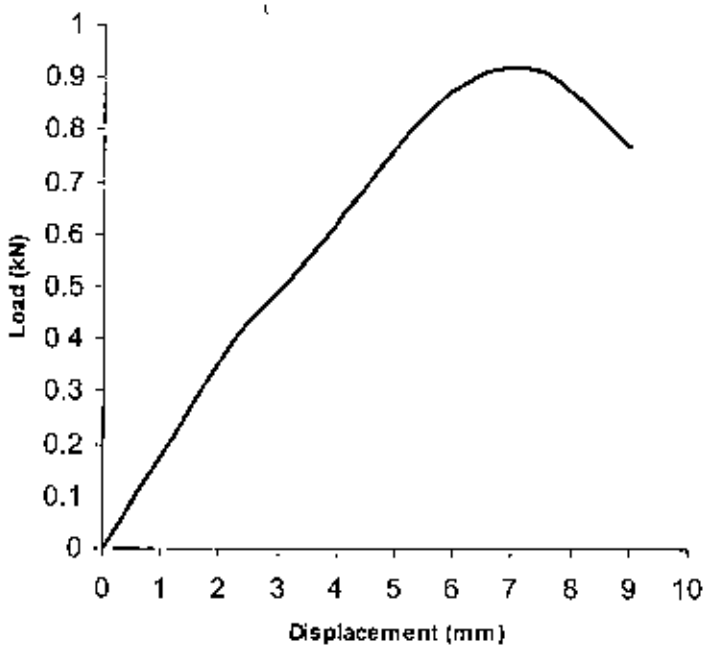


Fig. 5.9(a). Load-Displacement Diagram of the Composite Specimen B09

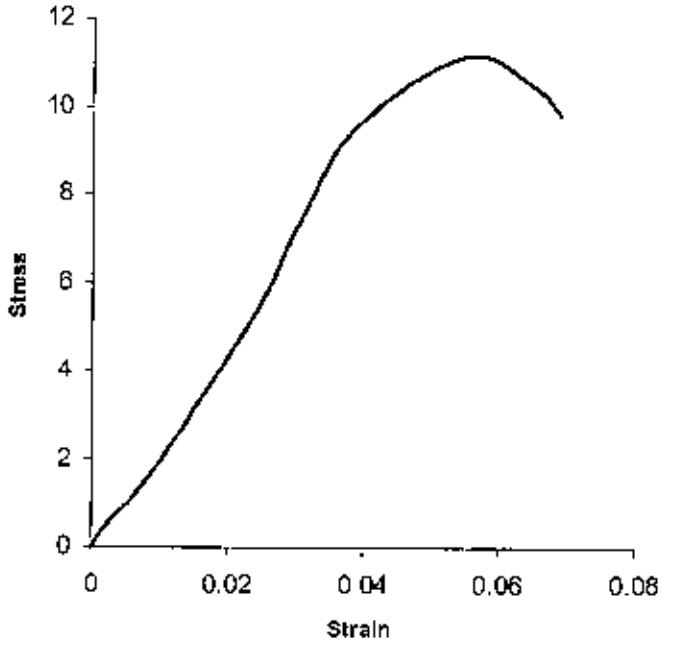


Fig. 5.9(b). Tensile Stress-Strain Diagram of the Composite Specimen B09

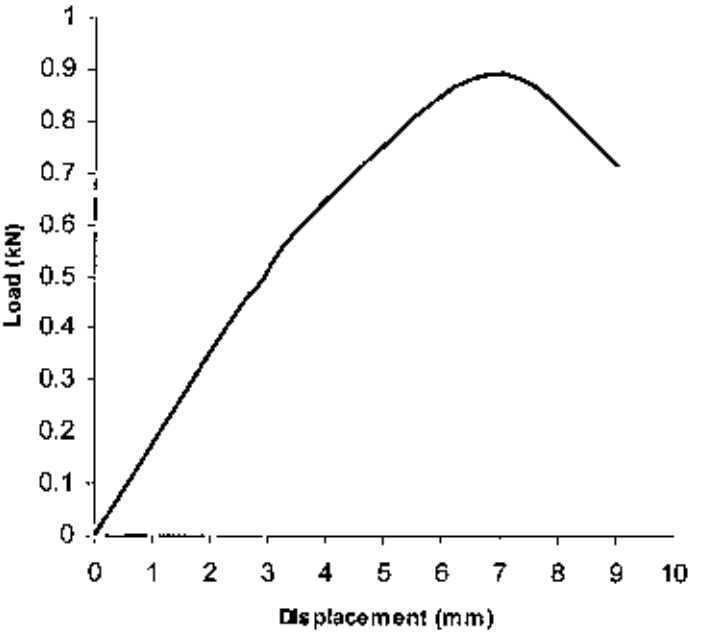


Fig. 5.10(a). Load-Displacement Diagram of the Composite Specimen B10

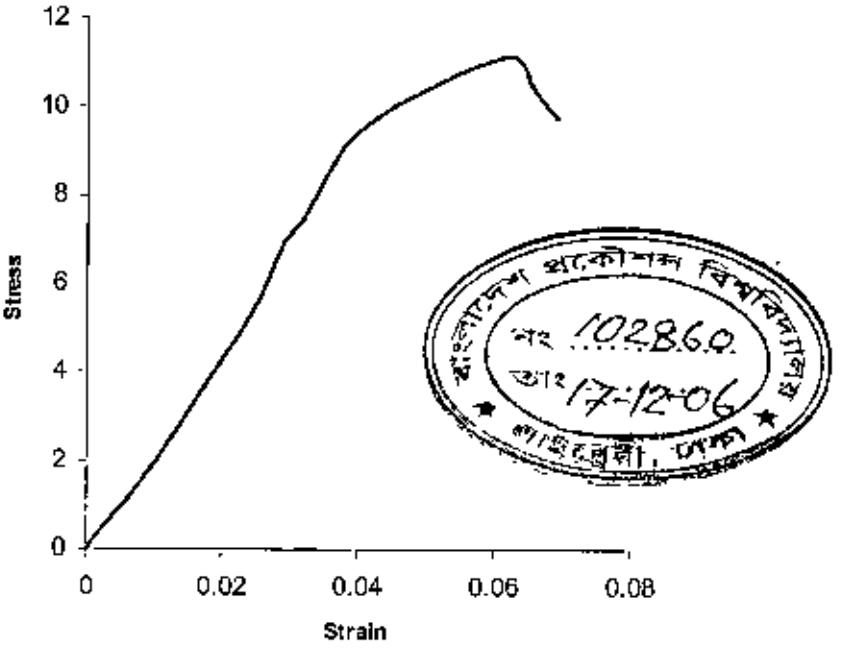


Fig. 5.10(b). Tensile Stress-Strain Diagram of the Composite Specimen B10