STUDY OF MECHANICAL BEHAVIOR OF VEGETABLE OIL BASED PVC COMPOSITE

**A Thesis Submitted
in Partial Fulfillment of the Requirement
for the Degree of**

DUAL DEGREE
in

MECHANICAL ENGINEERING

**With specialization
in
"Production and Industrial Engineering"
by**

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Under the Supervision of

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DEPARTMENT OF MECHANICAL ENGINEERING
INTEGRAL UNIVERSITY, LUCKNOW

2022

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CERTIFICATE

Certified that **Mr. Mohd Hassan** (Enrollment No. **1700102313**) has carried out the research work presented in this thesis entitled "**Study of Mechanical Behavior of vegetable Oil Based PVC Composite**" for the award of **Dual Degree in Production & Industrial Engineering** from Integral University, Lucknow under my supervision. The thesis embodies result of original work and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any degree to the candidate or to anybody else from this or any other university/Institution.

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<u>DECLARATION</u>

I hereby declare that the thesis titled **"Study of Mechanical Behavior of vegetable Oil Based PVC Composite"** is an authentic record of the research work carried out by me under the supervision of **Er. Mahmood Alam**, Department of Mechanical Engineering at Integral University, Lucknow. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certify that I have not willfully taken other's work, para, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at web-sites without their permission, and have not included those in this Ph.D. thesis citing as my own work.

Date: **Signature** _____

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At this moment of accomplishment, I wish to pay my heartfelt gratitude and the sincerest thanks to my guide, assistant professor Er. Mahmood Alam, department of Mechanical Engineering, Integral University Lucknow. This work would not have possible without his able guidance, support and encouragement. Under his guidance I have successfully overcome many difficulties and learned a lot. He used to review my thesis progress, give his valuable suggestions and made corrections. His unflinching courage and conviction will always inspire me, and I hope to continue to work on his noble thought.

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TABLEOFCONTENT

LISTOFTABLE

LISTOFFIGURE

ABBREVIATION

PVC	Polyvinylchloride
ANOVA	AnalysisofVariance
L	Initiallength
l	Finallength
E	Elongation
Mm	Millimeter
gm	Gram
ml	Milliliter
kgf	Kilogram-force
N	Newton
T	Tensilestrength
P	Phosphorus
Mg	Magnesium
K	Potassium
Ca	Calcium
Cu	Copper
Zn	Zinc
Mn	Manganese
Fe	Iron
B	Boron
Mo	Molybednum

ABSTRACT

The present work has been carried out to study the mechanical behavior of vegetable oil-based PVC composite. In this work full factorial technique has been used for the design of experiment. The effect of peanut oil and corn oil over PVC has been evaluated. To check the mechanical and thermal properties of the reinforced PVC composite tensile strength test, hardness test and thermal gravimetric test has been performed.

The effect of all the input parameter on the output responses have been analyzed using the analysis of variance (ANOVA) and empirical modeling. Plots of significant factors and empirical modeling have been used to determine the best fit relationship between the input parameters and response. It indicates which is most influencing factor or parameter. A confidence level of 96% has been taken for the analysis.

Results obtained from the experiments have been analyzed by using ANOVA which help in predicting the significance of input parameter for any desired response function. The PVC reinforcement mainly affected by the type and amount of material used. This reinforcement improves the mechanical and thermal property of PVC.

INTRODUCTION

In the consideration of environmental aspects we all know that the world arrives closer to the global realization of our diminishing fossil fuel resources. As scientists and innovators begin to search for alternative sources of some of common materials in our environment, such as plastics, other important factors, such as degradability and environmental sustainability, are being considered. In order to reduce the production cost of plastic products, and to improve certain characteristics, one or more fillers are usually used as an addition to the resin matrix. Polymeric materials from renewable resources have attracted a lot of attention in recent years. The development and utilization of vegetable oils for polymeric materials are currently in the spotlight of the polymer and chemical industry, as they are the largest renewable platform due to their universal wide availability, ingrained biodegradability, low cost, and excellent environmental aspects i.e. low toxicity. The EPA supports the 'beneficial use' of waste products and defines it as "the reuse in a product that provides a functional benefit, replaces a product made from virgin raw materials, conserves natural resources and meets product specifications and industry standards. Beneficial use of waste products can contribute to a sustainable future by reducing production costs, reducing energy consumption and greenhouse gasses."

Due to reduce environmental concerns and disposal difficulties, the utilization of vegetable oils has become of great importance. Other researchers have also shown the advantageous use of treated fly ash in a wide variety of polymer matrices. Although incidental success stories are published, a systematic approach on investigating the influence of polymer properties for the various different polymer types and the enormous amount of possibleformulations has not yet been properly undertaken. In order to reduce the production cost of plastic products, and to improve certain characteristics, one or more fillers are usually used as an addition to the resin matrix.

COMPOSITE

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing/dispersed phase and the one in which it is embedded is called the matrix. It is made by dispersing one material in the other in a controlled way to achieve optimum properties. The properties of the composite are superior and possibly unique in some specific respects to the properties of individual components.

Classification of composite:

Many composite materials are composed of two phases one phase is matrix and the other is dispersed/Reinforced phase. In which Matrix is continuous or completely surrounds the other (or dispersed) phase. Dispersed phase is discontinuous phase that is surrounded by the matrix phase. Composites have two categories on the basis of reinforcement and matrix.

On the basis of reinforcement:-
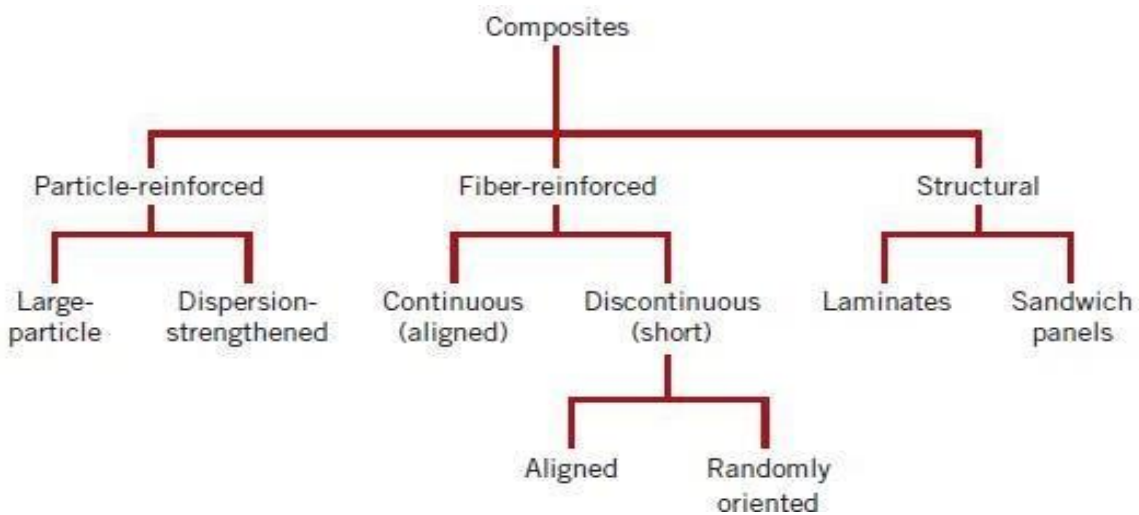
Figure 1.1: Classification of different composites on the basis of reinforcement

Particle- reinforced composites: Large particle and dispersion-strengthened composites are the two sub classifications of particle reinforced composites. Large particle composite: a type of particle-reinforced composite wherein particle-matrix interactions cannot be treated on an atomic or molecular level; the particle reinforced the matrix phase. The degree reinforcement or improvement of mechanical behavior depends on strong bonding at the matrix- particle interface. For dispersion-strengthened composites, particles are normally much smaller with diameters between 0.01 & 0.1 μm (10 & 100nm). It is of types-

Large-particle composite:

Some polymeric materials to which fillers have been added are really large- particle composites. The fillers modify or improve the properties of the material. Example of large-particle composite is concrete, which is composed of cement (the matrix), and sand and gravel (the particulates).

Dispersion-strengthened composite:

These composite consists of strengthening material of very small particles (usually less than 0.1μm). These composites are uniformly dispersed within a load – bearing matrix phase. The dispersed phase may be metallic or nonmetallic, oxides.

Fiber- reinforcement composite:

A composite in which the dispersed phase is in the form of a fiber (i.e., a filament that has a large length to diameter ratio) are known as fiber-reinforced composite. A fibre is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibres are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices.

Structural composite:

These composites are used in structural applications like construction etc. It is of two types-

Laminated composite:

A laminate is fabricated by stacking a number of laminate in the thickness direction. Generally three layers are arranged alternatively for better bonding between reinforcement and the polymer matrix, for example plywood and paper. These laminates can have unidirectional or bi-directional orientation of the fibre reinforcement according to the end use of the composite. A hybrid laminate can also be fabricated by the use of different constituent materials or of the same material with different reinforcing pattern. In most of the applications of laminated composite, man-made fibres are used due to their good combination of physical, mechanical and thermal behaviour.

Sandwich panels:

A sandwich-structured composite is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. It consists of two main parts-The outer skin which supports the material externally and the core for internal support. These two parts are connected through adhesive

On the basis of Matrix:-
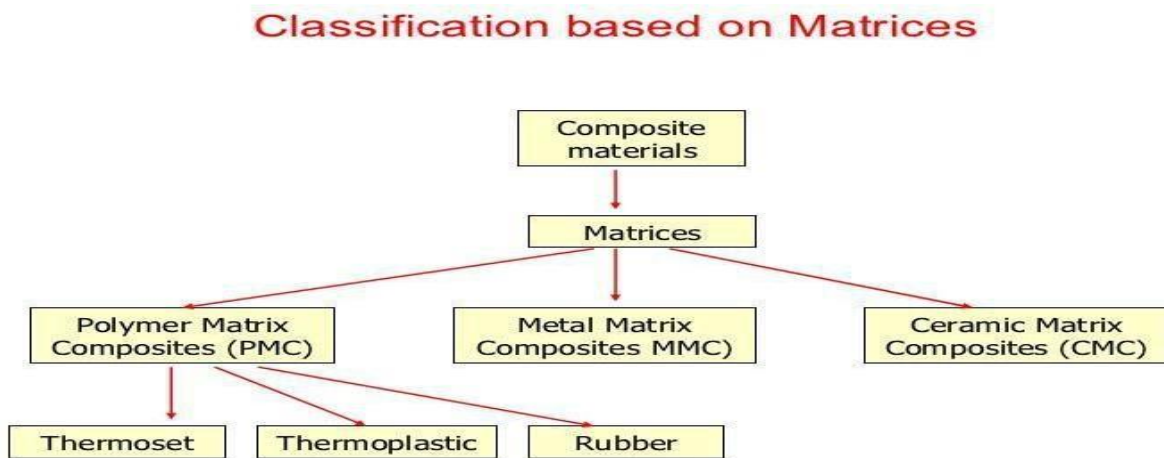
Figure 1.2: Classification of different composites on the basis of matrices

Metal matrix composite:

A composite material consisting of metal as matrix is called metal matrix composites (MMC). It has many advantages over monolithic metals like higher specific strength and modulus, lower coefficient of thermal expansion, and better properties at elevated temperatures. Due to their above mentioned advantages, metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), tubing, cables, heat exchangers, structural members, housings, etc.

Ceramic matrix composite:

If the matrix material is ceramic, then the composite is called ceramic matrix composite (CMC). One of the main objectives in producing ceramic matrix composite is to increase the toughness. Naturally, it is hoped and indeed often found that there is a concomitant improvement in the strength and stiffness of ceramic matrix composites. The most commonly used matrix materials are SiC, Al_2O_3, ZrO_2, Aluminium Nitride, Silicon Nitride, etc.

Polymer matrix composite:

Most commonly used matrix materials are polymeric. The reasons for this are twofold. In general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly, the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature also. Additionally, equipment's required for manufacturing polymer matrix composites are simpler. For this reason polymer matrix composites developed rapidly and soon became popular for structural applications.

REINFORCEMENT OF COMPOSITE

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. All of the different materials used in composites have different properties and so affect the properties of the composite in different ways. Here composite is reinforced by adding three different materials with different properties to make composite rich in properties. In this project a polymer matrix composite is fabricated by using plasticised PVC as a matrix whereas fly ash, soyabean oil and linseed oil as a reinforcing agent material . Detailed analysis of composite material is-

PVC(Poly Vinyl Chloride)

PVC (polyvinyl chloride) is the third most widely used plastic after polyethylene and polypropylene. Polyvinyl chloride is produced by polymerization of the vinyl chloride monomer (VCM),
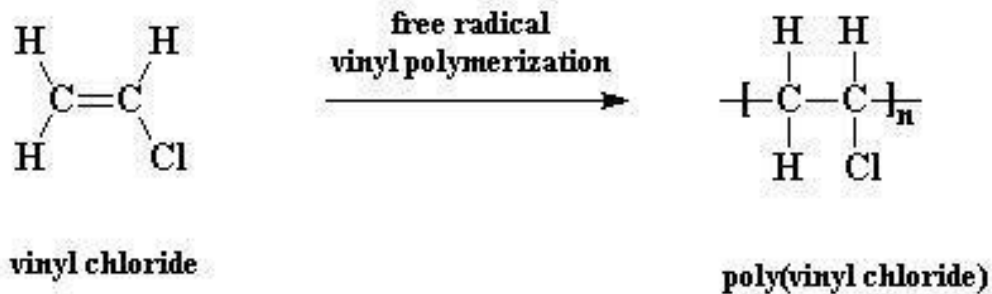
Figure 1.3: Formation of PVC

Steps in pvc production process:

- The extraction of salt and hydrocarbon resources

- The production of ethylene and chlorine from these resources

- The combination of chlorine and ethylene to make the vinyl chloride monomer (VCM)

- The polymerisation of VCM to make poly-vinyl-chloride (PVC)

- The blending of PVC polymer with other materials to produce different formulations providing a wide range of physical properties.
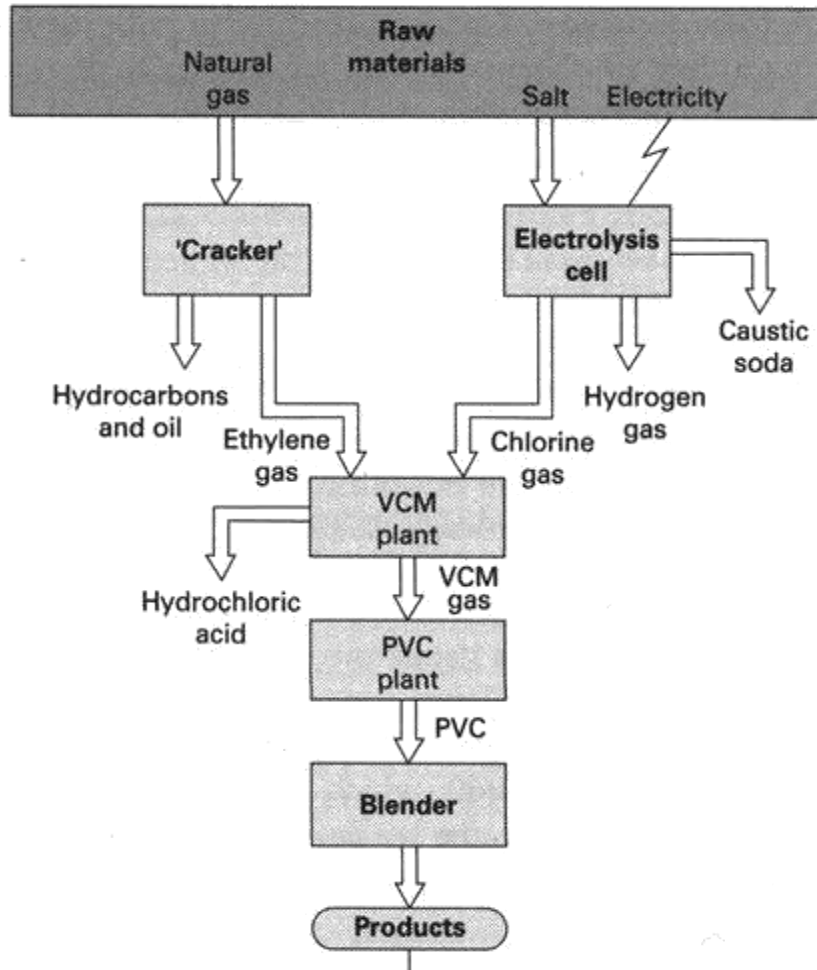
Figure 1.4: Production of PVC

PVC is also produced by various polymerization processes:

-Suspension Polymeristion

-Emulsion Polymeristion

-Bulk Polymeristion

About 80% of production involves suspension polymerization. Emulsion polymerization accounts for about 12% and bulk polymerization accounts for 8%. Suspension polymerization affords particles with average diameters of 100–180 μm, whereas emulsion polymerization gives much smaller particles of average size around 0.2 μm. VCM and water are introduced into the reactor and a polymerization initiator, along with other additives.

Various properties of PVC:-

The inherent properties of PVC make it valuable to many industries. It has a high strength to weight ratio, does not corrode and is very durable. Various properties are-

Physical and mechanical properties:

PVC is a thermoplastic polymer and therefore essentially uncrystallized. However, sometimes PVC shows crystalline phase also. The density of PVC is 1.38 g/cm^3.   Uncrystallized PVC is   transparent and relatively permeable for steam. PVC has high ignition temperature i.e. upto 455^{0}C. PVC offers excellent resistance to abrasion. PVCs are fragile with respect to shocks at low temperatures. The addition of plasticizers reduces the degradation rate which makes it possible to provide a flexible PVC at ambient temperature. Unplasticized PVC resists very well (up to 60°C) acids and bases as well as oils, alcohols and aliphatic hydrocarbons. Flexible PVC is sensitive to atmospheric agents and sunlight.

Electrical properties:

PVC has good insulating properties but the electrical losses in the material are sufficiently high so as to permit high-frequency welding.

Thermal properties:

PVC (uncrystallized) has a vitreous transition temperature lying between 75 and 80°C, i.e. at ambient temperature it is rigid and above 90°C it is rubbery (low resistance, high distortion). PVC decomposes in a flame, releasing gaseous chlorohydric acid, but it is self-extinguishing.

Dimensional properties:

PVC shows good dimensional stability and limited retraction due to its uncrystallized structure.

Implementation properties:

PVC can be easily hot-formed for the inner appointments of our "PLASTICASE" boxes.

Classification of PVC:-

PVC comes in two forms- rigid and flexible. On the basis of formation PVC is of two types-

Unplasticised PVC: it is also known as rigid PVC(RPVC)/uPVC. It is hard in nature. The rigid form of PVC is used in construction for pipe and in profile applications such as doors and windows. It is also used for bottles, other non-food packaging, and cards (such as bank or membership cards).

Plasticised PVC: It is also known as flexible PVC or μPVC. It is soft in nature. It is made by adding plasticizers in rigid PVC. It is also used in plumbing, electrical cable insulation, imitation leather, signage, inflatable products, and many applications where it replaces rubber.

Applications:-

PVC is chemically stable and does not depolymerise. All these properties make this plastic an especially cost-effective material in both economic and environmental terms across a wide range of applications. The price/performance ratio of PVC is one of the best for any material.

About 60% of PVC manufactured has a service life of between 15-100 years. Main applications are in construction as window frames and shutters, water and waste pipes, and electrical applications such as cable and wire insulation.

PVC window profiles and piping last for more than 40 and 100 years respectively, reducing both maintenance costs, consumption or resources and environmental impact. There are also environmental benefits in shorter-life PVC products. For example, PVC used for medical devices such as blood bags , is less-energy intensive to make compared with glass, but it is also lighter to transport, therefore causing comparatively less environmental emission of carbon dioxide. The same comparison is true of the use of PVC versus other materials in car components.

In addition, PVC presents a very low fire hazard. PVC is specified for building materials and its excellent fire prevention properties are widely recognized. It is difficult to ignite, and in the absence of a powerful external flame, will not continue to burn.PVC acts as a barrier against air, oxygen, moisture and odours, and has anti-bacterial properties, helping to keep packaged food fresh and clean. It also is used in medical applications from packing pharmaceuticals to hospital flooring. Blood stored in PVC bags lasts much longer than other storage methods.

VEGETABLE OIL:-

Vegetables or plant oils represent a renewable resource that can be used as reliable starting material to access new products with a wide array of structural and functional variations. The ample availability and the relatively low cost make plant oils an industrially attractive raw material for the plastics industry. Already for a long time, plant oils and their derivatives have been used by polymer chemists due to their renewable nature, world wide availability at relatively low price, and their wide application possibilities. In recent year, there has been a large amount of demand for plant oils as an alternative resource for the production of additive for various applications such as polymer, coating, adhesive and nanocomposite. The necessity of releasing the polymer industry from its dependence on depleting resources represents a major

concern, pushing the search for industrially applicable renewable alternatives. In this case, plant oils offer many advantages apart from their renewability. Their worldwide availability and relatively low prices make them industrially attractive and feasible, as daily demonstrated with industrial oleo chemistry. The largest sources of vegetable oils are annual plants such as soybean, corn, linseed, cottonseed or peanuts. However, other sources are oil-bearing perennials such as the palm, olive or coconut.

Classification of vegetable oils:-

Vegetable oils can be classified in several ways-

• **By source**: most, but not all vegetable oils are extracted from the fruits or seeds of plants, and the oils may be classified by grouping oils from similar plants, such as "nut oils".

• **By use:** as described above, oils from plants are used in cooking, for fuel, for cosmetics, for medical purposes, and for other industrial purposes.

The vegetable oils are grouped below in common classes of use. Various types of oils used-

1. Sunflower oil
2. Soyabean oil
3. Safflower oil
4. Peanut oil
5. Castor oil
6. Olive oil
7. Linseed oil
8. Rapeseed oil

Naturally occurring plant oils and fatty acids derived mostly are considered to be the most important renewable feedstock processed in the chemical industry and in the preparation of bio-based functional polymers and polymeric materials.

Constituents of Vegetable Oil:

The main constituents of plant oils are triglycerides 90% - 95% of the total weight of triglycerides accounts for fatty acids and their content is characteristic of each plant oil.

A triglyceride (TG),triacylglycerol(TAG)or triacylglyceride) is an ester derived from glycerol and three fatty acids (tri + glyceride). Triglycerides are the main constituents of body fat in humans and other animals, as well as vegetable fat. They are also present in the blood to enable the bidirectional transference of adipose fat and blood glucose from the liver, and are a major component of human skin oils.
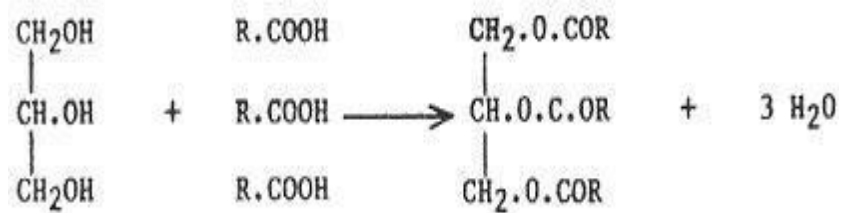
(Glycerol+3 fatty acids = Triglycerides+ water)

Figure1.5: Formation of triglycerides
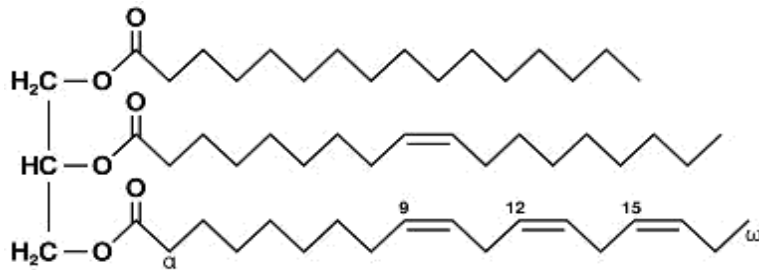
Figure1.6: Triglyceride
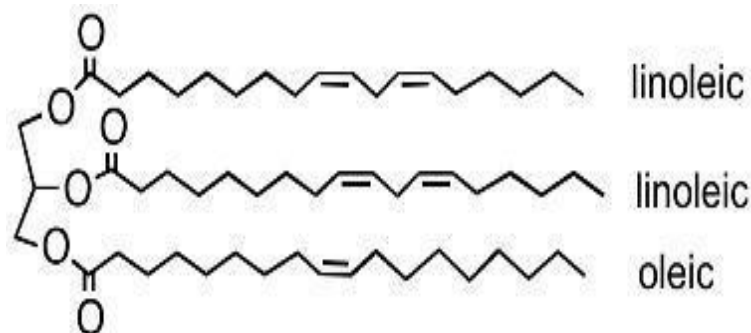
Figure1.6: Fatty acids

There are many different types of triglyceride, with the main division being between saturated and unsaturated types. Saturated fats are "saturated" with hydrogen – all available places where hydrogen atoms could be bonded to carbon atoms are occupied. These have a higher melting point and are more likely to be solid at room temperature. Unsaturated fats have double bonds between some of the carbon atoms, reducing the number of places where hydrogen atoms can bond to carbon atoms. These have a lower melting point and are more likely to be liquid at room temperature. Vegetable oils with high viscosity indices, low volatility and a high flash point have been applied in a series of applications as lubricants and additives in polymer, coatings and resins. For example- Epoxidised vegetable oil not only improves the stability of the oil, but also provides adequate reactivity to form chemical linkages with other polymer chains. For example, vernonia oil, in conjunction with other epoxidised plant oils, has been used as a plasticizer and stabilizer to modify the properties of plastic resins or to act as a reactive modifier (diluent or toughener) in epoxy resins.

Properties & Applications of vegetable oil:

Properties: Vegetable oils were commonly used as plasticizers, stabilizers, lubricants and starting materials to produce polyols, pre-polymers in surface coating formulations and to synthesize of polyurethane foams. Also, modified vegetable oils could be used to improve the efficiency of the fabrication process of linoleum floor cloth, to modify other thermoset polymers and to synthesize new polymers that were appropriate for liquid molding. Triglyceride oils have been utilized quite extensively to produce coatings, inks, plasticizer and lubricants. Within the

polymer field, the application of these oils as toughening agents was also reported. Many vegetable oils are used to make soaps, skin products, candles, perfumes and other personal care cosmetic products. Some oils are particularly suitable as drying oils and are used in making paints and wood treatment products. For example, Dammar oil (a mixture of linseed oil and dammar resin) is used almost exclusively in treating the hulls of wooden boats. Vegetable oils are increasingly being used in the electrical industry as insulators as vegetable oils are not toxic to the environment and biodegradable.

Applications: Various applications of vegetable oils are given in the following table-

Table 1.1: Applications of different vegetable oils

Vegetable Oils	Applications
Sunflower and Soyabean oil	Stabiloization
Soyabean and Rapeseed oil	Lubrication
Castor oil, Sunflower oil, Linseed oil, Soyabean oil, Camphor oil	Plasticization
Coconut and Palm oil	Surfactants
Linseed and Castor oil	Paints, Coatings

MOULDING METHODS

Moulding of plastics comprises forming an article to desired shape by application of heat and pressure to the moulding compound in a suitable mould and hardening the material in the mould. Selection of moulding process is largely determined by the moulding material selected to provide the desired physical properties in the finished moulds pieces. Often the moulding method is

determined by such element design as thin section, long delicate inserts; and requirements of exact concentricity and accuracy of dimensions. Process determination is sometimes complex because there is two types of moulding materials in general use i.e, thermosetting and thermoplastic, and four base mouding methods i.e,

1. Compression moulding

2. Transfer moulding

3. Injection moulding

4. Extrusion moulding

Thermosetting materials are generally processed by compression and transfer moulding and for thermoplastic material injection and extrusion moulding processes are used. There are some exceptions in as much as thermoplastic sare sometimes compression moulded or cast in heavy sections also, thermosetting materials are sometimes extruded or injection moulded. In my dissertation, I will focus only on compression moulding technique which details are given below:

COMPRESSION MOULDING

The process in general

In compression moulding and transfer moulding the monomers are partially polymerised in a separate operation and the polymerization reaction is completed in the mould. The partially polymerized is prepared as pallets for compression moulding. It is placed in a heated mould. After the compound is softened and plastics the upper part of the die moves downward, compressing the material to required shape and density , continuous heat and pressure produce chemical reaction, leading to crosslinking between the molecule chains, that hardens the thermosetting material. The mould remain closed until the curing is complete. Compression moulding is suitable for large bulk of both thermosetting and thermoplastic materials and for small parts of thermosetting materials. Thick sections can be a problem as center may not be properly heated and the curing action may be incomplete. The moulding may be in granual form or in a performed slug.
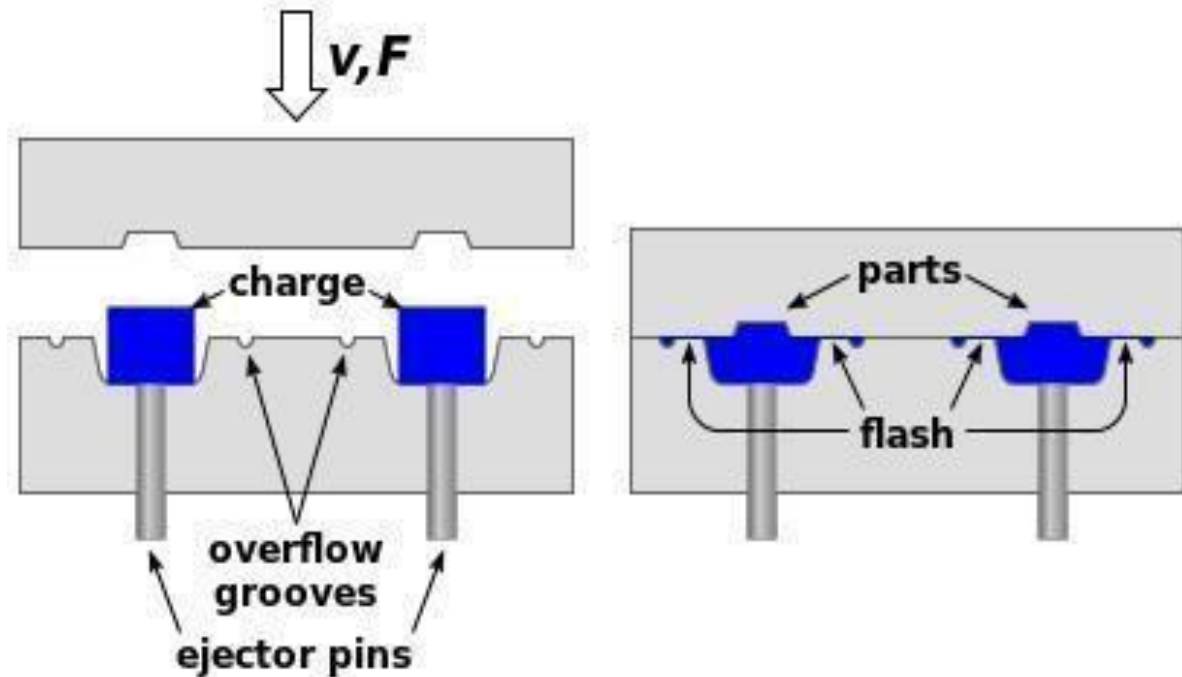
Figure 1.7 A diagram of original compression moulding machine

The moulding temperature of thermosettings ranges from 150ºC to 180ºC. the moulding pressure ranges from 135-535 kgf/cm^2. The temperature and pressure for thermoplastic material depend upon type of material and percentage of plasticizer. The time required to harden the mould piece ranges from 1 to 15 minutes depending upon the maximum thickness of the moulded article and the cooling facilities in the die.

Moulds for compressing process

These moulds range from relatively simple one cavity form to large multiple cavity dies. The number of cavities is detected by the quantity of parts to be produced,size of the part and size or capacity of the moulding press.

There are four basic types of processes for compression moulding.

1. Flash type

2. Positive type

3. Landed positive type

4. Semi positive type

Material preparation

A good homogeneous thermoplastic requires proper preparation of the material. The material should be free of any impurities such as dirt, oil, etc. Any dust should be wiped off with a clean cloth. Solvents or cleaners should not be used since they introduce chemicals with unknown and possible adverse effects.

Raw materials used in PVC reinforcement

Raw material used for PVC reinforcement are- plasticised PVC granuals, fly ash, soyabean oil and linseed oil.

Production of PVC granules

Granulation is the act or process of forming or crystallizing into grains. Granules typically have a size range between 0.2 and 4.0 mm depending on their subsequent use. Granulation is carried out for various reasons, one of which is to prevent the segregation of the constituents of powder mix. Segregation is due to differences in the size or density of the component of the mix. Normally, the smaller and/or denser particles tend to concentrate at the base of the container with the larger and/or less dense ones on the top. An ideal granulation will contain all the constituents of the mix in the correct proportion in each granule and segregation of granules will not occur.

Figure 1.8 Original image of natural PVC granules

Many powders, because of their small size, irregular shape or surface characteristics, are cohesive and do not flow well. Granules produced from such a cohesive system will be larger and more isodiametric, both factors contributing to improved flow properties.

Some powders are difficult to compact even if a readily compactable adhesive is included in the mix, but granules of the same powders are often more easily compacted. This is associated with the distribution of the adhesive within the granule and is a function of the method employed to produce the granule.

For example, if one were to make tablets from granulated sugar versus powdered sugar, powdered sugar would be difficult to compress into a tablet and granulated sugar would be easy to compress.

Powdered sugar's small particles have poor flow and compression characteristics.
These small particles would have to be compressed very slowly for a long period of time to make a worthwhile tablet. Unless the powdered sugar is granulated, it could not efficiently be made into a tablet that has good tablet characteristics such as uniform content or consistent hardness. In the pharmaceutical industry, two types of granulation technologies are employed: wet granulation and dry granulation.

Production of fly ash

Fly ash is produced from the combustion of coal in electric utility or industrial boilers. There are four basic types of coal-fired boilers: pulverized coal (PC), stoker-fired or traveling grate, cyclone, and fluidized-bed combustion (FBC) boilers. The PC boiler is the most widely used, especially for large electric generating units. The other boilers are more common at industrial or cogeneration facilities. Fly ash is captured from the flue gases using electrostatic precipitators (ESP) or in filter fabric collectors, commonly referred to as bag houses. The physical and chemical characteristics of fly ash vary among combustion methods, coal source, and particle shape. Fly ash is generally used as a filler material in metals, polymer and cements matrices due to its unique properties which are low cost, low density and smooth spherical surface. Fly ash also used to improve polymer properties such as strength, stiffness, and wear resistance. An improvement in tensile, flexural, and impact properties of composite in the presence of fly ash was observed. Fly ash is generally formed by different partials, it mainly contains quartz (SiO_2), mullite (3Al2O3.2SiO2), hematite (Fe2O3), magnetite (Fe3O4), lime (CaO), and gypsum, (CaSO4.2H2O).
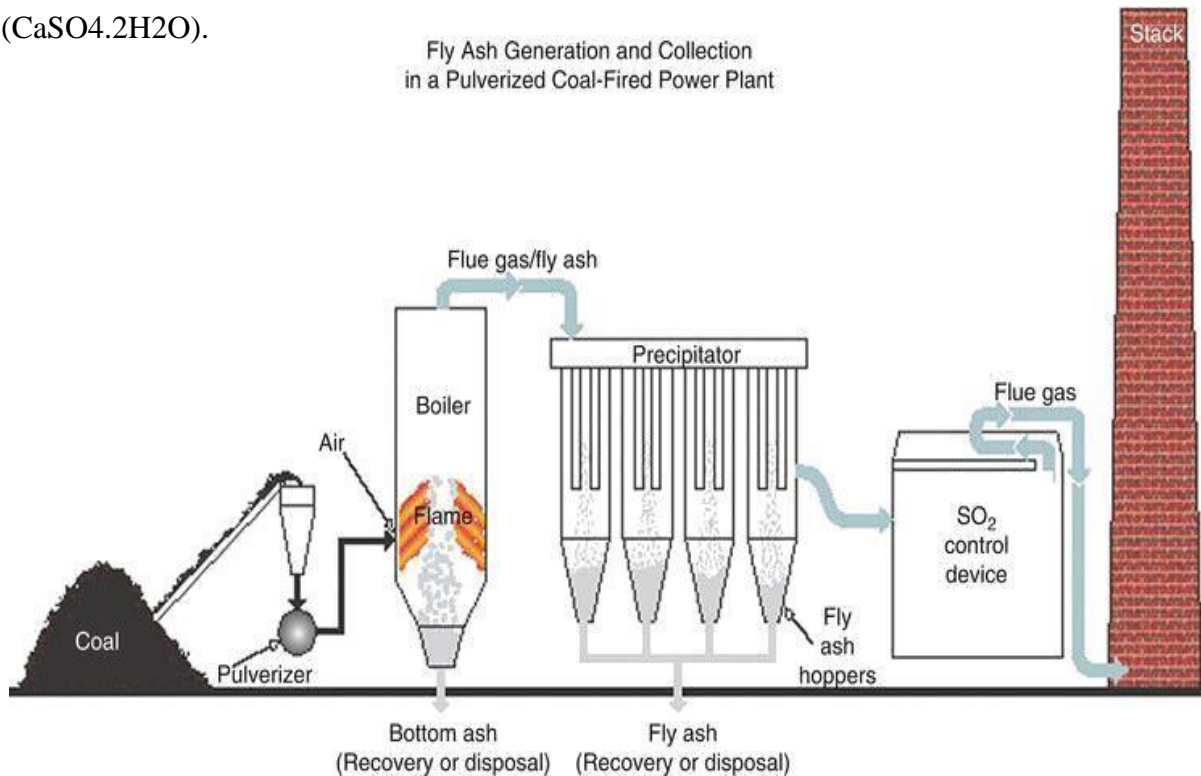
Figure 1.9 A setup of fly ash generation in a power plant

Table 1.2 Chemical composition of fly ash

Component	Content (wt %)	
	Class F	**Class C**
Silicon	23.95	26.39
Oxygen	17.28	13.75
Aluminium	14.25	15.00
Iron	22.65	5.77
Calcium	13.22	26.78
Potassium	1.58	1.77
Sodium	1.05	1.27
Titanium	1.04	0.77
Sulphur	3.11	1.15
Magnesium	1.08	2.10
Carbon	0.53	0.57

Fly ash is basically of two types in which I have used Class C Fly ash.

Figure 1.10 Original image of fly ash

There are some engineering properties of fly ash are also present, the given table 1.2 gives a description about these engineering properties-

Table 1.3 Engineering properties of fly ash

Parameter	Range
Specific gravity	1.90-2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9-1.6
Optimum moisture content (%)	38.0-18.0
Cohesion (kN/m^2)	Negligible
Compression index C_c	0.05-0.4
Permeability (cm/sec)	8×10^{-6} -7×10^{-4}
Particle size distribution(% of material) Clay size fraction Silt size fraction Sand size fraction Gravel size fraction	1-10 8-85 7-90 0-10
Coefficient of uniformity	3.1-10.7

Fly ash properties are unusual among engineering materials. Unlike soils typically used for embankment construction, fly ash has a large uniformity coefficient and it consists of clay-sized particles. Engineering properties that affect the use of fly ash in embankments include grain size distribution, compaction characteristics, shear strength, compressibility, permeability, and frost susceptibility.

Nearly all the types of fly ash used in embankments are Class F. The physical and chemical progenies' of coal ash are determined by reactions that occur during the high-temperament combustion of the coal and subsequent cooling of the flue gas. A considerable amount of research has gone into understanding how coal ash forms, its characteristics, and how it weathers in the environment. The properties of fly ash and bottom ash make them useful for a variety of construction applications.

Production of Soyabean oil and Linseed oil

Soybean oil is a vegetable oil extracted from the seeds of the soybean (*Glycine max*). It is one of the most widely consumed cooking oils. To produce soybean oil, the soybeans are cracked, adjusted for moisture content, heated to between 60 and 88 °C (140–190 °F). Per 100 g, soybean oil has 16 g of saturated fat, 23 g of monounsaturated fat, and 58 g of polyunsaturated fat. The major unsaturated fatty acids in soybean oil triglycerides are the polyunsaturated alpha-linolenic acid, linoleic acid , and monounsaturated oleic acid. It also contains the saturated fatty acids stearic acid and palmitic acid . Soybean oil is one of many drying oils, which means that it will slowly harden upon exposure to air, forming a flexible, transparent, and waterproof solid. Because of this property, it is used in some printing ink and oil paint formulations.
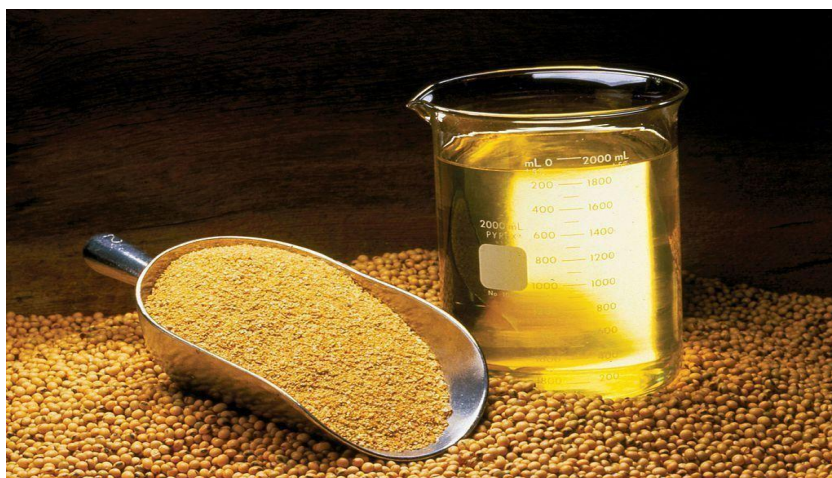
Figure 1.11: Soyabean oil

Linseed oil is also known as flaxseed oil or flax oil, is a colourless to yellowish oil obtained from the dried, ripened seeds of the flax plant (Linum usitatissimum). The oil is obtained by pressing. Linseed oil is also a drying oil, meaning it can polymerize into a solid form. Due to its polymer-forming properties, linseed oil can be used on its own or blended with combinations of other oils, resins or solvents as an impregnator, drying oil finish or varnish in wood finishing, as a pigment binder in oil paints, as a plasticizer and hardener in putty, and in the manufacture of linoleum.

Linseed oil is a triglyceride, like other fats. It consists of α-linolenic acid, saturated acids-palmitic acid and stearic acid, monounsaturated oleic acid and doubly unsaturated linoleic acid.

Figure 1.12 : Linseed oil

Linseed oil is also used in drammar oil(a mixture of linseed and drammar resin). This oil is thick in nature and provides strength to the the product with whom it is mixed.

Table 1.4: Proportion of different acids in soyabean oil and linseed oil:-
(values of acids are as percentage by weight of total fat)

Oil	Oleic acid(ω-9)	Linolenic acid(ω-3)	Linoleic acid(ω-6)	Palmitic Acid	Stearic acid	Smoke point(^{0}C)
Soyabean oil	24	7	50	10	4	238
Linseed oil	11	64	15	7	3.4-4.6	107

COST OF THE EXPERIMENT

Table 1.5 Cost of different components for PVC reinforcement

S.No.	Material	Cost
1	PVC granules	200
2	Fly ash	100
3	Soyabean oil	100
4	Linseed oil	400
5	Fabrication	2165
6	Hardness test	1750
	Total	4715 Rs.

APPLICATION

The diversity of PVC applications challenges the imagination. In everyday life, they are all around us. PVC is used for everything from construction profiles to medical devices,

from roofing membranes to credit cards, and from children's toys to pipes for water and gas. Few other materials are as versatile or able to fulfill such demanding specifications. In this way, PVC fosters creativity and innovation, making new possibilities available every day.

LITERATURE REVIEW

The literature survey is carried out as a part of the thesis work to have an overview of the development and characterization processes, properties and behaviour of PVC composite. Composite structures have shown universally a savings of metal counterparts and a lower operational and maintenance cost. The aim is to understand the different aspects of PVC composite with vegetable oils. Survey of literature indicates that in the area of the reinforcement of PVC plastic no significant work has been done. Whatever work is available has been summarized in the following paragraph. First an introduction is given on plastics, its importance in our daily life.

Plastics have excellent strength to weight ratio, good corrosion resistance and ability to take good finish. Plastics can be categorized as thermosets and thermoplastics. Among these two only the thermoplastic is weldable. In case of thermosets resin, a chemical reaction occurs during processing and curing, that is, as a result of irreversible cross-linking reaction in the mold. Both molded thermosets and vulcanized elastomer components cannot be reshaped by means of heating, because of the irreversible reaction that occur [7]. So in this case joining can be obtained by adhesive bonding and mechanical fastening only.

Literature on reinforcement of PVC plastics is not easily available because of less work is done in this area. I found some of literature which is discussed below-

JAYAMMA FRANCIS,etal in year 1992 conduct a research in Department of Polymer Science & Rubber Technology,Cochin University of Science and Technology, Kochi,India and found that chemical modification of blends of Poly(vinyl chloride) with linear low Density polyethylene, Functionalization of LLDPE/PVC blends using acrylic acid in the presence of DCP is a good means for improving the mechanical behavior of the blends. Functionalized LLDPE/PVC blends show very good bond strength with metals such as steel and aluminum.[1]

M.T. Benaniba, N.Belhaneche-Bensemra and G.Gelbard in year 2002 studied about Stabilization of PVC by epoxidized sunflower oil in the presenceof zinc and calcium stearates. In this paper Sunflower oil was epoxidized & characterized and used as an organic thermal co-stabilizer for plasticized polyvinyl chloride (PVC) in the presence of Zn and Ca stearates. Epoxidized sunflower oil showed excellent properties as a secondary stabilizer for PVC when used in combination with the synergistic Ca/Zn stearates. The effectiveness of Epoxidized sunflower oil depends on the level of epoxidation of the oil. This system retards the development of discoloration and reduces the initial rate of dehydrochlorination.[2]

L.Karunanayake and P.N.J.Fernando in year 2006 had done an analysis on Effect of incorporation of peanut and sesame oils and their epoxides on the structure of Poly Vinyl Chloride. In this paper epoxidised sesame oil and peanut oil is used with PVC instead of soyabean oil. It had been seen that sesame oil and peanut oil has better molecular interaction with Poly Vinyl Chloride as compare to soyabean oil.[3]

P. Karmalm,etal in year 2009 studied about thermal stability of poly vinyl chloride with epoxidised soybean oil as primary plasticizer. In this paper Epoxidised soybean oil (ESBO) has been tested as a primary plasticizer in suspensionof PVC. The stabilization of the material with different traditional stabilizers has been evaluated and compared to a compound with PVC–ESBO only.Different traditional stabilizers havebeen evaluated and the result surprisingly showed that traditional stabilizers, for instance CaSt2/ZnSt2, do not work in/are not optimal for PVC–ESBO. From the result of the traditional stabilizers cause worse degradation compared to PVC–ESBO with no added stabilizers.[4]

C.Bueno-Ferrer,M.C.Garrigos&A.Jimenez in year 2010 studied about Characteization and thermal stability of Poly Vinyl Chloride plasticized with epoxidizedsoyabean oil for food packaging. In this paper phthalates used in Poly Vinyl Chloride has been shown toxic and harmful. Phthalates can be replaced by epoxidisedSoyabean oil an environment friendly plasticizer and efficient stabilizer, which also PVC from degradation.It has been clearly seen that

the thermal degradation of PVC is limited by the addition of ESBO at amount higher than 1-2wt%.[5]

O. Fenollar,etal in year 2010 analysed the effect of the epoxidized linseed oil concentration as natural plasticizer in vinyl plastisols. The use of natural-based additives as plasticizers for plasticized Polyvinyl Chloride (p-PVC) has been evaluated in this study. PVC traditional plasticizers based in phthalate have been substituted by epoxidized linseed oil(ELO). From the industrial point of view, this substitution presents an interesting alternative because ELO is a natural product, harmless, and biodegradable. The effects on the characteristics of plasticized PVC in the migration phenomenon have been analyzed.The use of natural plasticizers, such as ELO, has emerged as an interesting alternative for obtaining plastisols withlow toxicity and low environmental impact.[6]

BaljeevKumar, RajeevGarg and Upinderpal Singh in year 2012 studied about Utilization Of Flyash As Filler In Hdpe/Flyash Polymer Composites: A Review, From the literature survey it is concluded that Fly ash is used as reinforcing filler in High density polyethylene (HDPE) Some studies have pointed to the excellent compatibility between fly ash and polymers.. Although incidental success stories are published, a systematic approach on investigating the influence of fly ash on polymer properties for the various different polymer types and the enormous amount of possible formulations has not yet been properly undertaken. Modification of Fly ash accompanied by compatibilization leads to the substantial improvement properties of the composites.[7]

A. Porabka, etal in year 2013 research about Determination of the Influence of Fly Ash Particles on the Properties of Low-Density Polyethylene, research says Polymers are the materials whose structure can be very easily influenced by e.g. physical modification, which determines at the same time the manner of their use . The obtained results showed that the addition of FA to LDPE is a well-founded and effective solution to modify LDPE. Thus, with the acceptable mechanical

properties and convenient processing, there are no obstacles to substitute even 20% of the polymer mass by fly ash.[8]

Syed Javid Ahmad Andrabi,etal in year 2013 says Influence of Chemical Composition on the Electrical Resistivity of Fly Ash Generated from Indian Coal Based Thermal Power Plants, as a result they found that the foregoing expressions developed for predicting resistivity represents is an initial attempt to predict volume resistivity as a function of ash chemistry and temperature and surface resistivity as a function of moisture and temperatures. The characterization of ashes representing a wide variety of coals suggests that 75-85% is glassy solid. It has been rationalized that the volume conduction takes place through a continuous matrix of these glassy particles. It has been verified that volume conduction is an ionic mechanism involving the alkali metal ions, principally sodium as charge carrier and iron contributes in decreasing the magnitude of resistivity with the increase in percentage. Sodium and potassium show inverse correlation with the resistivity. In surface conduction mechanism the moisture plays a significant role in decreasing the magnitude of resistivity with the increase in percentages.[9]

FigenBalo, H. LütfiYucelin year 2013, says about Assessment of Thermal Performance of Green Building Materials Produced with Plant Oils, This study explores the possibility of use of FA by-product, natural C and renewable EVO in the sample to produce construction materials. The work presented herein has focused on the thermal conductivity properties of the construction material containing FA, C and EVO. FA (30%, 40%, 50%, 60% and 70%), C (30%, 40%, 50%, 60% and 70%) and EVO (40%, 45% and 50%) are effective for decreasing the thermal conductivity of sample up to 49.59%, which is mainly due to the relatively low conductivity of these admixtures and the consequent low density of the sample. The thermal conductivity and density of sample decreased with increasing FA and EVO content. Densities decreased from 1.754 to 0.969 g/cm3 with the increasing FA and EVO content of admixtures. Both EVO (50%) and FA (70%) show the maximum reduction of thermal conductivity with 30% C in all groups, and maximum reduction is observed at group ESO. EVO is more effective than FA in decreasing the thermal conductivity. The maximum reduction is due to the FA (at 30% by weight of C) and it is 44.95%. The EVO reduces the thermal conductivity, and density of samples. The maximum

reduction due to 50% EVO is 40.65%. The results thus indicate that the samples with EVO-FA-C offer a good alternative for making environmental friendly fired construction material.[10]

Sri PhaniSushma and AmireddyKiran Kumar in year 2014, research about Hardness and Tensile Testing of PVC and Fly Ash Composite, Effect of fly ash as filler material in PVC has beendiscussed in this project. Concentration of fly ash was varied from 0% to 30 % by weight with an increment of 10% for each sample, With varying percentage of fly ash, two samples of same fly ash composition are tested(10% fly ash 2 samples) and the aggregate of the respective two values is considered and these tests have resulted that the change in composition of the fly ash varies the properties of the composite in considerable manner. Hardness was found to increase with fly ash concentration between 0-15% and reduce beyond that. Elongation drastically reduced for fly ash concentration beyond 20%. With increasing fly ash concentration hardness value decreases. Overall, the mechanical properties of PVC-product obtained were affected positively and better PVC composites were obtained upto certain values and then decreases further.[11]

Ajit Kumar Senapati, etal in year 2014, says an extensive literature review on the usage of fly ash as a reinforcing agent for different matrices, The current literature review reveals that, extensive work has been reported to improve properties of different matrices by forming their composites being reinforced with fly ash particle , and from the above review it may be concluded that almost all properties except very few exceptions proved to have distinctive improvement in their properties , and hence fly ash should be implemented extensively in the commercial production of composites in industries as its use for the production of composites can turn industrial waste into industrial wealth. This also solves the problem of storage of fly ash as well as brings down the production cost giving an economical and eco-friendly solution.[12]

Samson Oluropo Adeosun, etal in year 2014, Characterization of LDPE Reinforced with Calcium Carbonate—Fly Ash Hybrid Filler, The study on the effect of addition of calcium carbonate-fly ash hybrid filler on the mechanical, physical and chemical properties of LDPE has been done. Composites are found to possess higher melt flow index at higher amount of CC

butlower melt flow index at higher amount of FA. Composite with 45 wt% and 5 wt% exhibits a typical triclinic polyethylene structure indicating that the composite is amorphous in nature. The hybrid of FA and CC fillers exhibits the synergetic effect on flexural strength and crystallinity of the composite. However, they show the parallel effect on energy at peak and micro-hardness.[13]

Pallavi Tiwari, etal, in year 2015 found in Study on Mechanical, Thermal and Morphological Properties of RHA Filled PVC Composite, they found that Tensile strength, elongation at break and flexural strength has been decreased due the poor filler dispersion and interaction with the matrix. While the tensile modulus is increased due to the rigidity and toughness of the RHA filler provided to the matrix PVC. Thermal property has been increased when the concentration of the filler is increased due to the higher temperature of rice husk ash RHA, the presence of the silica (SiO2) and other elements and their higher amount of melting and ignition temperature increased the thermal properties.[14]

Puyou Jia,etal in year 2015 studied Synthesis and Application of Environmental Castor Oil Based PolyolEster Plasticizers for Poly vinyl chloride. PVC materials were prepared via blending the synthesized castor oil based polyol esters as the main plasticizer. Properties of the PVC materials were investigated and compared to those of commercial plasticizers (DOP and ESO). The results showed that castor oil based polyol esters could significantly improve thermal stability of PVC blends. Both migration stability and volatility stability tests showed that with the increasing of the molecular weight of castor oil based polyol ester, the migration stability and volatility stability enhanced. Different tests showed that PVC is more efficient with castor oilas a plasticizer as compare to dioctyl phthalate (DOP) plasticizer.[15]

Nidal H. Abu-Zahra, etal in year 2015 studied about Enhanced Thermal Properties of Rigid PVC Foams Using Fly Ash PVC foam-fly ash, says composites (PVC-FA) are characterized for their structural, morphological, mechanical and thermal properties. The tensile strength of the composites increased modestly with higher fly ash loading, while there was a significant increase in the elastic modulus for the same composites. On the other hand, a decrease in elongation at UTS was observed upon increasing fly ash content due to increased rigidity of the composites.

Similarly, the flexural modulus increased as the fly ash loading increased, where the composites containing 25 phr fly ash showed the highest flexural strength.[16]

Kar Min Lim, YernCheeChing and Seng Neon Gan in year 2015 published an article Effect of Palm Oil Bio-Based Plasticizer on the Morphological, Thermal and Mechanical Properties of PolyVinyl Chloride. In this paperflexible poly vinyl chloride (PVC) was fabricated using a palm oil-based alkyd as a co-plasticizer to di-octyl phthalate (DOP) and di-isononyl phthalate (DiNP). The effects of the incorporation of the palm oil-based alkyd on morphological, thermal and mechanical properties of PVC compounds were studied. Results showed the incorporation of the alkyd enhanced the mechanical and thermal properties of the PVC compounds. Improved mechanical properties are observed with the increased alkyd content, effectively enhancing the overall plasticizing efficiency of the PVC blends. DOP and DiNP are small molecules while the alkyd is large molecule that can entangle with the PVC chains. The amount of entanglements increases with the alkyd content and hence leads to higher tensile strength and elastic modulus of the PVC samples.[17]

Nikesh B. Samarth,etal in year,2015 studied about Modified Vegetable Oil Based Additives as a Future Polymeric Material—Review, says with the examples of recent product innovations from oleochemistry, the successful development of environmentally compatible and powerful polymeric products in the sense of a sustainable development has been demonstrated.The combination of various vegetable raw materials to form new products will also be a challenge for research and development in the future, as is the development of additive for polymer or composite applications. Use of Modified vegetable oil is a convenient way toward the goal of green chemistry, and is strongly recommended to use in polymer area. The examples cited above are impressive and provide a good insight into the field of utilization of vegetable oil as polymeric material. In order to achieve further development in this field, improved method and modification, which give rise to better properties and constitute a minimal hazard, should be used instead of the petrochemical based material.[18]

DESIGN OF EXPERIMENT AND EXPERIMENTAL WORK

3.1 2nd FULL FACTORIAL DESIGN

The design of experiment is based on 2nd factorial design which is known as full factorial technique. Here n is number of variables taken during the experiment. In my experiment n= 3. A full factorial design contains all possible combinations of a set of factors. This is the most fool proof design approach, but it is also the most costly in experimental resources. The full factorial designer supports both continuous factors and categorical factors with up to nine levels. In full factorial designs, an experimental run at every combination of the factor levels. The sample size is the product of the numbers of levels of the factors. For every experimental work a design of experiment is needed.

Design of Experiments (DOE) is a method to identify the important factors in a process, identify and fix the problem in a process, and also identify the possibility of estimating interactions. In real engineering settings, there are usually multiple factors involved and it is typically important to consider them together in case they interact (influence each other). This is done using a full factorial DOE. In this, a two level factorial DOE will be used. This means two levels of each factor will be studied at once. If there are n factors that we need to evaluate in a process we need to run the experiment 2^n times. Each factor will have two levels, a "high" and "low" level. Table 3.1 shows the factorial design in a standard order matrix.

The 2^3 factorial design has two levels of each of the three variables requires $2 \times 2 \times 2 = 8$ run. The 2^3 design matrix is shown in Table 3.1

3.2 DESIGN MATRIX

Table 3.1 Matrix for input variables and corresponding responses

S.No.	X_1 S(ml)	X_2 L(ml)	Response $T(N/mm^2)$
1	-1	-1	
2	-1	+1	
3	+1	-1	
4	+1	+1	
5	-1	-1	
6	-1	+1	
7	+1	-1	
8	+1	+1	

Where

+1 indicates the maximum value of input parameter

-1 indicates the minimum value of input parameter

X_1= Peanut oil in mililetre (S), X_2= Corn oil in mililetre (L)

The matrix of runs is generated by alternating between levels -1 and +1 for runs one to eight of variable X_1. Then variable X_2 is generated by alternating pairs of -1s and +1s. Finally, variable x_1 is generated by taking four -1s and then +1s. Since the same number of -1s and =1s appear in each column, the experiment is balanced. The assignment of the names X_1 and X_2 to the two columns is arbitrary. The experimental run is organized by their logical or standard order indicated by the column labeled S. No.

3.3 EXPERIMENTAL WORK

To perform the experiment compression moulding is done.

Steps of experiment: To perform any work, it needs a systematic plan to perform that work. In order to complete the experimental work successfully I have plan the work as given the following flow chart.

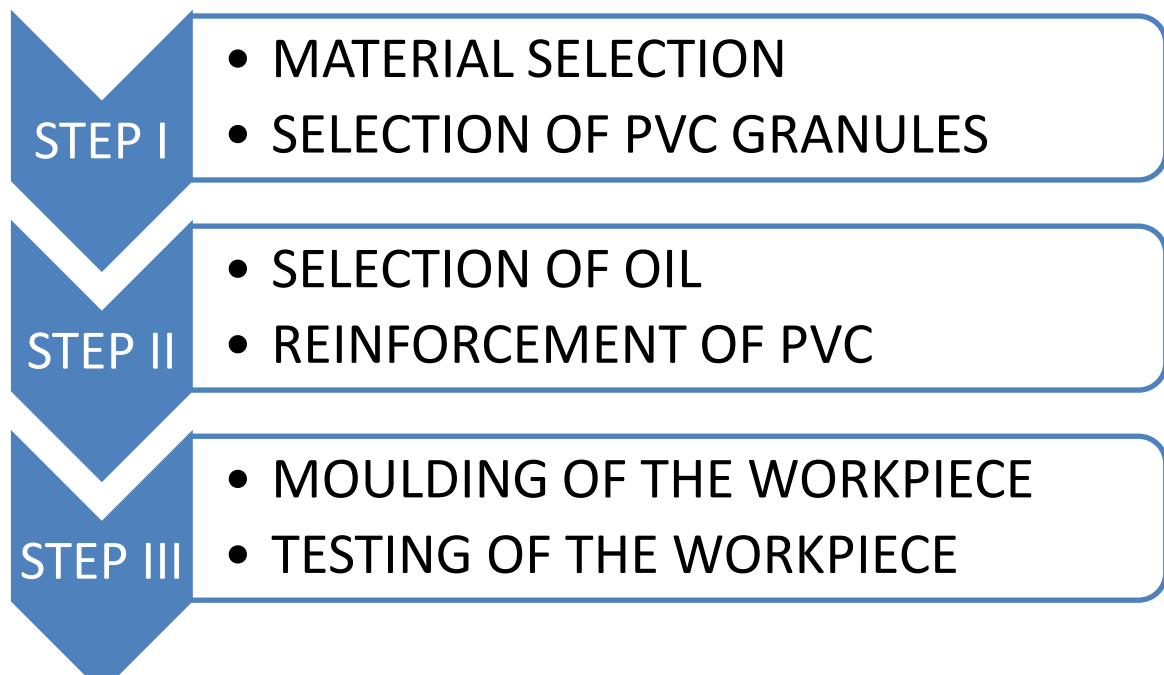Following are the basic steps are taken to perform the final experiment

STEP I
- MATERIAL SELECTION
- SELECTION OF PVC GRANULES

STEP II
- SELECTION OF OIL
- REINFORCEMENT OF PVC

STEP III
- MOULDING OF THE WORKPIECE
- TESTING OF THE WORKPIECE

Figure 3.1 Flow chart of experimental work

1. Material selection: Plasticised PVC is selected for the reinforcement. Peanut oil and corn oil are used as reinforcing material. PVC has the following chemical formula-
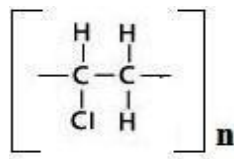
2. **Selection of PVC granules**: For this experiment plasticised PVC granules are selected, so that there is no coating or mixing of any material will present that prevent from any kind of chemical reaction with the other materials**.**

3. **Selection of Oil:** Peanut oil and corn oil has been used.

4. **Reinforcement of PVC:** Reinforcement of PVC is done by mixing peanut oil and corn oil with the use of two roll mill. The process is done at the temperature of 120^0C. The two roll mill consists of two rollers of cast iron. This machine takes 12 minutes to musticate all the four contents.

Table 3.2: Mixing time of each material

Material	Time for mastication
PVC	3-4 min
Peanut oil	3 min
Corn oil	3 min

Figure 3.2 Two Roll Mill

Figure 3.3 (a) Pure PVC (b) PVC with Oil

5. Moulding of the work piece/ fabrication of the composite: Composite is fabricated by compression moulding. It is done by using hydraulic press. This machine works automatically with manual handling. First, the machine is maintained at 130^0C- 140^0C(for pure PVC, temperature is 130^0C and rest samples are treated at 140^0C). A mould of 12x12x3(in mm) dimension has been used. This mould is filled with material by using two cast iron sheets along OHP sheets as supporting elements. Mould along sheets is placed between the two jaws in which lower jaw is fixed and upper jaw is movable. For fixation of jaw a pressure of 60kg/cm^2 is applied by using a hand lever .This pressure is applied for 2 minutes for the proper occupation of material in mould i.e. proper flow of material in mould. Now a pressure a 150kg/cm^2 is applied again by pushing down the hand lever. This pressure is applied for 6 minutes with heat. After proper heating, cooling is done for 2 minutes. It is abrupt cooling which lowers down the temperature about 25-35^{0}C. Now mould is taken out from the jaws. Material is then cooled at room temperature very slowly. Final composite is taken out from the mould after proper cooling.

Figure 3.4 Hydraulic press for moulding

6. Testing of the workpiece:

Total 8 experiments have been conducted at different parameter. The combination of input parameter is taken on the basis of full factorial technique. Two parameter have been taken as ultimate load and elongation of the reinforced PVC. Detail description of input parameter are given below-

3.4 INPUT PARAMETERS

3.4.1 Composition of material

PVC= 80gm(fixed)

Peanut oil= 25-45 ml

Corn oil=65-75 ml

3.4.2 Experiment No.1

First experiment conducted by taking the one of the material constant i.e; PVC and two

variables, taking corn oil at its higher value and peanut oil at its lower value.
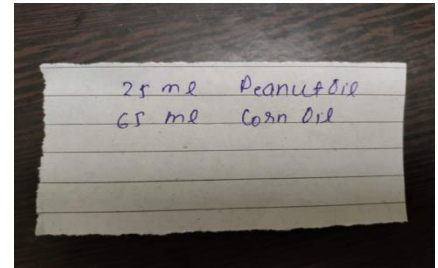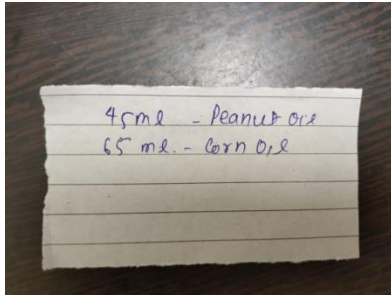
PVC = fixed
peanut oil = 45ml
corn oil= 65ml

Figure 3.5 (a) Sample no. 1 (b) Sample no.2

3.4.3 Experiment 2

Second experiment conducted by taking PVC constant and two variables, taking peanut oil and corn oil at its lower value.

PVC = fixed

Peanut oil =25ml

Corn oil= 65ml

3.4.4 Experiment 3

Third experiment conducted by taking PVC constant and two variables, taking peanut oil & corn oil at its higher value.
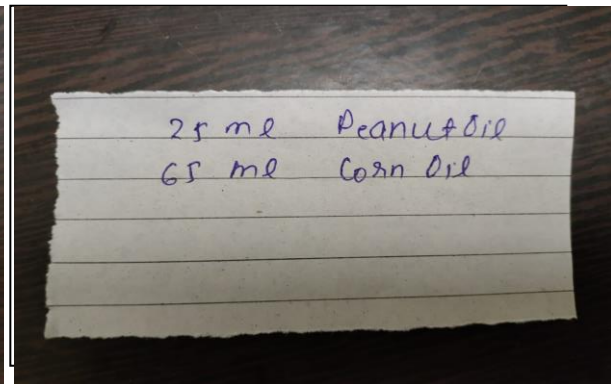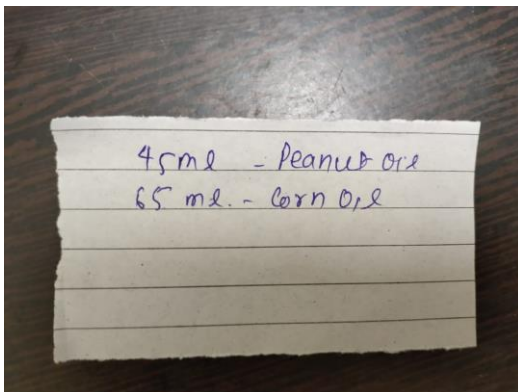
PVC = fixed

peanut oil = 45ml

 corn oil =65 ml

Figure 3.6 (a) Sample no. 3 (b) Sample no.

3.4.5 Experiment 4

Fourth experiment conducted by taking PVC constant and two variables, taking corn oil & peanut oil at its lower value.

PVC = fixed

peanut oil = 25ml

corn oil= 65ml

3.4.6 Experiment 5

Fifth experiment conducted by taking PVC constant and two variables, taking

peanut oil at its lower value and corn oil at its higher value.

PVC = fixed

Peanut oil = 25ml

Corn oil= 65ml

Figure 3.7 (a) Sample no. 5 (b) Sample no.6

3.4.7 Experiment 6

Sixth experiment conducted by taking PVC constant and two variables, taking peanut oil at its lower value and corn oil at its higher value.
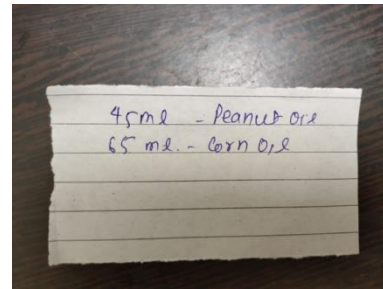
PVC = fixed
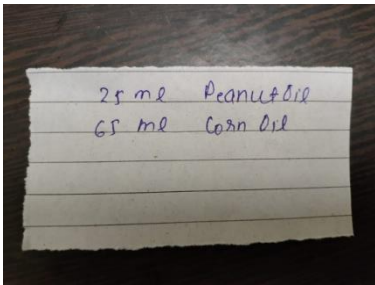
Peanut oil = 45ml

Corn oil= 65ml

3.4.8 Experiment 7

Seventh experiment conducted by taking PVC constant and two variables, taking

Peanut oil at its higher value and corn oil at its lower value.

PVC = fixed

corn   oil   =   25ml
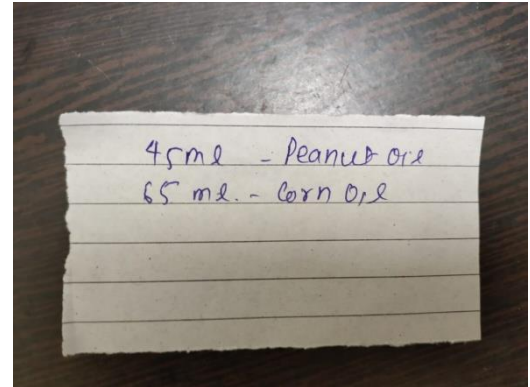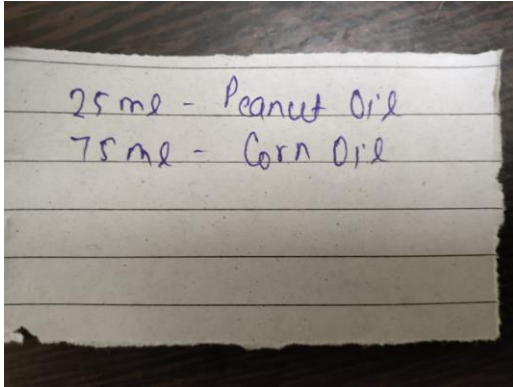Peanut oil= 75ml

Figure 3.8 (a) Sample no. 7 (b) Sample no.8

3.4.9 Experiment 8

Eighth experiment conducted by taking PVC constant and two variables, taking peanut oil and corn oil at its higher value.

PVC = fixed

Peanut   oil   =   45ml

Corn oil= 65ml

3.5 TESTING OF REINFORCED WORKPIECE

3.5.4 **Tensile test**-

Tensile tests have been being conducted on tensile testing machine of the university workshop. Workpiece specimens were clamped in the jaw of tensile testing machine and tensile load is applied. Range of the load is upto 500 kgf or 4905 Newton. When gradual load (tensile) is applied to the workpiece.

Figure 3.9 Tensile testing machine (work piece is ready for tensile test)

Specimen-1 is clamped in jaws of the machine and gradual tensile load is applied, now it gets deformed and after a long deflection is fractured. Similarly other 7 specimens are tested on this machine to find the tensile strength. During test we can measure ultimate load at which the specimen gets fractured, and at this ultimate load, we can measure the deflection in material before fracture. So by these two responses on machine during testing, we can calculate the tensile strength of the specimen. 8 specimens have been tested on the tensile testing machine and the result is shown in below-
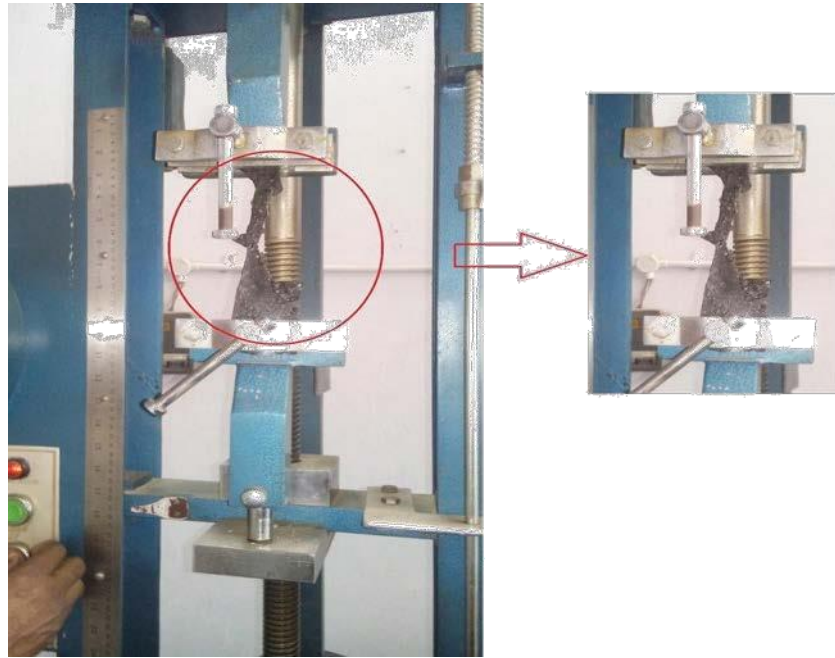
Figure 3.10 Fractured specimens during testing

Table 3.3 Shows observed values of deflection and ultimate load

S.No.	Peanutoil (ml)	Corn oil (ml)	Initial length	Final length	Deflection	Ultimate load(W) Kg	Ultimate load (W) in Newton
1	45	65	30.5	32.3	1.5	7	7×9.81=68.67
2	25	65	29.5	42.7	11.2	31.1	31.1×9.81=305.71
3	45	75	29.5	31.8	2	8.1	8.1×9.81= 79.46
4	25	65	28.5	31.6	2.9	4.5	4.5×9.81= 44.14
5	25	75	28.5	37	6.1	10	10×9.81= 98.1
6	45	65	30.5	39.8	7.4	18	18×9.81= 176.5
7	25	75	28.5	34	4	19	19x9.81= 186.3
8	45	75	29.5	32	2.9	6	6×9.81=58.86

Table 3.4 Calculated value of Tensile strength

S.No	Peanut oil (ml)	Corn oil(ml)	Ultimate load(W) in Newton	Area in mm^2	Tensile Strength=(load/Area) in N/mm^2
1	45	65	68.67	80x50=4000	68.67/4000= 0.017
2	25	65	305.7	80x50=4000	305.7/4000= 0.076
3	45	75	79.46	80x50=4000	79.46/4000= 0.019
4	25	65	44.14	80x50=4000	44.14/4000= 0.011
5	25	75	98.1	80x50=4000	98.1/4000= 0.024
6	45	65	176.5	80x50=4000	176.5/4000= 0.044
7	25	75	186.3	80x50=4000	186.3/4000= 0.046
8	45	75	58.86	80x50=4000	58.86/4000= 0.014

3.5.5 Hardness test

Hardness test is done to check the wear resistance or abrasion resistance. In my experiment hardness test is done by shore hardness test as it is used for flexible and soft materials. Shore hardness test is of two types-

Shore A hardness test

Shore D hardness test

Shore A hardness testers/durometers are designed for testing various rubber, elastomers, leather, wax and plastic products where as Shore D hardness testers are designed for testing the hardness of hard rubber, such as thermoplastic plastics, bowls, plastic. Specifications of this hardness tester are-

    □   Measuring range: 0-100 Shore A units

    □   Depth of indentation: 0 - 2.5 mm (the testing material has to be thicker than 6 mm)

- ⬜ Indenter: Flat Cone Point 35°

- ⬜ Measuring force: 0.55 - 8.065 N

- ⬜ Weight: 200 g (net); 300 g (gross)

- ⬜ Dimensions: 115 x 60 x 25 mm

The Indenter Point is made of hardened alloy steel. An Indicating dial or scale is provided. It is graduated from 0 to 100 divisions; 0 denoting the lowest and 100 is the highest degree of hardness.

Figure 3.11 Shore A hardness tester & testing of workpiece

Table 3.5 Calculated value of Hardness

S.No	Peanut oil (ml)	Corn oil(ml)	Hardness
1	45	65	89.2
2	25	65	70.9
3	45	75	78.4
4	25	65	72.1
5	25	75	80.7
6	45	65	74
7	25	75	83.7
8	45	75	82.9

3.5.6 Thermal gravimetric test

Thermo gravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which changes in physical and chemical properties of materials are measured as a function of increasing temperature (with constant heating rate), or as a function of time (with constant temperature and/or constant mass loss). TGA is commonly used to determine selected characteristics of materials that exhibit either mass loss or gain due to decomposition, oxidation. It measures the amount of weight change of a material, either as a function of increasing temperature, or isothermally as a function of time, in an atmosphere of nitrogen, helium, air, other gas, or in vacuum. It is an especially useful technique for the study of polymeric materials, including thermoplastics, thermosets, elastomers, composites, plasticfilms, fibers, coatings an d paints. TGA can be used to evaluate the thermal stability of a material. In a desired temperature range, if a species is thermally stable, there will be no observed mass change. TGA also gives the upper use temperature of a material. Beyond this temperature the material will begin to degrade. TGA has a wide variety of applications, including analysis of ceramics and thermally stable polymers. Ceramics usually melt before they decompose as they are thermally stable over a large temperature range, thus TGA is mainly used to investigate the thermal stability of polymers. Most polymers melt or degrade before 200 °C. However, there is a class of thermally stable polymers that are able to withstand temperatures of at least 300 °C in air and 500 °C in inert gases without structural changes or strength loss, which can be analyzed by TGA. Temperature range from 25°C to 900°C routinely. The maximum temperature is 1000°C on our instrument. As the temperature increases, various components of the sample are decomposed and the weight percentage of each resulting mass change can be measured. Results are plotted with temperature on the X-axis and mass loss on the Y-axis. Sample weight can range from 1 mg to 150 mg. Sample weights of more than 10 mg are preferred, but excellent results are sometimes obtainable on 1 mg of material. Samples can be analyzed in the form of powder or small pieces so the interior sample temperature remains close to the measured gas temperature.

Figure 3.12 Thermal Gravimetric testing machine

Thermogravimetric analysis (TGA) relies on a high degree of precision in three measurements: mass change, temperature, and temperature change. Therefore, the basic instrumental requirements for TGA are a precision balance with a pan loaded with the sample, and a programmable furnace. The furnace can be programmed either for a constant heating rate, or for heating to acquire a constant mass loss with time. Regardless of the furnace programming, the sample is placed in a small, electrically heated furnace equipped with a thermocouple to monitor accurate measurements of the temperature. The atmosphere in the sample chamber may be purged with an inert gas to prevent oxidation or other undesired reactions. In my experiment-

3.5.6.1 Firstly, material of 10 mg weight is considered for testing.

3.5.6.2 First sample is placed in the furnace at 100^0C, Here it starts degrading at differenttemperature with constant mass loss rate of 10^0C/min.

3.5.6.3 Similarly rest seven samples are tested in the furnace.

3.5.6.4 Maximum degradation is seen upto 700^0C.

3.5.6.5 These tests are performed in the atmosphere of Nitrogen.

3.5.6.6   The sample with the highest initial degradation temperature is the most thermally stablesample.

Table 3.6 Observed value of dergradation temperature and weight loss

S.No	Peanut oil (ml)	Corn oil	$X_1(^0C)$	$Y_1(\%)$	$X_2(^0C)$	$Y_2(\%)$	$\Delta Y=Y_1-Y_2$
1	45	65	160.38	95.805	500.68	39.745	52.061
2	25	65	174.53	94.424	540.80	22.875	69.548
3	45	75	168.12	93.698	520.51	30.265	61.434
4	25	65	140.13	92.916	550.88	38.473	52.444
5	25	75	152.93	94.366	560.05	23.366	69.010
6	45	65	139.36	92.896	520.59	23.204	65.692
7	25	75	137.39	91.873	570.17	42.796	45.077
8	45	75	172.78	92.591	520.77	42.000	45.591

Where X_1= initial degradation temperature

X_2= final degradation temperature

Y_1= weight loss in percent at X_1

Y_2= weight loss in percent at X_2

EMPIRICAL MODELING

4.1 REGRESSION ANALYSIS

In statistics, regression analysis includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical values of the dependent variable changes when any one of independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables that is, the average value of the dependent variable when the independent variables are held fixed. Less commonly, the focus is on a quintile, or other location parameter of the conditional distribution of the dependent variable given the independent variables. In all cases, the estimation target is a function of the independent variables called the regression function. In regression analysis, it is also of interest to characterize the variation of the dependent variable around the regression function, which can be described by a probability distribution.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer casual relationship between the independent and dependent variables.

Regression analysis is used to establish relationship between two variables. The response variable y is independent variable or variable of interest, and the predictor variable x is the dependent variable. An objective of regression analysis is to develop a regression model, relation y to x that can be used to predict values of the response variable. As in case of simple linear regression model relation y to x is

$$Y = B_0 + B_1X_1 + \epsilon$$

Two parameters of the model are B_0, the y-intercept, and B_1 the slope of the line. B_0 is the mean value of y when x is zero. B1 is the change in the mean value of y for one unit change in x. he random error ϵ, accounts for the variability in y that is not explained by the independent variable x. This variability could be due to other important independent, variable or to some random phenomenon. The model assumes that errors are independent, i.e. the error associated with any one observation has no effect on the error associated with any one observation. The model also assumes a normal probability distribution of ϵ with zero mean and constant variance σ^2 for all values of general linear model. In this experiment more than one variable is significantly affecting the response variable, and a multiple linear regression model may better estimate or predict the value of a response variable.

4.1.1 Linear regression model

In linear regression, the model specification is that the independent variable, is a linear combination of the parameters (but need not be linear in the independent variable). For example, in a simple linear regression for modeling data points there is one independent variable, and two parameter and linear regression is

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots\ldots\ldots\ldots B_kX_k + \epsilon$$

4.1.2 Statistical assumption for regression analysis

When the number of measurements, N, is larger than the number of unknown parameters k and the measurement error ϵ are normally distributed then the excess of information contained in (N-k) measurements is used to make statistical predictions about the unknown parameters. This excess of information is referred to as the degree of freedom of the regression.

4.1.3 Underlying assumptions

Classical assumptions for regression analysis include

1) The sample is representative of the population for the interference prediction.
2) The error is a random variable with a mean of zero conditional on the explanatory variables.
3) The independent variables are measured with no error. (Note: if this is not so, modeling may be done instead using errors-in variable model technique)
4) The predictors are linearly independent, i.e. it is not possible to express any predictors as a linear combination of the others.
5) The errors are uncorrelated, that is, the variance-co variance matrix of the errors is diagonal, and each non-zero element is the variance of the error.
6) The variance of the error is constant across observation (homoscedasticity). (Note: if not, weighted least square or other methods might instead be used)

4.2   REGRESSION ANALYSIS OF EXPERIMENTAL OBSERVATION

Regression analysis is done to establish the relationship between two variables. Regression analysis indicates the relationship among the dependent variable and independent variable. Value of depend variable can be predicted only by putting the desired value of independent variable in the regression equation. Regression analysis has been done using statistical software MINITAB15.

4.2.1 Regression analysis for tensile strength of the obtained composite

Equation 4.1 is the regression equation obtained from regression analysis. ANOVA for the regression has been given in table 4.1. Regression table also suggests that welding speed is most significant factor. Table 4.1 indicates that p value for regression equation is significant. The regression equation is

Tensile strength (T) =0.000765 P - 0.00100 C .... (4.1)

Where

P= Peanut oil

C = corn oil

**Table 4.1 Regression table for Tensile Strength of the obtained
Composite**

Predictor	Coef	SE Coef	T	P
Constant	0.1738	0.1254	1.26	0.210
S	-0.0007650	0.0007800	-0.80	0.360
L	-0.0010000	0.001452	-0.62	0.500

S = 0.0195139
R-Sq = 45.6%   R-Sq(adj) = 0.0%

Table 4.2 Analysis of variance table for Tensile Strength of the obtained composite

Source	DF	SS	MS	F	P
Regression	4	0.0013335	0.0003915	0.93	.467
Residual Error	5	0.0020005	0.0004069		
Total	8	0.0034100			

4.2.2 Residual analysis for tensile strength

Residual is the difference between the observed and fitted value of the response. There are four different plots are available as normal probability plot, histogram, versus fit and versus order as shown in given graphs-
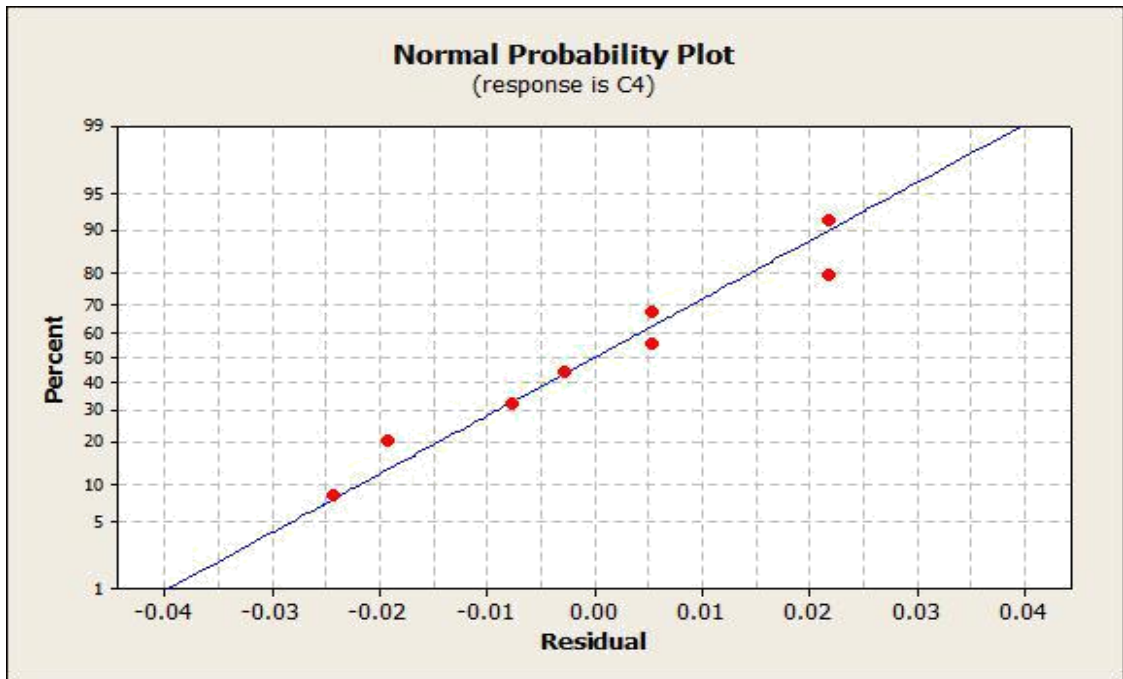
Figure 4.1 Normal probability plots for Tensile Strength
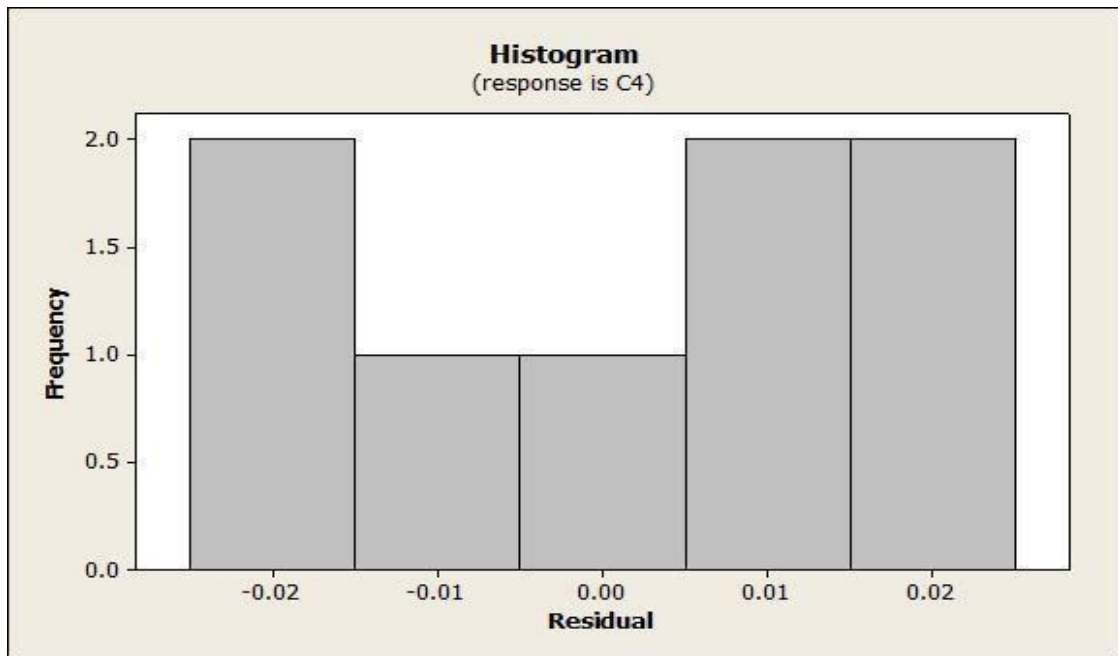
Figure 4.2 Histogram for tensile strength
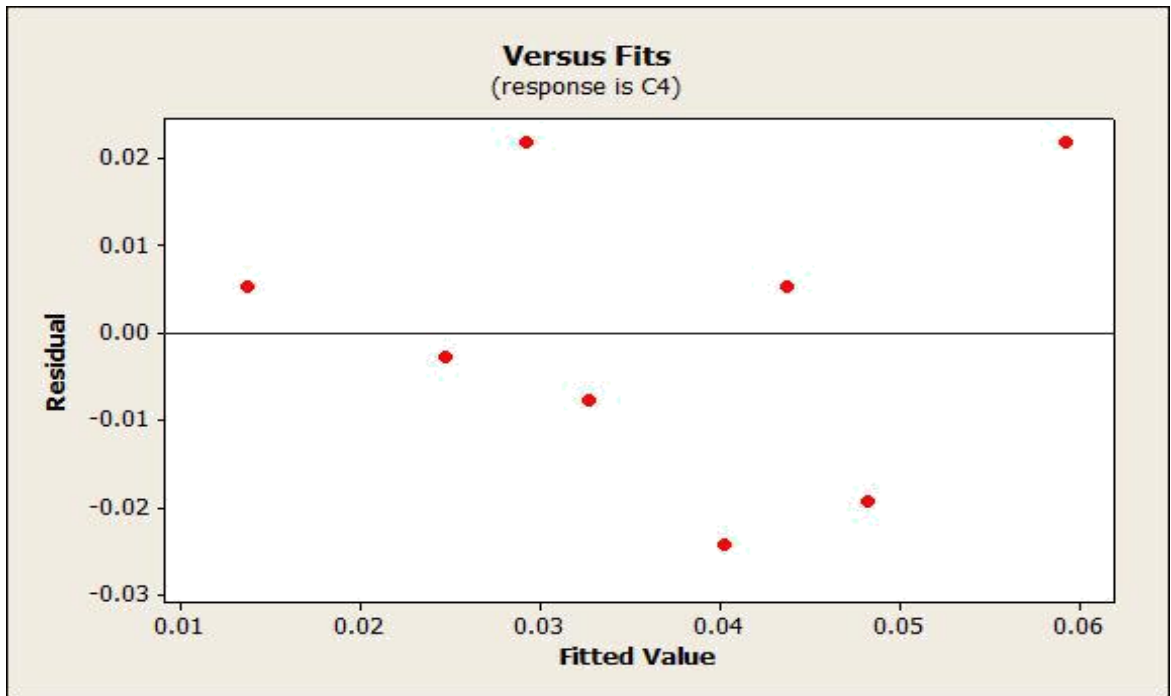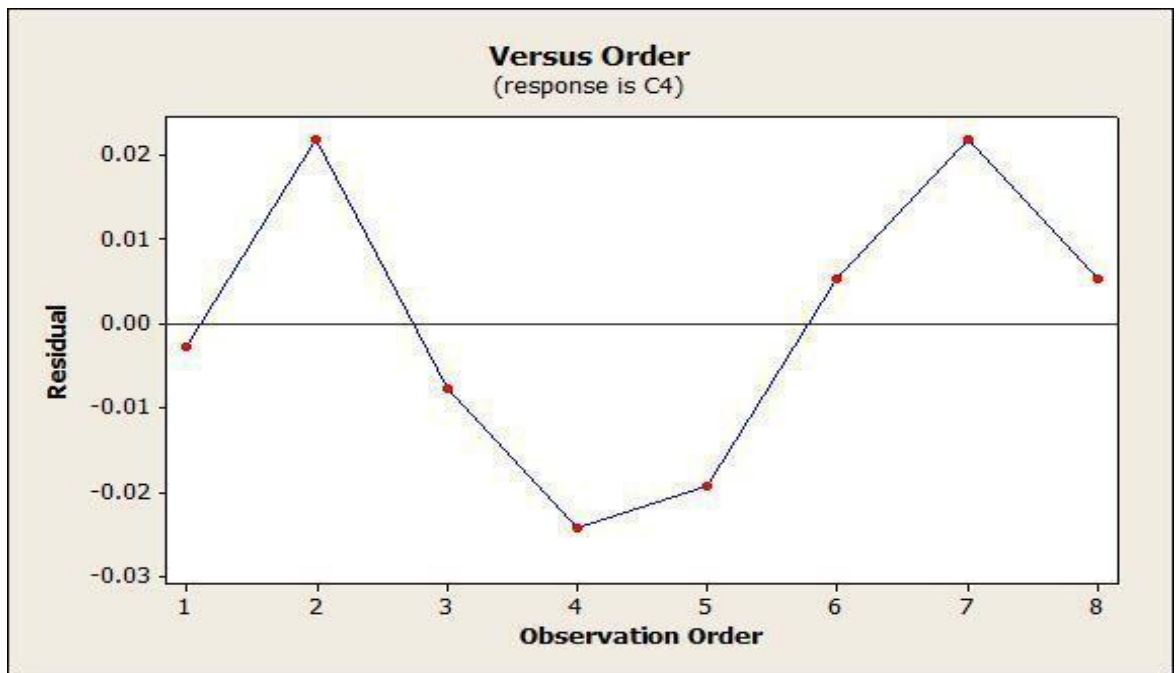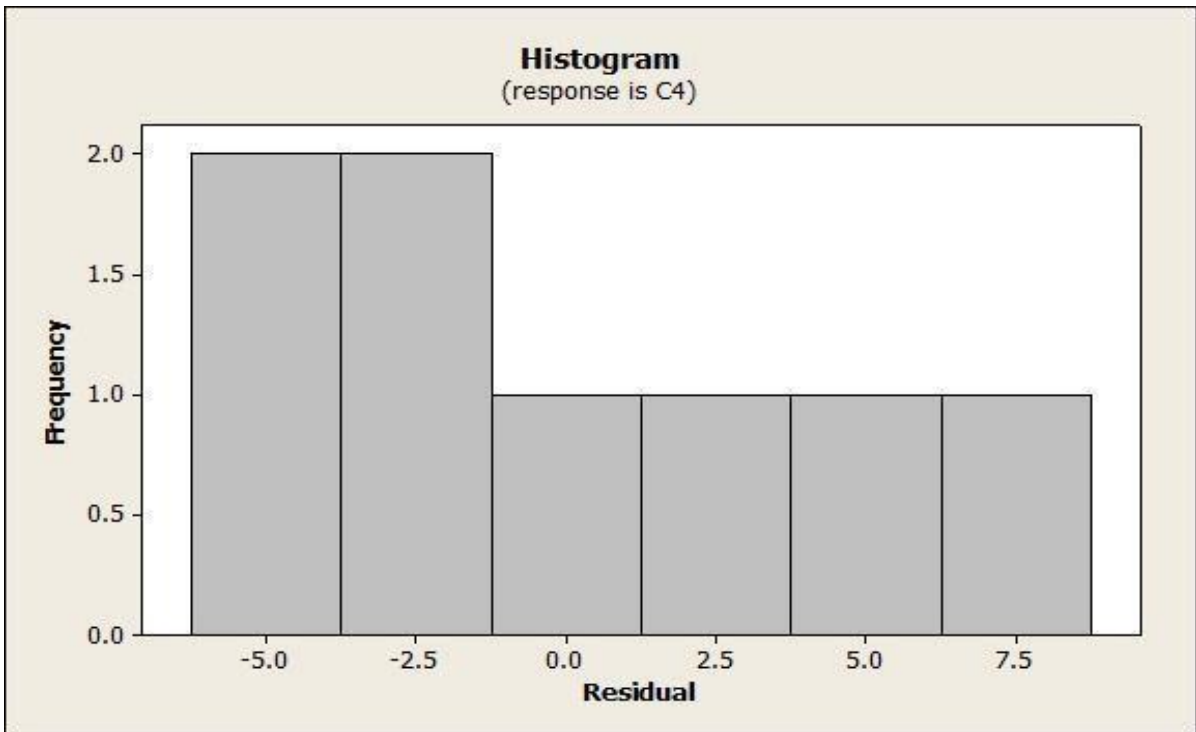
Figure 4.3 Versus fits plot for Tensile Strength

Figure 4.4 Versus order plot for Tensile Strength

4.2.3 Regression analysis for hardness of the obtained composite

Hardness (H) = 38.3 +0.220P + 0.379 C ....(4.1)

Where

P= Peanut oil

C = Corn oil

Table 4.3 Regression table for Hardness of the obtained composite

Predictor	Coef	SE Coef	T	P
Constant	35.28	25.52	1.20	0.238
S	0.2152	0.1637	1.20	0.265
L	0.3831	0.3654	1.00	0.354

S = 4.46834
R-Sq = 52.0%   R-Sq(adj) = 16.8%

Table 4.4 Analysis of variance table for Hardness of the obtained composite

Source	DF	SS	MS	F	P
Regression	4	110.58	40.19	1.41	0.312
Residual Error	5	102.07	28.02		
Total	8	225.66			

4.2.4 RESIDUAL ANALYSIS FOR HARDNESS

Residual is the difference between the observed and fitted value of the response. There are four different plots are available as normal probability plot, histogram, versus fit and versus order as shown in given graphs-
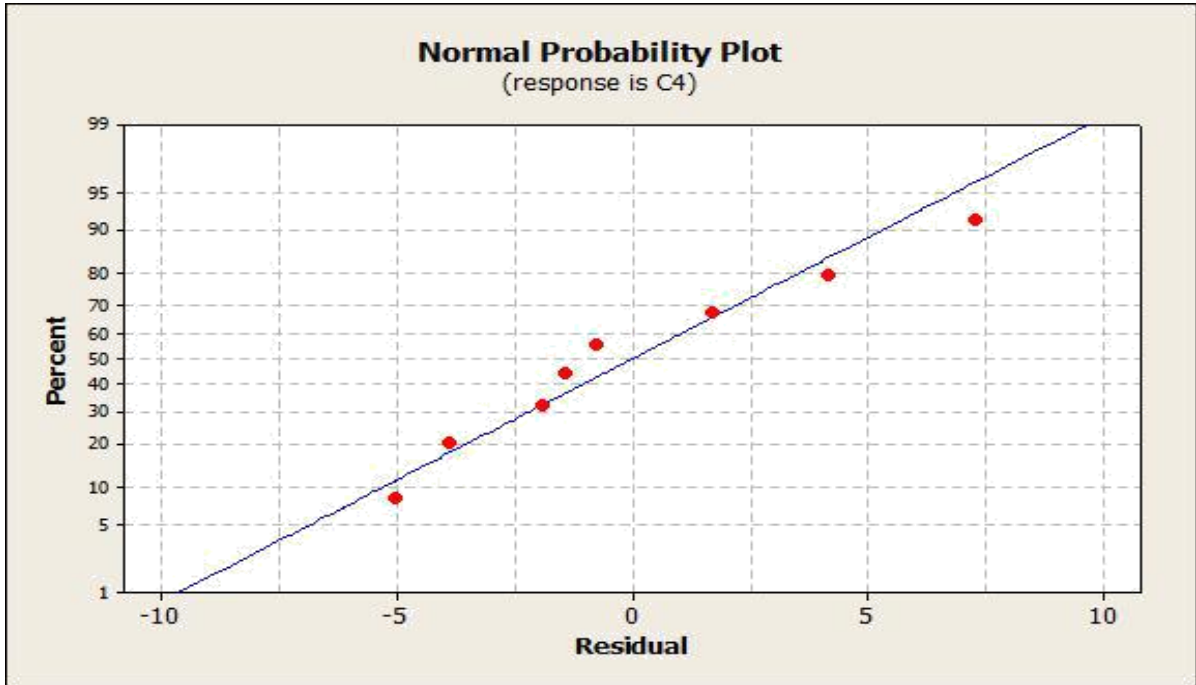
Figure 4.5 Normal probability plots for Hardness
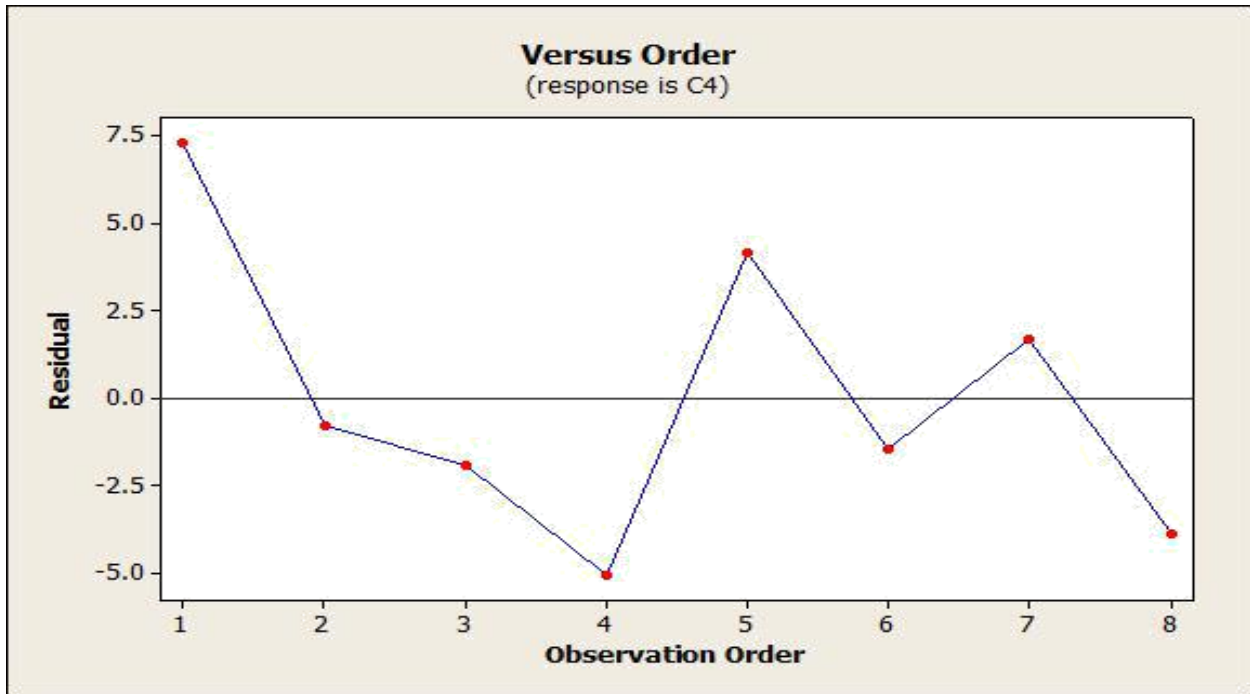

Figure 4.6 Histogram for Hardness

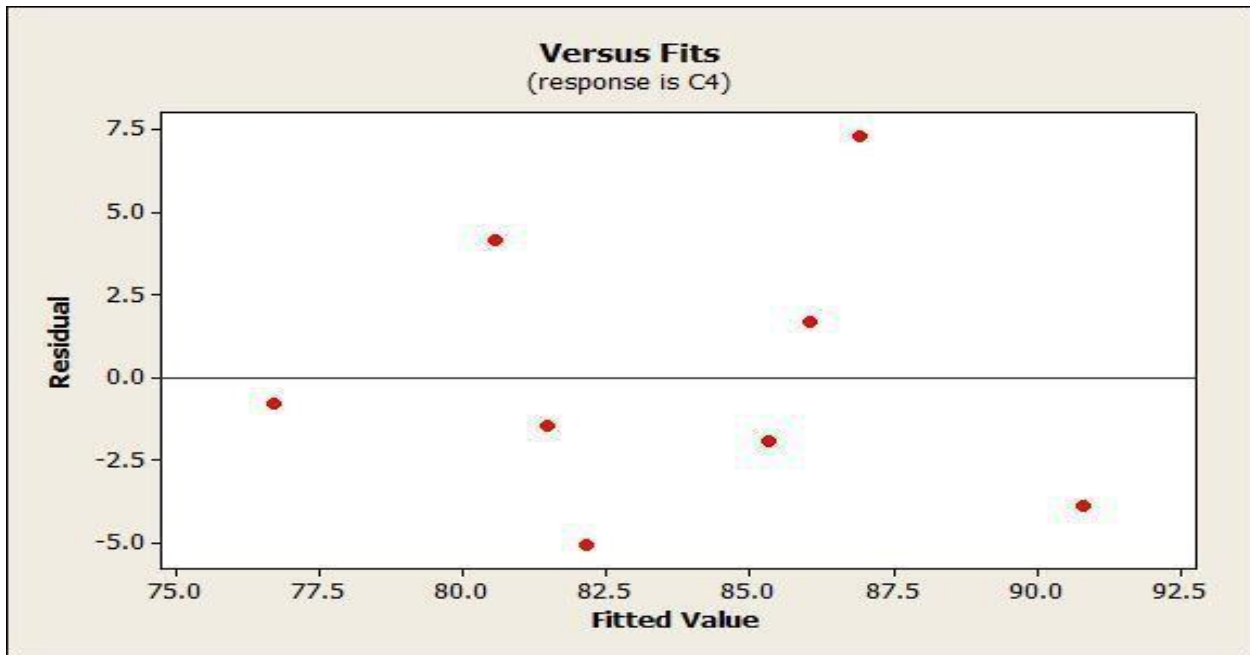**Figure 4.7 Versus order plots for Hardness**

Figure 4.8 Versus fit plots for Hardness

RESULTS AND DISCUSSION

INTRODUCTION

The effect of input parameter was studied on tensile strength and hardness of the weld bead by using Regression analysis and full factorial design and on thermal stability by Thermal Gravimetric Analysis. Tensile strength and hardness were measured as the response parameter. Regression analysis was completed for all the responses to analyze the significance of the input factors. Regression equation was developed to predict the relationship amongst the dependent and independent variables. Table 5.1 shows the values of responses measured.

Table 5.1 Input variables and the corresponding Responses

S.No.	Peanut Oil (ml)	Corn Oil (ml)	Responses	
			Tensile Strength	Hardness
1	45	65	0.017	89.2
2	25	65	0.076	70.9
3	45	75	0.019	78.4
4	25	65	0.011	72.1
5	25	75	0.024	80.7
6	45	65	0.044	74.0
7	25	75	0.046	83.7
8	45	75	0.014	82.9

TENSILE STRENGTH OF THE OBTAINED COMPOSITE

1. Maximum value of tensile strength can be calculated by the model developed as Tensile strength-

Tensile strength (T) = 0.170 - 0.000770 P - 0.00105 C.

The maximum value of tensile strength predicted by above formula is **0.0556 N/mm^2** which is shown in given Table 5.2 and obtained at higher level of weld current.

Table 5.2 Predicted values of tensile strength of composite at different input parameters

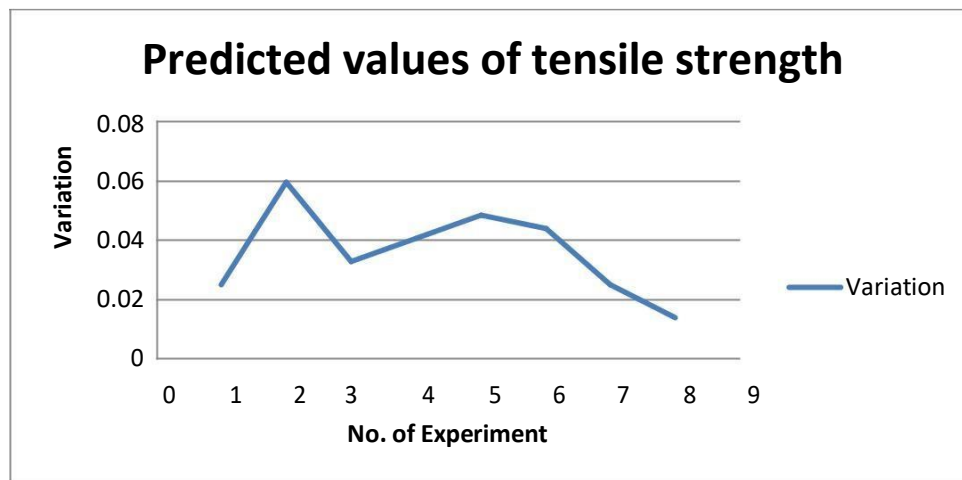| P(ml)	C(ml)	T(N/mm^2)
45	65	0.020
25	65	0.0556
45	75	0.030
25	65	0.0401
25	75	0.0470
45	65	0.040
25	75	0.021
45	75	0.011

Figure 5.1 variation in Tensile Strength

2. Comparison between predicted value and observed value of tensile strength is given in table 5.3

Table 5.3 Comparison between predicted and observed value of Tensile Strength

Predicted values	Observed values	Error
0.020	0.017	0.003
0.0556	0.076	-0.0204
0.030	0.019	0.011
0.0401	0.011	0.0291
0.0470	0.024	0.0231
0.040	0.044	-0.004
0.021	0.046	-0.025
0.011	0.014	-0.003
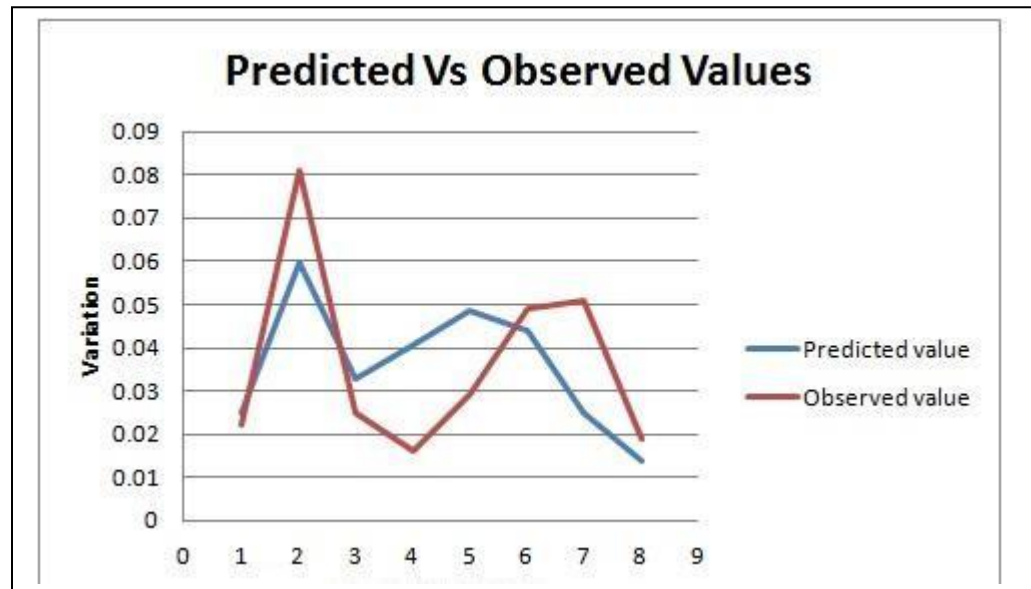
Figure 5.2 Comparison between predicted and observed value of tensile strength

There is very small variation between predicted value and observed value of tensile strength, hence developed model is justified and suitable.

HARDNESS OF THE OBTAINED COMPOSITE

1. Predicted values of Hardness shown in Table 5.4 is calculated by Hardness (H) $= 37.3 + 0.235P + 0.380C$. Maximum predicted value ofHardness is **87.90** and it is also shown in Figure 5.3.

Table 5.4 Predicted values of hardness of composite for different input parameters

P(ml)	C(ml)	H
45	65	83.93
35	65	74.67
45	75	83.32
25	65	79.15
25	75	78.54
45	65	82.45
25	75	82.02
45	75	87.90
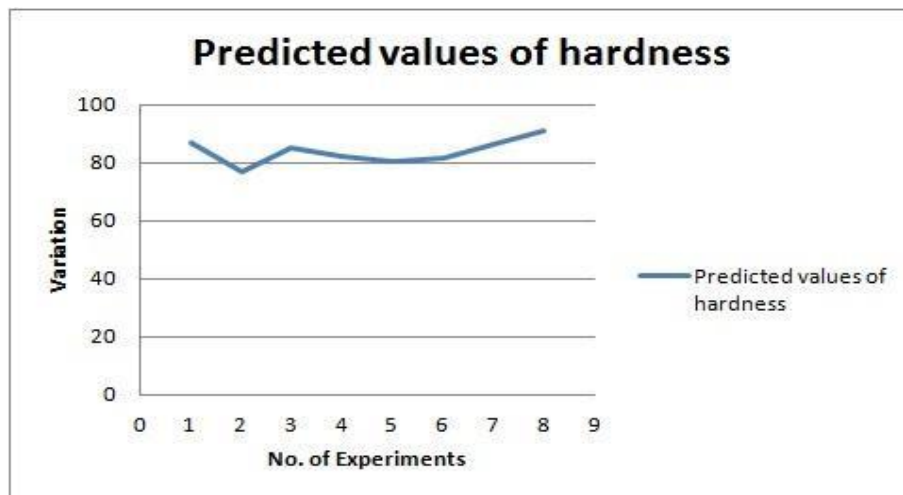
Figure 5.3 Variation in Hardness

From the Table 5.4 indicates the maximum value of Hardness is 87.90

Comparison between predicted value and observed value is given in Table 5.5
Since is very less difference between predicted values and observed values, smallerror
shows that model is suitable and justified

Table 5.5 Comparison between predicted and observed value of Hardness

Predicted values	Observed values	Error
83.93	89.2	-5.27
74.67	70.9	3.77
83.32	78.4	4.92
79.15	72.1	7.05
78.54	80.7	-2.16
82.45	84.0	2.45
82.02	83.7	-1.67
87.90	92.8	-4.90
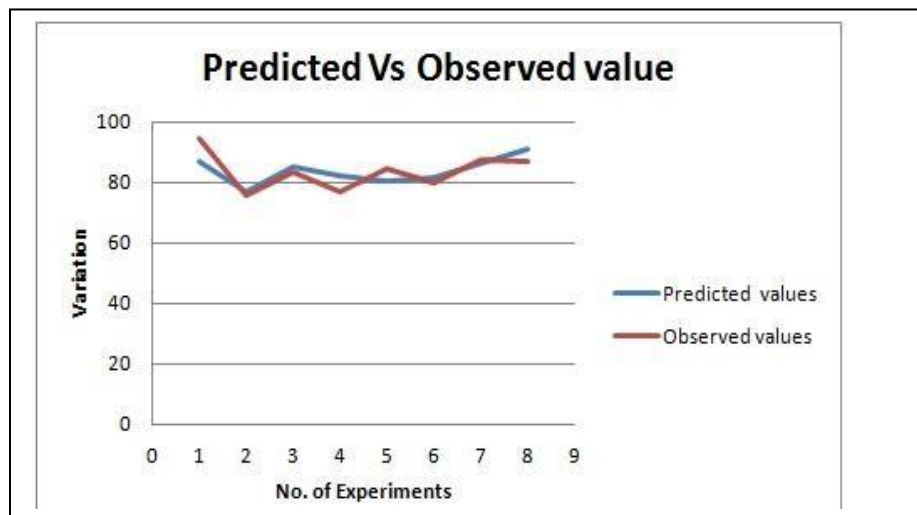
Figure 5.4 comparison between predicted and observed values of Hardness

5.1.3 THERMAL STABILITY OF THE OBTAINED COMPOSITE

For thermal stability thermal gravimetric analysis is done. This analysis shows variation in degradation temperature and weight of samples of different experiments. It can be seen by the following figures. Maximum thermal stability is shown by experiment no.2 as the sample has maximum degradation temperature i.e. **179.53 ^{0}C**
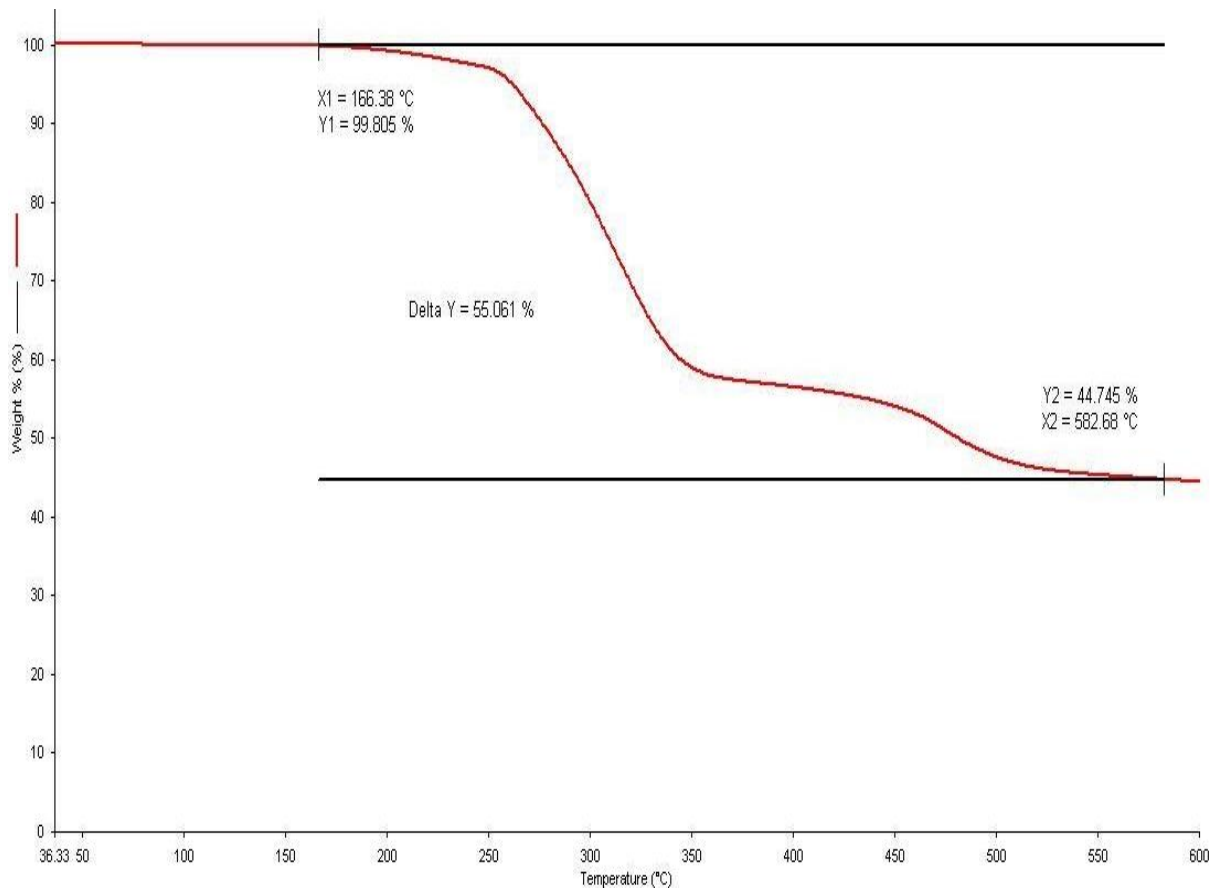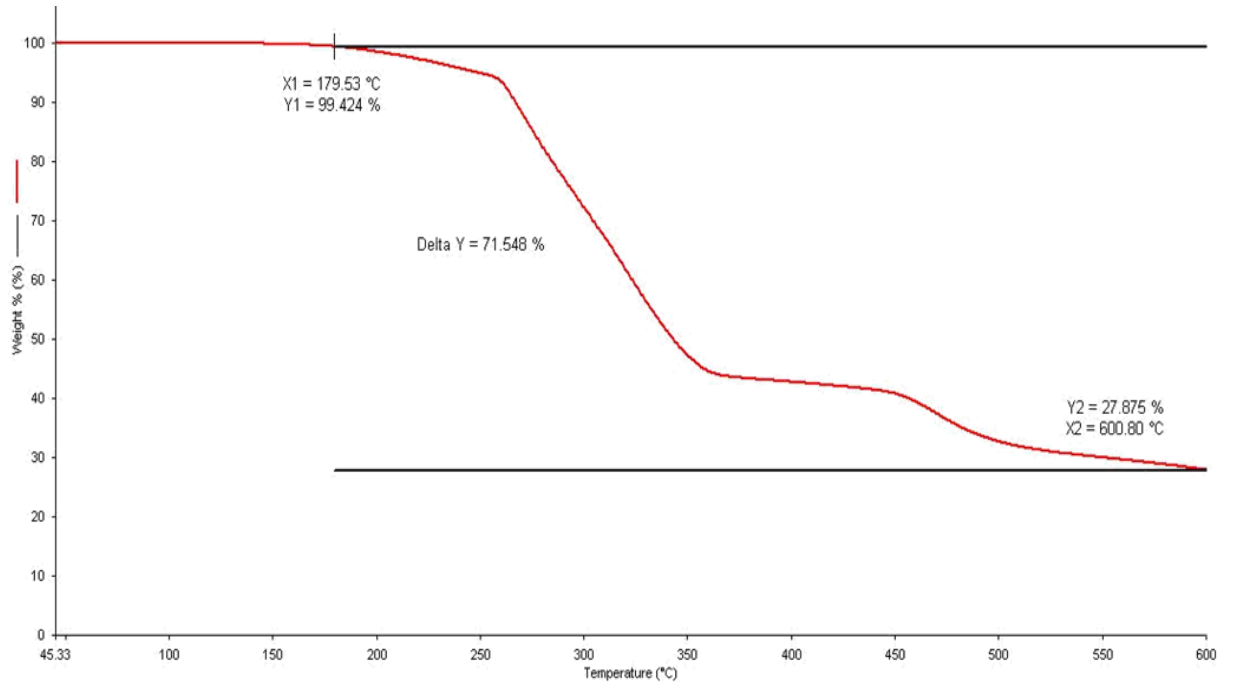

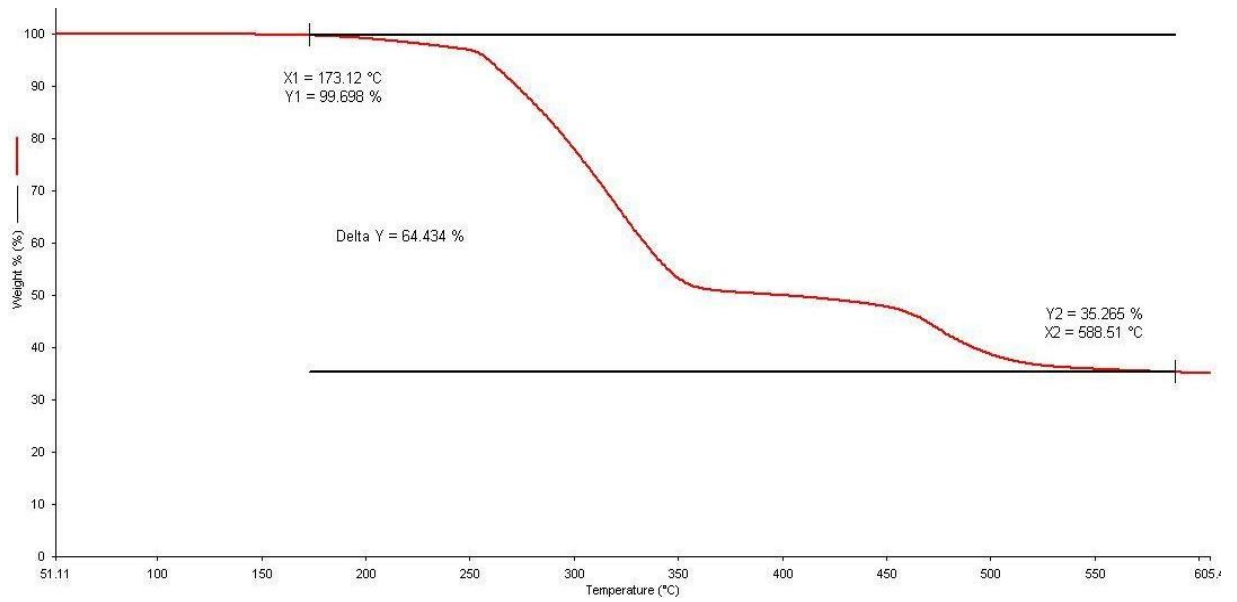**Figure5.5 Graph for experiment no.1**

Figure5.6 Graph for experiment no.2

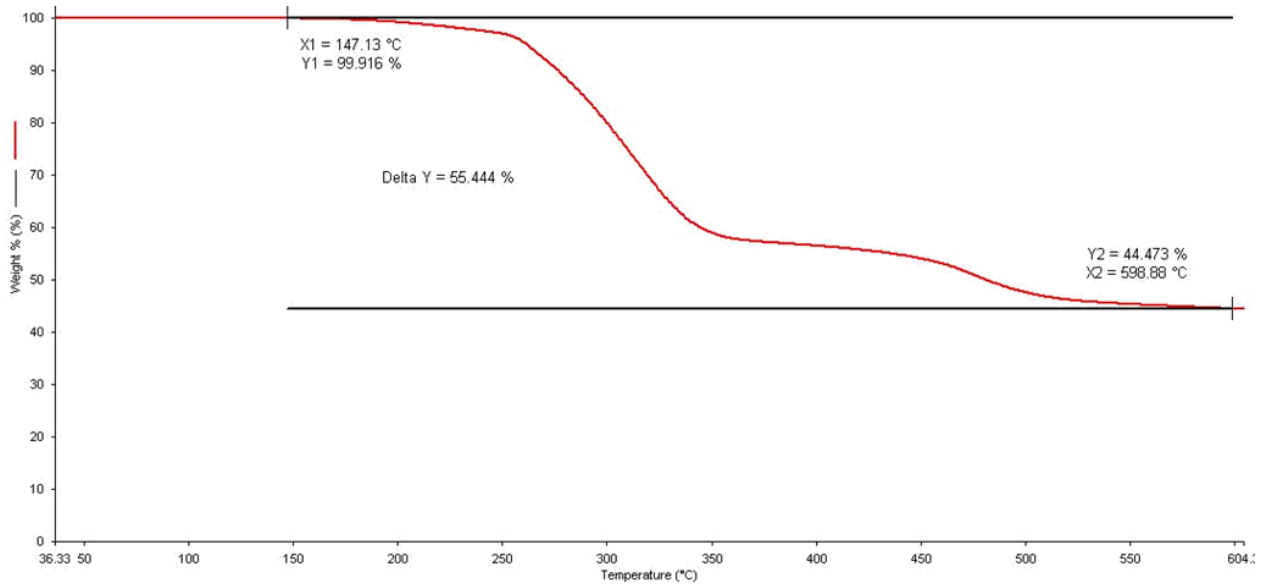

Figure5.7 Graph for experiment no.3

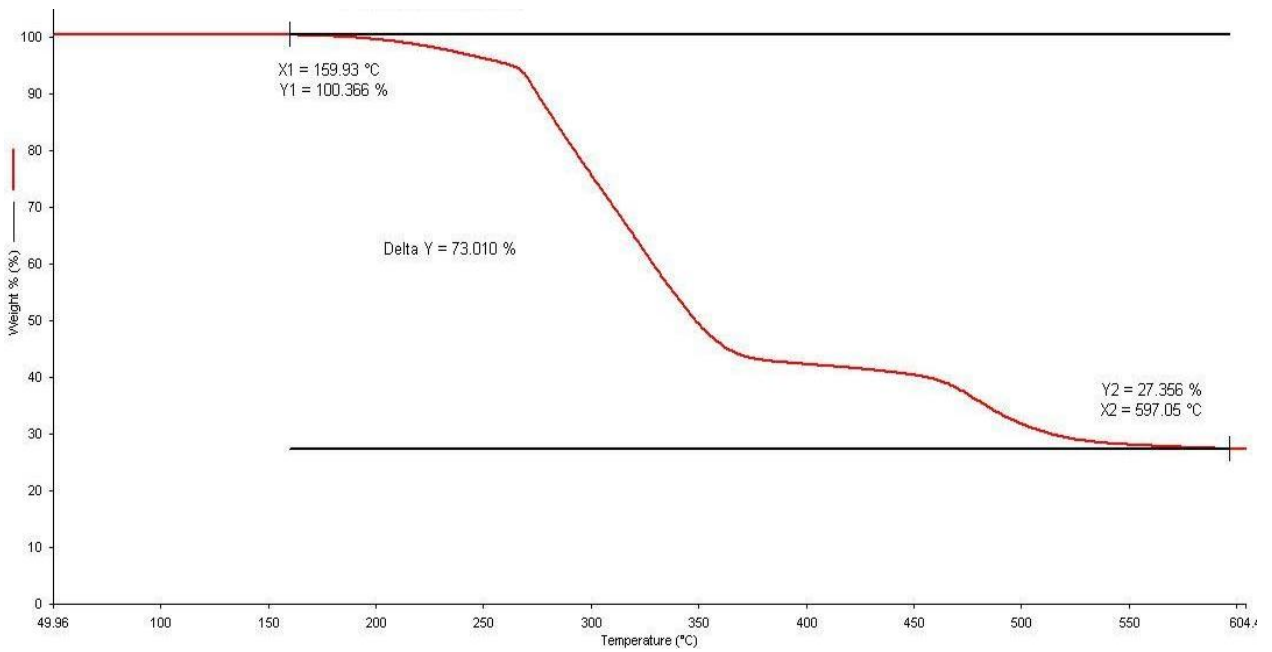**Figure5.8 Graph for experiment no.4**

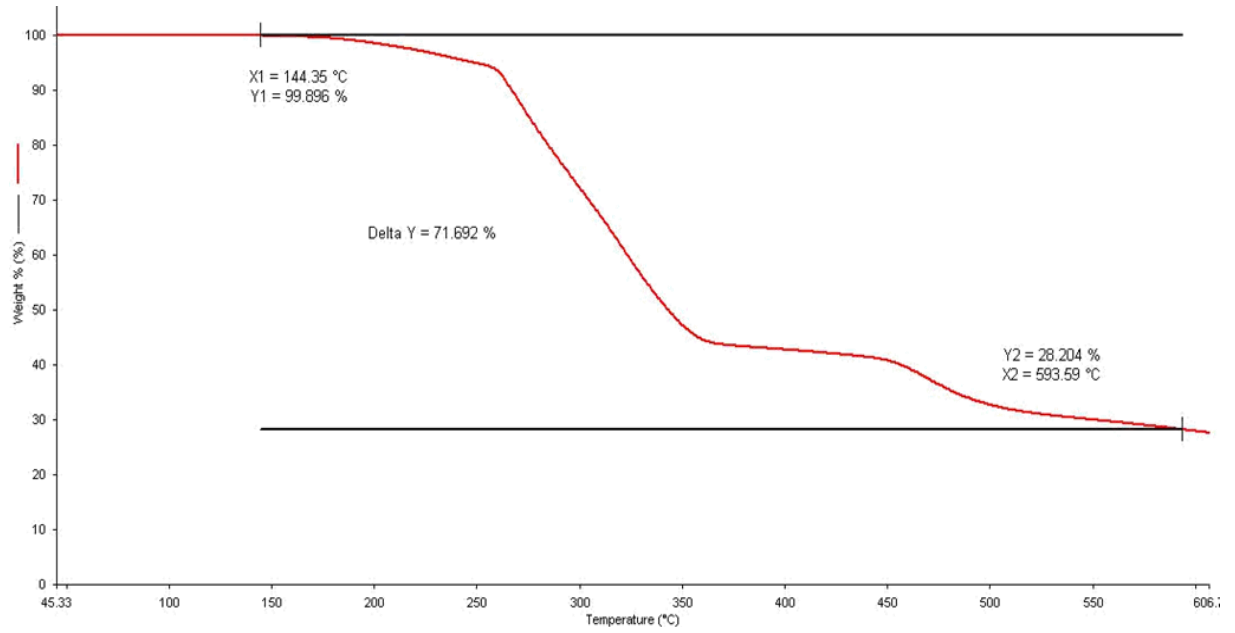**Figure5.9 Graph for experiment no.5**

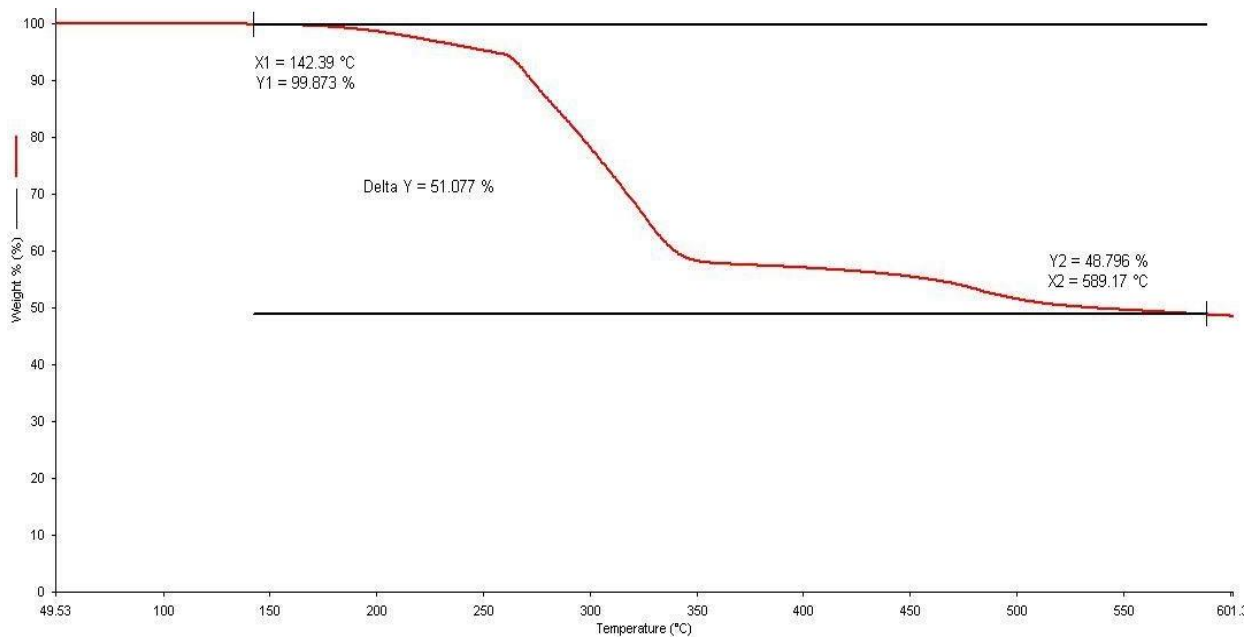**Figure5.10 Graph for experiment no.6**

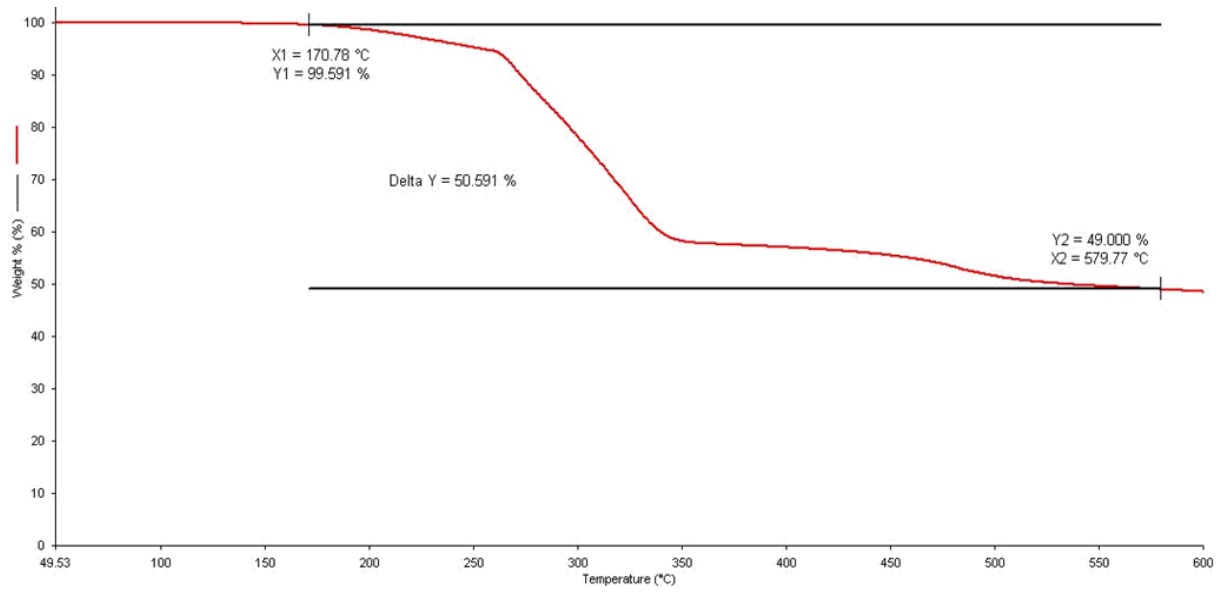**Figure5.11 Graph for experiment no.7**

Figure5.12 Graph for experiment no.8

CONCLUSION AND SCOPE OF FUTURE WORK

6.1 CONCLUSION

The present work has been carried out to study the effect of input parameters on the some mechanical properties (i.e. Tensile strength, hardness and thermal stability) of vegetable oil and PVC composite. These parameters (Peanut oil and Corn oil)are varied at two levels as higher level and lower level. The following conclusions have beendrawn from the study

1. Change in composition of vegetable oil varies the properties of the composite in considerable manner.

2. Tensile strength remains unchanged.

3. Hardness increases by 18%.

4. Thermal stability increases by 25-28%.

5. Reinforcement of vegetable oil increases the hardness and thermalstability of composite up to certain values.

6. Overall, the mechanical properties of PVC product obtain were affected positively and better PVC composites were obtain upto certain values and then decrease further.

SCOPE FOR FURTHER WORK

Further work in PVC welding could be carried out by considering the variation in parameter not considered in the present work. Further work in PVC reinforcement could be carried out by considering the variation in material not considered in the present work.

1. The work can be carried out by using different percentage of material.

2.   Instead of Peanut oil and Corn oil some other oils can be used.

3.   As the reinforced material have a strong elastic behavior, so that it can be used to produce different daily used materials.

4.   A good way to recycle plastic material to keep environment clean.

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Study of Mechanical Behavior of Vegetable Oil based PVC Composites

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Abstract

The cause of this look at is to study the mechanical behaviour of vegetable oil & Poly Vinyl Chloride (PVC) composite, to broaden more solid and flexible PVC. Vegetable oils can be without problems used with PVC due to their availability, biodegradability, low cost, low toxicity& environmental characteristics. Here Epoxidised Vegetable Oils (EVOs) are used at the region of phthalates in PVC to make it non-poisonous.

Keywords: PVC; Epoxidised Vegetable Oils, Reinforcement

I. INTRODUCTION

Poly Vinyl Chloride is one of the maximum the use of thermoplastic fabric after Polypropylene & Polyethylene. It is made by means of polymerization of Vinyl chloride monomer (VCM) or Chloroethene. It is known for its numerous houses which includes durability, high thermal & oxidation resistance, high ignition temperature and many others. PVC turned into being significantly used with the intake of 45.3 million metric lots in 2017. [1]
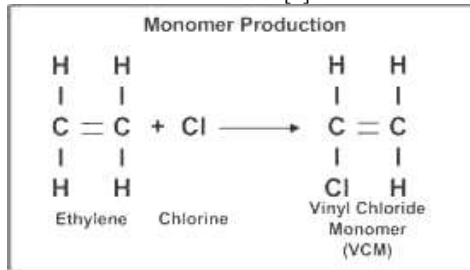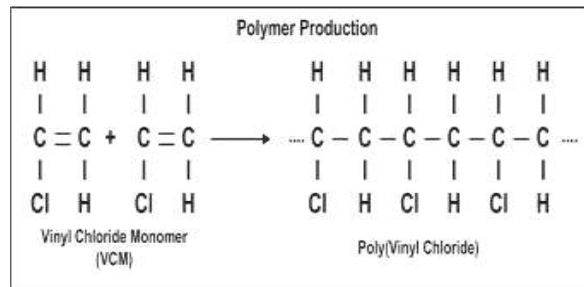

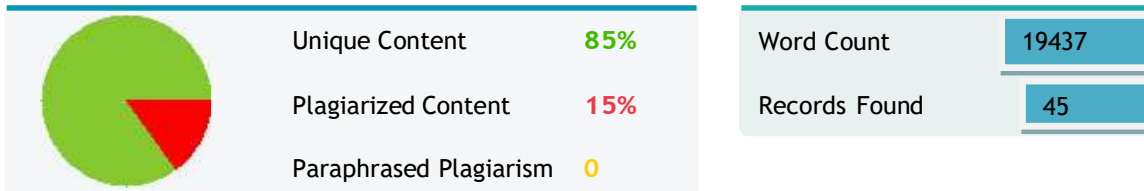Fig. 01: Formation of VCM

Fig. 02: Formation of PVC

PVC is subjected to a one-of-a-kind conflation of bodily and mechanical houses which makes it exclusive from other thermoplastics. After Polyethylene PVC is the second one most produced thermoplastic. [2] Poly Vinyl Chloride possesses a high value of ratio among strength & weight. It is corrosion resistance which makes it extra long lasting & usable. It is also recognised for its service existence as 60% of PVC may be used for 15-a hundred years. PVC has various packages in constructing & pipe production, transportation, packing of substances, covers, agricultural enterprise, electric powered electricity verbal exchange and so on.

INTRODUCTION

In the consideration of environmental aspects we all know that the world arrives closer to the global realization of our diminishing fossil fuel resources. As scientists and innovators begin to search for alternative sources of some of common materials in our environment, such as plastics, other important factors, such as degradability and environmental sustainability, are being considered. In order to reduce the production cost of plastic products, and to improve certain characteristics, one or more fillers are usually used as an addition to the resin matrix. Polymeric materials from renewable resources have attracted a lot of attention in recent years. The development and utilization of vegetable oils for polymeric materials are currently in the spotlight of the polymer and chemical industry, as they are the largest renewable platform due to their universal wide availability, ingrained biodegradability, low cost, and excellent environmental aspects i.e. low toxicity. The EPA supports the 'beneficial use' of waste products and defines it as "the reuse in a product that provides a functional benefit, replaces a product made from virgin raw materials, conserves natural resources and meets product specifications and industry standards. Beneficial use of waste products can contribute to a sustainable future by reducing production costs, reducing energy consumption and greenhouse gasses."

Due to reduce environmental concerns and disposal difficulties, the utilization of vegetable oils has become of great importance. Other researchers have also shown the advantageous use of treated fly ash in a wide variety of polymer matrices. Although incidental success stories are published, a systematic approach on investigating the influence of polymer properties for the various different