Mechanical and Structural Changes of PVC when Subjected to Heat

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Abstract:

Polyvinyl chloride (PVC) usage has gained a huge popularity among other polymers in industries, building sites, electrical, mechanical and household materials. The areas in which polyvinyl chloride (PVC) materials are needed, will determine the type of polyvinyl chlorides (PVCs) to be employed. This thesis work is based on the mechanical and structural changes of properties of the different polyvinyl chlorides (PVCs) when subjected to heating and load force on the heater and testometric tensile test machine in the laboratory. The results show that temperature changes have great impact on the different polyvinyl chloride (PVC) due to difference in additives. The mechanical properties like stress, strain etc. were affected. The structural appearances too were distorted when mounted on the testometric tensile testing machine by subjection of loading force.

Keywords:	Pvc, Heating, Mechanical properties, Elongation, Stress & Strain
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TABLE OF CONTENT

TABLES

FIGURES

ABBREVIATION

PVC: Polyvinyl chloride

VCM: Vinyl chloride monomer

WC: Water cut

MC: Milled cut

CNC: Computer numerical control

UPVC: Unplasticized polyvinyl chloride

CPVC: Chlorinated polyvinyl chloride

OPVC: Oriented polyvinyl chloride

PP: Polypropene

ABS: Acrylonitrile butadiene styrene

LDPE: Low density polyethylene

HDPE: High density polyethylene

PHR: Parts per hundred parts of resin

Rs: Rupees

MT: Metric tons

EDC: Ethene dichloride

CAGR: Cumulative average growth rate

PS: Polystyrene

HIPS: High impact polystyrene

PPCO: Polypropylene copolymer

FOREWORD

All praises and gratitude be to God for sparing my life up to this moment, of which without him am nowhere to be found.

Appreciation goes to Arcada University of Applied Sciences, for giving me the opportunity to complete the degree program. And also to my supervisor, Mariann Holmberg for her advice, contribution, attention and corrective criticism during the course of writing the thesis. And am also grateful to her for believing in my ideas and ability. Thanks to my examiner in person of Mirja Andersson. I also appreciate the effort of Erland Nyroth and Valeria Poliakova for guiding me through during the practical work in the Arcada laboratory. A big thanks to Anna Hokkanen of PRIMO OY, who supplied the polyvinyl chlorides (PVCs) strips for the thesis work.

My profound gratitude goes to my parents Mr. & Mrs. Durosinmi, for their constant advice and care. Both of you shall reap the fruit of your labour.

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1. INTRODUCTION

1.1 BACKGROUND

In this present world of technological advancement, the use of polyvinyl chloride (PVC) is so numerous that virtually all industrials, homes, schools, offices and factories etc. appliances are made of PVC (polyvinyl chloride) materials. The advent of polyvinyl chloride (PVC) in making of pipes has really impacted a great discovery in transporting water to homes and various places without fear of lead poisoning which is caused in lead coated pipes used in transporting drinking water. Polyvinyl chloride (PVC) is also used in cable insulation and trunk in the electrical installation of transformers. Many toys, floor tiles, boots, phone cases and some special clothing materials are all made of polyvinyl chloride (PVC) products.

In the use of polyvinyl chloride (PVC) compare to metals in water pipe, the issue of rusting is a bygone. Little amount is spent on polyvinyl chloride (PVC) during maintenance. Unlike metal which needs an anti-rust and detection leak just to make the metal free of rust and contamination.

1.2 HISTORY OF POLYVINYL CHLORIDE (PVC)

The history of polyvinyl chloride (PVC) can never be told by not mentioning the people that contributed immensely to its existence into the global market and everyday use.

In 1835, Henry Victor Regnault a French scientist was accounted for the existence of the monomer called vinyl chloride (monomer). The ability of Regnault to further polymerize the vinyl chloride was not known then. In 1872 Eugen Baumann a German chemist investigated the effect of sunlight on vinyl chloride, when it shown that a white substance was formed due to its exposure to the sun.

During research, a little significant progress was then made. Not until 1912-1916 when Fritz Klatte a German chemist discovered the foundation for the production of polyvinyl chloride (PVC). In the manufacture of vinyl chloride by the reaction of hydrogen chloride with acetylene at 180°C using metal chloride as the catalyst, the polymerization by sunlight of the vinyl chloride is also made reference to in the patent, and some of its uses are being suggested. The patent given for the manufacture of polyvinyl chloride (PVC) lapsed after some years, and the first commercial production of polyvinyl chloride (PVC) commenced in the late 1920s in the USA, with a huge expansion in the 1930s. Polyvinyl chloride (PVC) resin pilot plant production was built in Germany in the year 1931. This stands as a remarkable breakthrough in polyvinyl chloride (PVC) production, two (2) companies under the patent disclosures of Semon BF Goodrich company Reid of carbide and carbon chemicals in 1933-1934. Polyvinyl chloride (PVC) was discovered to be a flexible material that looks like rubber or leather when it was heated in a high boiling point liquid. When additives such as Plasticisers are added, it gives a processable material at an acceptable melting temperature into product that is permanently soft and flexible.

During World War II, Germany, the USA and the UK produced PVC industrially using emulsion and suspension technology. During the war, the shortage of rubber aided development and more of different kinds were produced with advent of various additives, which gives it the required function during its use.

1.3 AIMS AND OBJECTIVES

The aims and objectives of this thesis are:

1. Cutting of the polyvinyl chlorides (PVC) sheets into required dog-bone shape.

2. Determining the standard dimension to be used.

3. Choosing of the proper cutting method.

4. Preparing the dog-bones for heating in the oven.

5. Testing of the dog-bones on the testometric tensile test machine by subjecting it to different load forces.

6. Viewing of the tested dog-bones under the light in the chemistry laboratory.

2. LITERATURE REVIEW

2.1 GENERAL PROPEERTIES OF POLYVINYL CHLORIDE (PVC) AND ADDITIVES

Polyvinyl chloride (PVC) cannot be processed by itself due to its thermal stability and high viscosity. Materials called additives needs to be added in different forms inorder to be put to use without failure or collapse in the area which they are needed. Its durability must be of utmost priority during production, inorder to stand a longer lifespan during application where it is needed. Due to its low cost effectiveness, it was ranked the second largest commodity after polyethylene (PE). During the production of PVC (polyvinyl chloride), some fumes and liquid chemicals are released to the atmosphere and sewage, which is harmful to human life. The health of the people living around the factories must be of concern to the factories owners. To reduce such pollution, government must really monitor how the factories discharge the fumes and used chemicals, for it not to pose threat to human and aquatic lives. The fumes and used chemicals should be properly treated before discharge.

2.2 DIFFERENT TYPES AND QUALITIES OF POLYVINYL CHLORIDE (PVC)

There are different types and qualities of polyvinyl chloride (PVC), which are available. The qualities depend on the additives that are blended together during its manufacture and the uses to which it will be employed. The following are the mentioned types of the polyvinyl chloride:

- Unplasticized polyvinyl chloride (UPVC)
- Chlorinated polyvinyl chloride (CPVC)
- Oriented polyvinyl chloride (OPVC)

2.2.1 UNPLASTICIZED POLYVINYL CHLORIDE (UPVC)

The unplasticized polyvinyl chloride (UPVC) sheet is the commonest thermoplastic sheet used in general purpose like construction and building industry as a low maintenance material. It is also used in the area of pipe and pipefittings, building products such as window frames, bottles, food packs and flooring tiles. It is rigid and hard in nature, it has ultimate tensile stress of approximately 52MPa at 20°C and it cannot be attacked by most chemicals. Unplasticized polyvinyl chloride can be used generally at a temperature of 60°C. Its actual temperature limit depends on stress and condition of the environment in which it is subjected to.

2.2.2 CHLORINATED POLYVINYL CHLORIDE (CPVC)

It is a high performance thermoplastic gotten as a result of further chlorination of polyvinyl chloride (PVC) resin with increase in chlorine content from 56.8wt% to the range of 63-69wt%. The two (2) reasons for trying to get clean chlorinated polyvinyl chloride (CPVC) are as follows;

Firstly, chlorinated polyvinyl chloride (CPVC) has superior characteristics to polyvinyl chloride (PVC); the properties are excellent mechanical properties, flame retardant and corrosion resistance. Virtually all the chlorinated polyvinyl chloride (CPVC) products are employed for wide range applications in everyday life; example is in hot and cold water used in homes, offices, textile industries and construction sites etc. Huge economic benefit is gotten from chlorinated polyvinyl chloride (CPVC) produced in large scale.

2.2.3 ORIENTED POLYVINYL CHLORIDE (OPVC)

Oriented polyvinyl chloride (OPVC) can be manufactured by a process, that gives preferential orientation of straight long chain polyvinyl chloride (PVC) molecules. In the hoop or circumferential direction. It provides a high quality of properties in the hoop direction of the polyvinyl chloride (PVC). The ultimate tensile strength that will be doubled that of unplasticized polyvinyl chloride can be obtained for oriented polyvinyl chloride (OPVC).

2.3 DIFFERENT TYPES OF ADDITIVES AND THEIR FUNCTIONS

Additives are chemical substances that are used to polymerize, process or modify final use properties of plastics and its materials. Additives will have control or determine the mechanical properties, thermal stability, colour, clarity and electrical properties etc., of polyvinyl chloride (PVC) plastics before it can be utilized where needed.

2.4 TYPES OF ADDITIVES

1. Plasticizers
2. Stabilizers
3. Lubricants
4. Impact modifiers
5. Pigments
6. Process Aids
7. Reinforcement
8. Flame retardant
9. Fillers
10. Compatibilizers

2.5 FUNCTIONS OF ADDITIVES

2.5.1 PLASTICIZERS

Plasticisers are substances which when added to a plastic material usually polyvinyl chloride (PVC); make it to be flexible, resilient and easier to handle for usage. Examples of plasticizers are phthalates and adipates, which widen the gap between the molecules distance in a polymer. Polyvinyl chloride (PVC) is mostly rigid at normal temperature due to the short distances between the molecules and the intermolecular forces between them. When heated at an elevated temperature the energy of the molecular motions become greater than the intermolecular forces, and this widen the molecular distances, which result in the softening of the resin. As the plasticizer is added to the polyvinyl chloride (PVC) at the previous stage, the Plasticisers molecules passes between the polyvinyl chloride (PVC) and this prevent the polyvinyl chloride (PVC) polymer molecules from coming closer to each other. The molecules of the polymer are kept apart even at normal temperature and its softness is maintained. The above process is called plasticizing.

2.5.2 STABILIZERS

Stabilizers prevent the chain reaction of decomposition of polyvinyl chloride (PVC). It also helps in resisting weathering, heat ageing, sunlight and have an essential influence on the physical properties of polyvinyl chloride (PVC) materials when heated above 80°C. When polyvinyl chloride (PVC) is subjected to heat within the range of 170-180°C, chlorine and hydrogen molecules are eliminated and hydrogen chloride are released and decomposed. Unstable structures are noticed in the molecule during the decomposition, which further prompt hydrogen chloride (HCl) elimination and decomposition. During extrusion and moulding, polyvinyl chloride (PVC) is heated inorder to be in its molten state. This is required so as to prevent elimination of hydrogen chloride due to heat and subsequent heat that is needed. Stabilizers (metal compounds) are very important inorder to avoid chain reaction of decomposition. They come in form of application blends of which its main constituents or contents are metal soaps, metal salts and organometallic compounds. The type of stabilizer’s to be used depends on some factors like; area of which the polyvinyl chloride (PVC) product is needed, regulatory body approval requirement and cost of the material.

2.5.3 LUBRICANTS

Lubricants play a vital role in the manner in which polyvinyl chloride (PVC) melts and flows during processing. Lubricants prevent damage to polyvinyl chloride (PVC) plastics and the mould during polyvinyl chloride (PVC) processing. It is always applied to the material or to the machine to allow for processing without causing any damage and improve melt flow rate of molten plastics materials. Most of the parameters like energy consumption of the equipment’s, pressure at which the materials melt in the machine, rate of productivity, dispersion of pigments and fillers of the polyvinyl chloride (PVC) forming gel etc., must be noted. All these directly play a vital role in right selection, the best combination and optimum amount of lubricants. The optimization of specific properties like mold release and surface effects behavior.

2.5.4 IMPACT MODIFIER

It enables polyvinyl chloride (PVC) materials or products to absorb shocks and resist impact without causing cracks or collapse of the materials or products when put in use in the place it is needed. It gives the material or product enough rigidity to prevent the product from creeping, warping and sagging when it is used under normal condition.

2.5.5 PIGMENTS

This is used to give colour and beauty to different plastics materials or products during production. They are tiny particles that have to be evenly mixed with the molten substance in the extruder machine to get required colour. The colours always comes in different forms and varieties, this depends on the choice of the customers. The forms are: powder pigments, pigment granulates, liquid or solid pigment in form of concentrates. The surface can also be painted or printed after molding.

2.5.6 PROCESS AIDS

It is use to improve the way polyvinyl chloride (PVC) materials can be processed by increasing the flow ability rate. Lubricant can be added, this is always internal lubricant that improve melt flow rate of the material and lowering its viscosity and heat dissipation rate.

2.5.7 REINFORCEMENT

It is used to reinforce and improve the mechanical properties of polyvinyl chloride (PVC) like materials properties; tensile strength, flexural strength and stiffness of the material.

2.5.8 FLAME RETARDANT

These additives prevent ignition or spread of flame in plastic material during fire outbreak or spark caused by electricity. Polyvinyl chloride (PVC) has basic high quality fire retarding properties because of its chlorine content, even when fire retardants are not present. This is why polyvinyl chloride (PVC) plastics materials are employed mainly at places where fire can occur. Fire safety standard must be met inorder to suit its proper use where it is needed. The flame retardant commonly employed in polyvinyl chloride (PVC) is Alumina trihydrate ($Al(OH)_3$).

2.5.9 FILLERS

Fillers are natural materials or substances that are used to improve strength, working properties, durability and lower cost of the materials in producing polyvinyl chloride (PVC). It increases overall bulk of the polyvinyl chloride (PVC) materials usually in mineral based form. It also increases thermal conductivity of the polyvinyl chloride (PVC) plastics so that they heat up and cool down quickly. Reinforced plastic is one with distinct strength properties that is greatly superior to the base resin due to the presence of high-strength fillers enclosed in the composition.

2.5.1.0 COMPATIBILIZERS

Compatibilizers enable polyvinyl chloride (PVC) compounds to be mixed with other plastics of different types or codes during recycling process without causing any impurities or contamination effects. It yield homogeneous product that does not separate into components. Good compatibilizers reduce the interfacial tension between the concentrated phase boundaries. Compatibilizers that are active react chemically with the materials they are to make compactible. The non-reactive compatibilizers make the various component materials compactible physically.

3. METHOD

This entails the materials needed, steps, process and methods of the manufacture of polyvinyl chlorides (PVC).

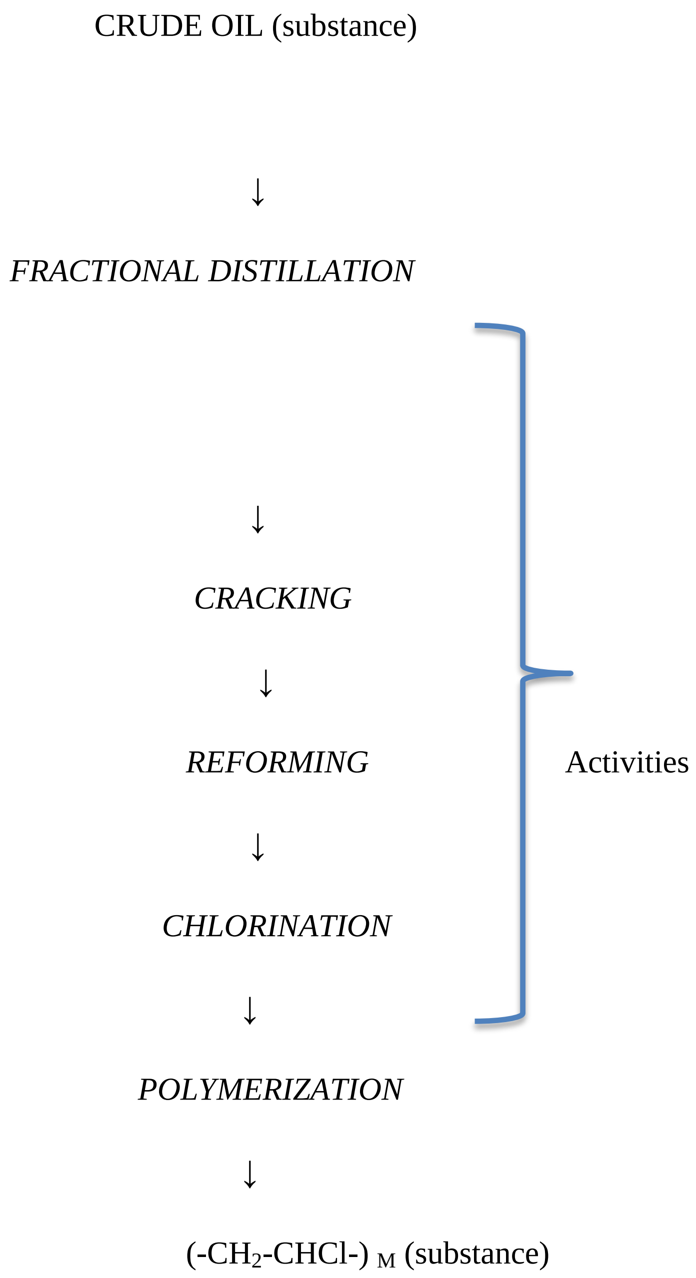
3.1 THE RAW MATERIALS OF POLYVINYL CHLORIDE (PVC)

The basic raw material of polyvinyl chloride (PVC) is chlorine with chemical formular (Cl_2), which can be gotten from electrolysis of sodium chloride (NaCl) in small or large quantities depending on the demand. Ethene is also one of the raw materials that are gotten from a product of fractional distillation of crude oil from the distillating column. Both chlorine and ethene combined together to form ethene dichloride, and it can be converted to vinyl chloride monomer (VCM) at a very high temperature.

3.2 A PETROCHEMICAL PRODUCT

Polyvinyl chloride (PVC) can be obtained from a range of hydrocarbons like coal and crude oil. The largest amount of world production of polyvinyl chloride (PVC) is gotten from the chemical compound called ethene. Ethene which chemical formular is C_2H_4, is a product of fractional distillation and reforming's of crude oil in oil and gas industry. Polyvinyl chloride (PVC) is termed a petrochemical product.

Ethene is combined with chlorine to produce an intermediate chemical substance called ethene dichloride or 1, 2- dichloroethene. Most ethene dichloride is used in the production of polyvinyl chloride (PVC) in virtually all-European countries. Small portion of the ethene dichloride is used in manufacture of organic solvents and pharmaceutical products. Ethene is among one of the five (5) products obtained from the cracking of naphtha during fractional distillation.



The stages needed to be mentioned to know how polyvinyl chloride (PVC) is gotten during the polymer production.

3.3 CRUDE OIL

Crude oil, natural gas and rock salt is a mixture of hydrocarbons that exist and are formed in the earth as a result of dead plants and animals, and it is always in liquid form when brought to the earth surface through piling of pipes of high diameters into the earth crust. All this mentioned above are the starting products for polyvinyl chloride (PVC) manufacturing.

3.4 FRACTIONAL DISTILLATION

Fractional distillation is the separation process of a mixture of crude oil and other impurities or substances into its components parts or fractions used in oil refineries. Separating different products of the treated crude oil by their boiling points by heating them to a temperature at which each component of the fractions of the crude oil vaporize. The hydrocarbons contained in the crude oil are of different boiling points. The fractions at the top of the distillation or fractionating column have lower boiling points than the one at the bottom. The crude oil fractions with higher boiling points have the following properties;

- More carbon atoms
- More branched chain alkane
- Darker in colour
- High molecular weights
- More difficult to ignite and burn
- Higher viscosity

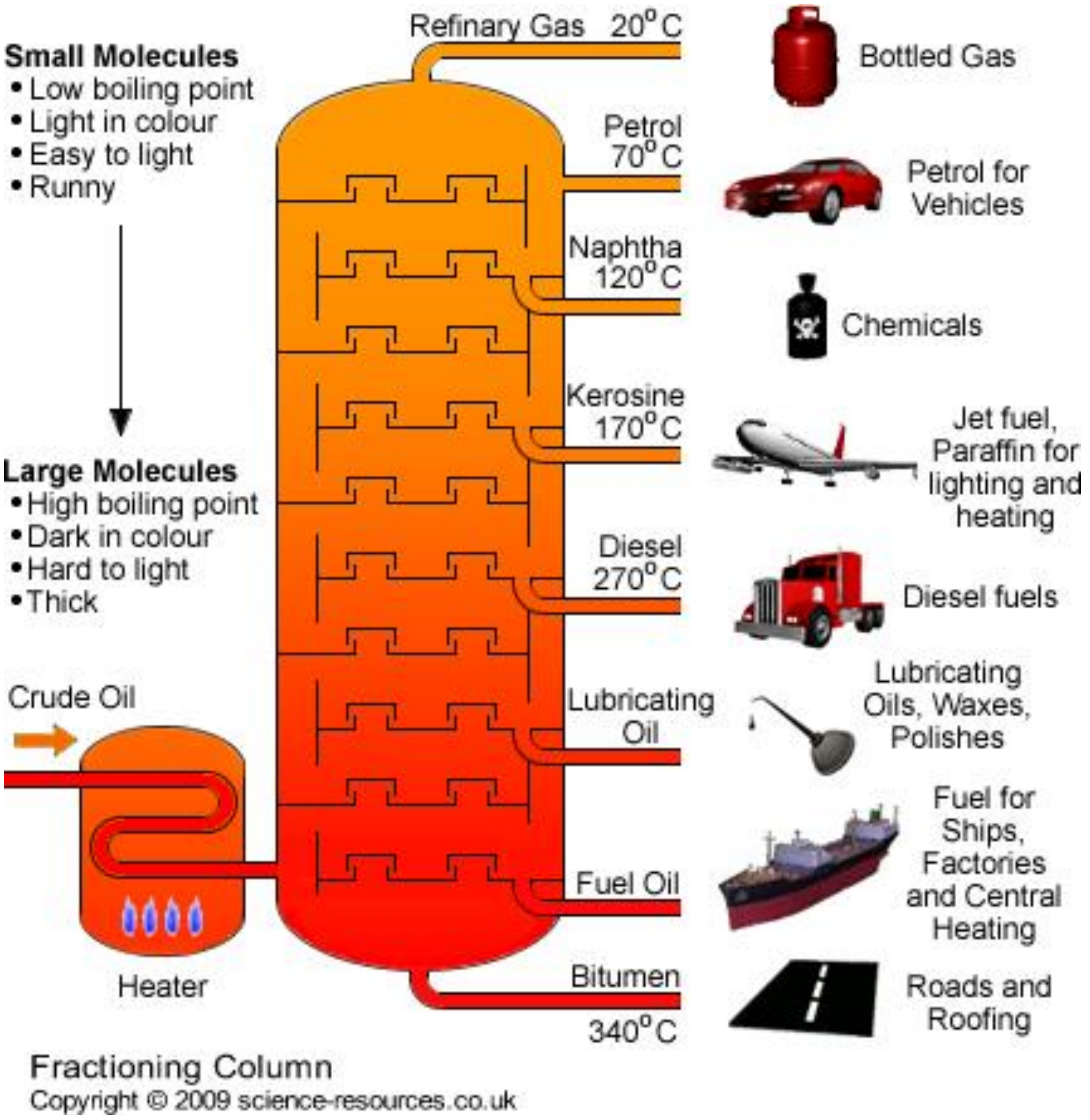


Figure 1: Fractional distillation chamber (science-resources, 2009)

3.5 CRACKING

Cracking of natural gas or naphtha gotten from fractional distillation of crude oil by high heat and temperature liquid is called thermal cracking. The heat and high temperature breaks the bonds and reduce the molecular weight of the natural gas or naphtha being cracked. Sometimes a catalyst is added to control and aid the chemical reaction during cracking with the aim of obtaining specific molecules. As the cracking continues, fractions of different molecular weight and boiling point are extracted and processed for further applications.

3.6 REFORMING

Catalytic reforming is a process employed in petroleum refinery in which small sized hydrocarbon molecules distillation product from crude oil known as naphtha's are chemically converted into molecules suitable for polymerization. The suitable molecules of reformed products that are produced from fractional distillation product called naphtha are used in industries. Reforming are categorized into two, they are as follows; Thermal and catalytic reforming.

Thermal reforming was developed in the late 1920s. Thermal reforming requires a temperature range of 510-565°C at an average pressure of 4MPa to obtain petrol's (gasoline's) with octane numbers of the range of 70-80 from heavy naphtha's of octane numbers of less than 40. The products of octane number yield high octane level included are aromatic compounds. The products is essentially unstable when stored and often form heavy polymers and gums like substance, it doesn't combust properly.

Catalytic reforming was introduced in the 1950 to improve the yield of the most needed gasoline component and minimizing the formation of unwanted heavy product and coke. As the name implies, the reforming process will employ a catalyst, which will promote the chemical reaction, but the catalyst does not react with it. In thermal reforming, naphtha stands as the feedstock and the reactions are carried out in the presence of hydrogen gas (H_2) which prevents the formation of unstable unsaturated compounds which later polymerize into higher boiling materials.

3.7 PRODUCTION OF POLYVINYL CHLORIDE (PVC) FROM VINYL CHLORIDE MONOMER (VCM)

Polyvinyl chloride (PVC) can be produced by a chemical process of taking simplest unit called monomer (vinyl chloride monomer), and linking it together to form larger or longer molecular chains called polymer, by a process called polymerization reaction. Polyvinyl chloride (PVC) is made from a material called vinyl chloride monomer (VCM). Chlorine and ethylene can be combined to form the monomer called vinyl chloride. While polyvinyl chloride (PVC) was gotten as a result of polymerization of vinyl chloride.

Vinyl chloride monomer (VCM) is a gas with molecular formular of C_2H_3Cl, molecular weight of 62.5 and boiling point of -13.9°C at a high vapour pressure at ambient temperature. Much strict and safety quality control is needed when it is manufactured.

Vinyl chloride monomer (VCM) can be manufactured from ethylene in two (2) ways; mainly through thermal cracking, they are;

- The direct chlorination method
- Oxychlorination method

3.8 CHLORINATION

The raising of chlorine content of polyvinyl chloride (PVC) polymer from 56% to around 66% is called chlorination. The process takes places initially at the methylene (CH_2) groups along the polymer chain for the resulting structure to become virtually a polymer of vinyl chloride with 1, 2-dichloroethene.

Polyvinyl chloride (PVC) chlorination will reduce the forces of attraction between the molecular chains. Chlorinated polyvinyl chloride (CPVC) is mainly amorphous in nature. The two (2) above named factors allow chlorinated polyvinyl chloride (CPVC) to be stretched more easily and to a greater length or extent than ordinary polyvinyl chloride (PVC) polymer above its glass transition temperature. The glass transition temperature of chlorinated polyvinyl chloride (CPVC) is higher than polyvinyl chloride (PVC) by 50% and also it has a higher melt viscosity during processing.

3.9 DIRECT CHLORINATION METHOD

Vinyl chloride monomer (VCM) can be produced from the chlorination of ethylene and pyrolysis of the ethylene dichloride (EDC) from the cracking unit gives vinyl chloride and hydrogen chloride is decomposed. It can be depicted with the following equation as follows; During the direct chlorination method, ethylene and chlorine gotten from electrolysis of certain salt react within a catalyst containing reactor to form the material called ethylene dichloride (EDC). Ethylene dichloride produced is thermally cracked to give vinyl chloride monomer (VCM) at a temperature above 100°C.

$CH_2=CH_2 \quad + \quad Cl_2 \quad \rightarrow \quad ClH_2C-CH_2Cl$ ……………………………………[1]

Ethylene Chlorine Ethene dichloride (EDC)

$CH_2Cl-CH_2Cl \quad \rightarrow \quad CH_2=CHCl \quad + \quad HCl$………………. [2]

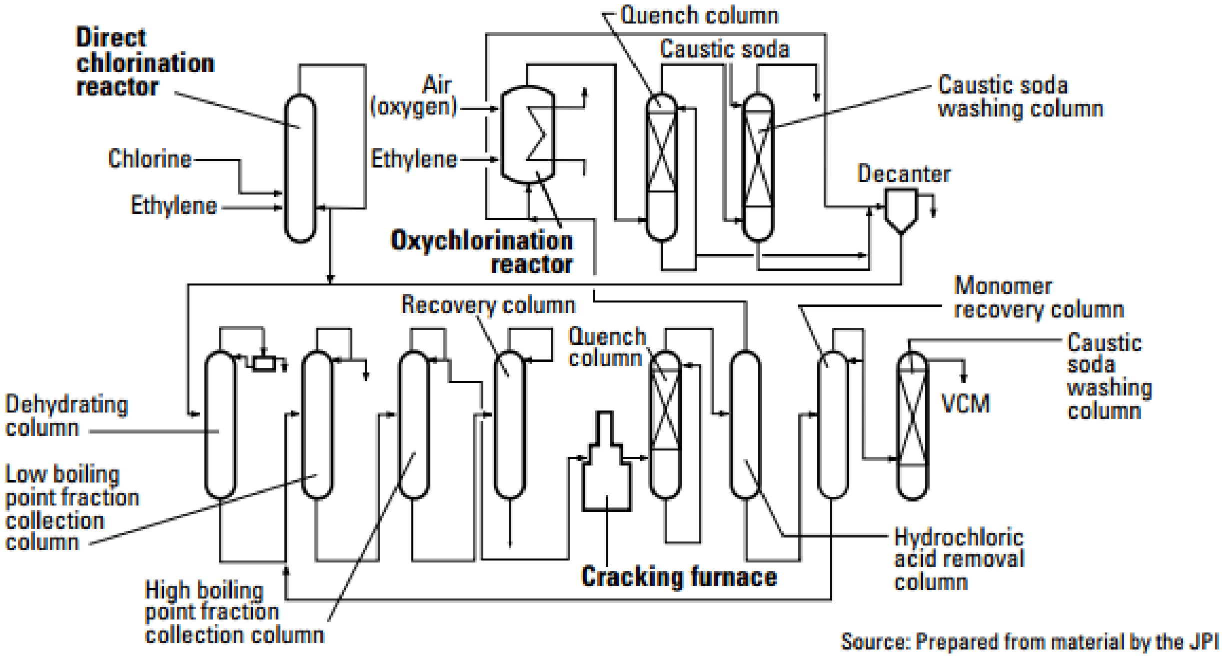
Ethene dichloride thermal decomp. Vinyl chloride hydrogen chloride

3.9.1 OXYCHLORINATION METHOD

Recycled hydrogen chloride is reacted with further ethene in the feedstock in the presence of catalyst and oxygen. This is involved to generate more quantities of ethene dichloride (EDC), and excess hydrogen is oxidized to form water. The by-product of hydrogen chloride obtained from the direct chlorination method reacts with ethene in the presence of catalyst and oxygen, ethene dichloride is obtained. This process is called Oxychlorination.

When the dehydration of ethene dichloride (EDC) from the Oxychlorination process is thermally cracked along with the ethene dichloride (EDC) from the direct chlorination, vinyl chloride monomer is obtained. These are the two (2) major methods employed in many plants in Western Europe.

$CH_2=CH_2 + 2HCl + \frac{1}{2}O_2 \quad \rightarrow \quad CH_2Cl-CH_2Cl \quad + \quad H_2O$……………………… [3]



Source: Prepared from material by the JPI

Figure 2: Thermal cracking flow diagram of vinyl chloride monomer production (Jay polytech industries n.d)

3.9.2 POLYMERIZATION

The process of connecting monomers of vinyl chloride together in a chain to form polyvinyl chloride is called polymerization reaction. The method of polymerization to be employed is called addition polymerization, which is also known as chain wise or chain growth polymerization. Addition polymerization involves the linking or joining together of molecules with double or triple bonds chemical. The unsaturated monomer called ethene has extra internal bonds, which are able to break and link and join or link with other monomers to form a repeating longer chain. Addition polymerization is always employed in the manufacture of PVC (polyvinyl chloride).

3.9.3 SUSPENSION POLYMERIZATION METHOD

This polymerization method can also be referred as bead or pearl polymerization.It can be carried out by suspending the monomer vinyl chloride (discontinuous phase) as droplets within range of 50-500μm in diameter, in the case of water(continuous phase). Vinyl chloride, styrene, acrylic, vinyl acetate and tetrafluoroethylene can be also be polymerized by the suspension method. Water with monomer weight ratio which varies from 1:1 to 4:1 in most of the polymerizations method.

The droplets of the monomer are later converted to polymer particles and are prevented from coalescing by agitation and the presence of suspension stabilizers (which are also referred to as dispersants or surfactants). The two (2) types of stabilizers often used are; (1) water-soluble (usually in the presence of electrolyte or buffer) and (2) water insoluble inorganic powders. The first (1st) type includes polyvinyl alcohol, hydroxyl propyl cellulose and sodium salt of acrylic acid-acrylate ester copolymer; The second (2nd) type includes talc, barium sulfate, kaolin, magnesium carbonate, magnesium hydroxide, aluminium hydroxide etc.The suspension levels of stabilizers are normally less than 0.1 weight % of the aqueous phase (though, the water-soluble polymers are sometimes used at higher concentrations). It is much lower than the surfactant concentration that is used in emulsion polymerization (it is as high as 1-5%), this can be accounted for in the higher monomer droplet sizes in suspension polymerization. The two (2) phase system cannot be maintained in suspension polymerization without agitation. Dispersants used in suspension polymerization rarely form colloidal micelles (molecular aggregates) compared to emulsion polymerization. In suspension polymerization, certain initiators are used which are soluble in the monomer droplets. These initiators are often referred to as oil-soluble initiators. In suspension polymerization, each monomer droplet is considered as a mini bulk polymerization system. The movement or flow of polymerization within individual droplet are the same as those for the corresponding bulk polymerization.

In the presence of high concentration which is less than 1% in suspension polymerization, the water-soluble stabilizers (usually initiated by water-soluble initiators) are normally used to produce latex-like dispersions particles with small particles size within the range of 0.5-10μm. It is sometimes referred to as dispersion polymerizations, when the monomer droplet size is 1μm or smaller.

4. CHARACTERISTICS OF POLYVINYL CHLORIDE(PVC) AS A MATERIAL

The features of polyvinyl chloride (PVC) are determined by its molecular structure and chemical composition. It has amorphous structure with polar chlorine atoms in the molecular structure. Each of the properties of polyvinyl chloride (PVC) will be listed and explained as follows:

- Versatility
- Fire retarding properties
- Durability
- Chemical resistant
- Mechanical stability
- Processability and mouldability

4.1.0 VERSATILITY

The numerous uses or applications such as building, packaging, clothing, transport, healthcare and electrical/electronics to which polyvinyl chloride (PVC) is employed has made it to be well recognized. Its ability to last longer for construction purpose in various materials either in rigid or flexible form with different available colors and sizes, made it to gain popularity in man daily needs. It is compatible with barely all additives making it to be a versatile polymer. Plasticizers can be added to polyvinyl chloride (PVC) to make it flexible in the manufacture of flooring tiles and medical products. Its inherent flame retardation made it to have edge over rubber in cable insulation. Due to its durability in making telecommunication cables without cracking or harden over time; cable insulation can be recycled through Recovinyl. Its great impact strength makes it suitable for use in construction.

4.1.1 FIRE RETARDING PROPERTIES

Due to its chlorine content, polyvinyl chloride (PVC) has high fire retarding properties even when fire retardant is not added during its production. It has less fire incident risk due to its high ignition temperature of 455°C, making it not to ignite easily when exposed to low temperature. This feature makes it to have edge over other polymers during fire outbreak because the temperature needed to ignite materials like polypropylene (PP), polystyrene (PS) etc., cannot ignite polyvinyl chloride (PVC). The heat released during the burning of other polymer cannot affect polyvinyl chloride (PVC) material.

The maximum energy in form of heat that can be released by polyvinyl chloride (PVC) is 91KW/m^2. That is the reason why polyvinyl chloride (PVC) is employed in everyday use in different facet of life.

4.1.2 DURABILITY

Polyvinyl chloride can last up to 100 years and above depending on its usage. Due to its relative low weight, polyvinyl chloride is strong and durable. This feature makes it a better choice for long time use in different facet of life like; sewage, domestic water pipes and underground deep-water piping systems. When maintained properly it last longer within some high temperature, it rarely ruptures when the proper maintenance is applied.

4.1.3 CHEMICALS RESISTANT

Polyvinyl chloride (PVC) is resistant to alkali, acid and virtually all inorganic chemicals that exist in nature. Polyvinyl chloride (PVC) got swollen or dissolves in aromatic hydrocarbon, ketones and cyclic ethers. In some organic solvents, polyvinyl chloride (PVC) is difficult to dissolve. These characteristics make it to be employed in exhaust gas ducts, sheets used in construction work, tubes, hoses and bottles.

Thermoplastics and some elastomer have excellent resistance to a lot range of chemical reagents. The chemical resistance of polyvinyl chloride (PVC) is mainly a function of the thermoplastic material and its compounding components. When less compounding components is used, the better the chemical resistance. Thermoplastic materials and pipes with important filler percentages may be prone to chemical attack in the area where there is uneven filler flow.

Chemicals that do not usually affect the properties of an unstressed thermoplastics can cause a completely different changes or behavior (such as stress cracking) when subjected to thermal or mechanical stress (constant internal pressure or frequent thermal or mechanical stress cycles). If a material is chemically resistant to a concentrated form of a particular chemical, it must be resistant to the diluted form of the same chemical. Through many years of research, resistance of polyvinyl chloride (PVC) to attacks by different chemical agent has been determined even from field experience. There are some factors affecting or militating against chemical resistance in a polyvinyl chloride (PVC), these factors are listed as follows:

- Temperature
- Chemical present
- Concentration of chemicals
- Time of exposure
- Frequency of exposure

Chemical resistance information for polyvinyl chloride (PVC) pipes or other materials are provided in a table that is based on temporary immersion of unstressed strips of polyvinyl chloride (PVC) in different chemicals (usually concentrated). The result can be used as a guide for the response of polyvinyl chloride pipes or strips to chemicals. National Association of Corrosion Engineers released a publication entitled "corrosion data survey, Nonmetals section".

Chemical resistance are depicted in the following polyvinyl chloride (PVC) tables, of which few will be shown as follows:

Table 1: Chemical resistance response table used as a guide for polyvinyl chloride (PVC) pipes or strips to various chemicals

R	General resistant
C	Less resistant than R but still suitable for some condition
N	Not resistant

RESISTANCE TO CHEMICALS

Dilute acid (HCl)……………………………………………………………………. Very good

Dilute Alkali (NaOH) ……………………………………………………………………… Very good

Oils and greases .... Good

Aliphatic and Hydrocarbons (C_2H_6).	Very good
Aromatic Hydrocarbons (C_6H_6)	Poor
Halogenated hydrocarbon (CH_2=CHCl).	Moderate
Alcohols (CH_3OH, C_2H_5OH).	Good

4.1.4 MECHANICAL STABILITY

Chemically, polyvinyl chloride (PVC) is a stable material, which exhibits small change in molecular structure and mechanical strength. Polyvinyl chloride (PVC) is a long chain polymer and is always viscoelastic in nature. It can be distorted or deformed by constant application of external force, even if the applied force is well below their yield point. When depicting such characteristic it is called creep deformation. Polyvinyl chloride (PVC) is a viscoelastic material with a very low creep deformation compared with other plastics material due to molecular distortion or motion at ordinary or low temperature, unlike polyethylene and polypropene, with high molecular motion in their amorphous section.

Creep behavior is shown by plastic products mainly polyvinyl chloride (PVC). The continuous applications of external forces influence its deformation at room temperature. The phenomenon is termed cold flow. Cold flow is very important and worthy to be considered when polyvinyl chloride (PVC) materials are used in construction and industrial applications. This is employed under normal environmental conditions like low temperature etc. Polyvinyl chloride show very little creep compared with other plastic products. It is employed in various interior and exterior construction materials like; ducts, window frames and decks, panels and machine parts.

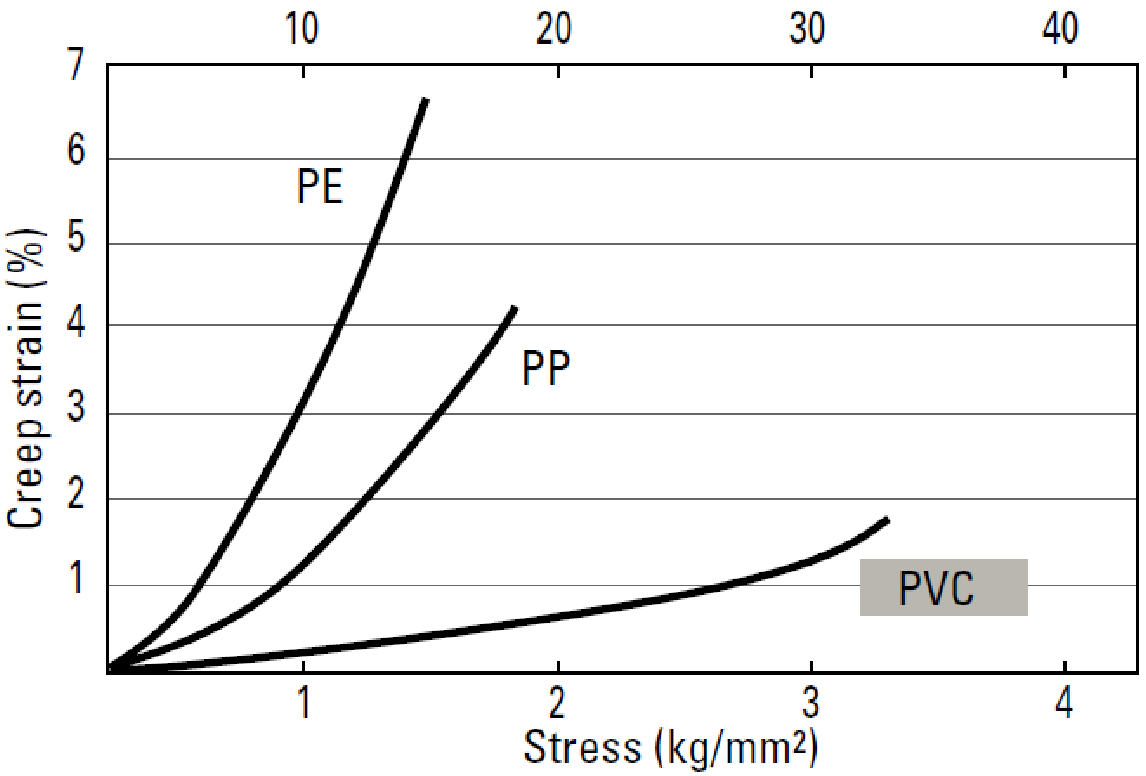


Figure 3: Creep strain (%)/stress (kg/mm) of different polymers (serviceability of PVC and PVC products, ch.5, n.d)

4.1.5 PROCESSABILITY AND MOULDABILITY

Processability of a thermoplastic material depends solely on its melt viscosity. Since its melt viscosity is very high, polyvinyl chloride (PVC) is unsuitable for injection moulding of large sized products. Furthermore, the viscoelastic behavior of molten polyvinyl chloride (PVC) is less dependent on temperature and is always stable. This characteristic makes it to be suitable for complex shaped extrusion profiling used in building or housing materials, it's also used in calendaring of films and sheets in agricultural films and polyvinyl chloride (PVC) leather.

The external surfaces of polyvinyl chloride (PVC) products are very good and posses superior embossing characteristic. This allow for a variety of surface treatment such as enamel gloss and de-lustered suede. Considering the fact that polyvinyl chloride (PVC) is an amorphous plastic with no phase transition, when the products are in moulded form it will have high dimensional accuracy. Polyvinyl chloride (PVC) also displays excellent secondary processability in welding, bending fabrication, vacuum forming etc. Some processing techniques that can be employed in polyvinyl chloride (PVC) are; screen printing and coating which are convenient processing techniques suitable for polyvinyl chloride (PVC) only. The processing methods can be employed in the area of automobile sealants, flooring, wall covering etc.

5. RECYCLING METHODS AND BENEFITS

5.1 RECYCLABILITY

The world resources is infinite in size, as the population of human increase day by day there is more demand and crave for products consumption, so also more waste products are generated, which littered our landfills. The method of recycling helps bring back the waste product into useful usable products for human consumption, and it helps to reduce more waste from our landfills. Plastics constitute one of the products that are recycled often not only by consumers, but with other big plastics companies and businesses on a larger scales. With a lot of campaign for green products and for firms to be environmentally friendly, plastics recycling have gain popularity in the society as a whole, thereby making it becoming a big and profitable business. Recycling has also reduced carbon dioxide emission and oil usage.

During plastics manufacturing, waste materials was not only produced, gases like carbon monoxide, nitrogen oxide, chlorine dioxide and sulphur hexafluoride, all these gases are evaporated and deposited in the atmosphere and water around us. The idea of recycling reduces the emission of those gases mentioned above, and giving less pollution and cleaner and safe planet.

Polyvinyl chloride (PVC) materials can be recycled in two (2) different forms.

Polyvinyl chloride (PVC) belongs to the number 3 ♵ in the plastic code. The recycling methods are as follows:

1. Mechanical recycling

2. Chemical recycling

5.1.1 MECHANICAL RECYCLING

Mechanical recycling of plastics mainly polyvinyl chloride (PVC), is the reuse of used plastic materials through re-melting which is a large part of an integrated means to manage waste along with feedstock (chemical) recycling and energy recovery. During the year 1996, 8.6% of post consumer waste i.e. where the waste producing use did not involve further production of another product. Nearly 100% of production scrap was reused for recycling in Western Europe. The increment was potentially estimated to be at a rate of 10.7% of post consumer plastics by the means of mechanical recycling in the year 2006, which is equal to 2700kT (kilotons) of recyclates. Type of the recycling method used depends on the material constantly renewed or steadily supplied for recycling. Examples are single, mixed and contaminated form of used plastics. The material source are; household products, industry, about the cost of sourcing, separation and cleansing. Concerning the market (need, standards, recognition and sorting, price of virgin or fresh material); concerning energy and ecological considerations (eco-balance); on legislative rewards or incentives, e.g. packaging order in Western Europe, Germany to be precised (Plastics additives handbook by Hans Zweifel, 5th edition pg.973). Polyvinyl chloride (PVC) always disturbs other plastic during recycling than other plastics disturb polyvinyl chloride (PVC). The formation of dioxin during recycling thermal waste treatment make it dangerous for workers and people around polyvinyl chloride (PVC) plant.

Close to 7.1 million tonnes of polyvinyl chloride (PVC) are used to make products in EU every year. Compounded polyvinyl chloride (PVC) that serves as waste in the disposable channels in EU is amounted to be around 4.1 million tonnes every year. The difference in figure is due to the lifespan of the polyvinyl chloride (PVC) used daily without ending up in the waste stream. It was predicted that the amount would be 7.2 million tonnes by year 2020, which will be 80% more than the present day.

5.1.2 CHEMICAL RECYCLING

Soft polyvinyl chloride (PVC) is the waste plastic material, which is the center of focus right now. And it is a representative of addition polymerization material. In chemical recycling of soft polyvinyl chloride (PVC), a pretreatment method that will separate the plasticizers and pulverized (powdery form) feed material in an insufficient aqueous material. The trend enabled the design of the technology that allow for the extraction of the plasticizer without damaging the polyvinyl chloride (PVC) structure that took time to process in the soft form. The method has made the recycling of the soft polyvinyl chloride possible. Two (2) stages processing method has been achieved in separating chlorine after the plasticizer are removed.

Figure 4: Supercritical reactor for plastic waste (Nikkiso co, ltd, 2000)

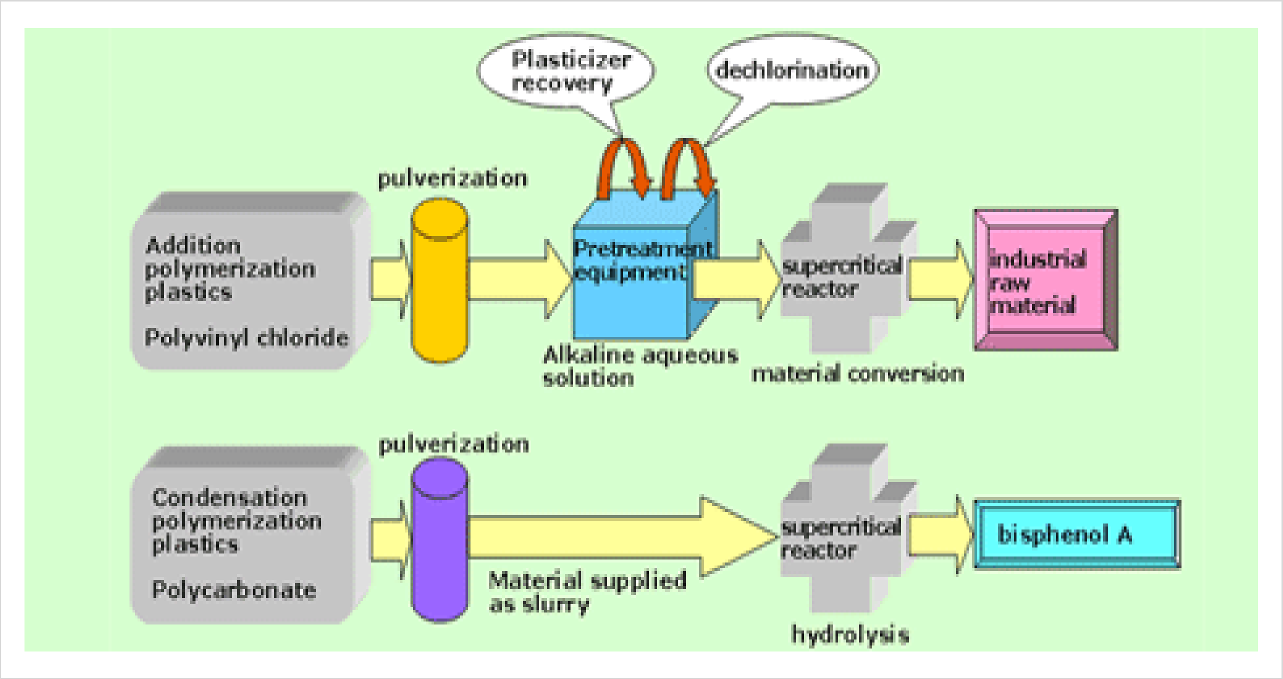


Figure 5: Conversion technology for plastic (Nikkiso co, ltd, 2000)

Conversion technology for plastic.

5.2 ECO-EFFICIENCY

Eco-efficiency is a vital tool employed by organizations to be aware of their environments and profitable in their dealings of producing polyvinyl chloride (PVC) and other polymers products. Eco-efficiency aids in producing large product from little raw materials available, thereby avoiding waste of natural resources and reduce emissions of poisonous gases or fumes that causes damage to the environment. Many industries has adopted the program working towards the above mentioned topic, which is the replacement of traditional procedure of dying textiles and releasing the remnant chemicals to the rivers and drainages that causes pollution, this has been replaced with co-efficient coating agents and lamination done by hi-tech programmable machines. Eco-efficiency also maximizes efficiency and minimizes the negative impact on the environment. It reflects or shows the relationship between the economic output and environmental impact caused by products produced for consumption.

5.3 PUBLIC SAFETY

Polyvinyl chloride (PVC) plants are mostly built in a downtrodden and low-income community where people welfare and health are not cared about. This brings about the issue of violation of human right to good health. The issue of polyvinyl chloride (PVC) manufacturing has led to the poisoning of workers and neighbors living near the plants, and it contributed to the pollution of water and air around the vicinity. Sometimes, aquatic lives and human beings are completely wiped out due to inhale gases that causes suffocation and cancer.

Every year in USA to be precised, about 230 tons of vinyl chloride is released to the atmosphere that contain carcinogens and other toxic materials, which caused lungs cancer and other terminal diseases that claims thousands of lives.

6. PLASTICS CONSUMPTION IN THE WORLD

6.1 VOLUME USED OF POLYVINYL CHLORIDE (PVC) IN THE WORLD.

The total volume of polyvinyl chloride that has been consumed by man since its inception into polymer markets can never be accounted for, but its consumption in different countries of the World presently can be gotten through statistical records.

Polyvinyl chloride (PVC) has been in existence before 1960s. It was in 1960 that advances were made for polyvinyl chloride (PVC) pipes and fittings. Before then, unplasticized polyvinyl chloride was being in use. Polyvinyl chloride (PVC) consumption in 2007 in the USA and Canada amounted to over 6.4 million metric tons, which is about 14.2 billion pounds.

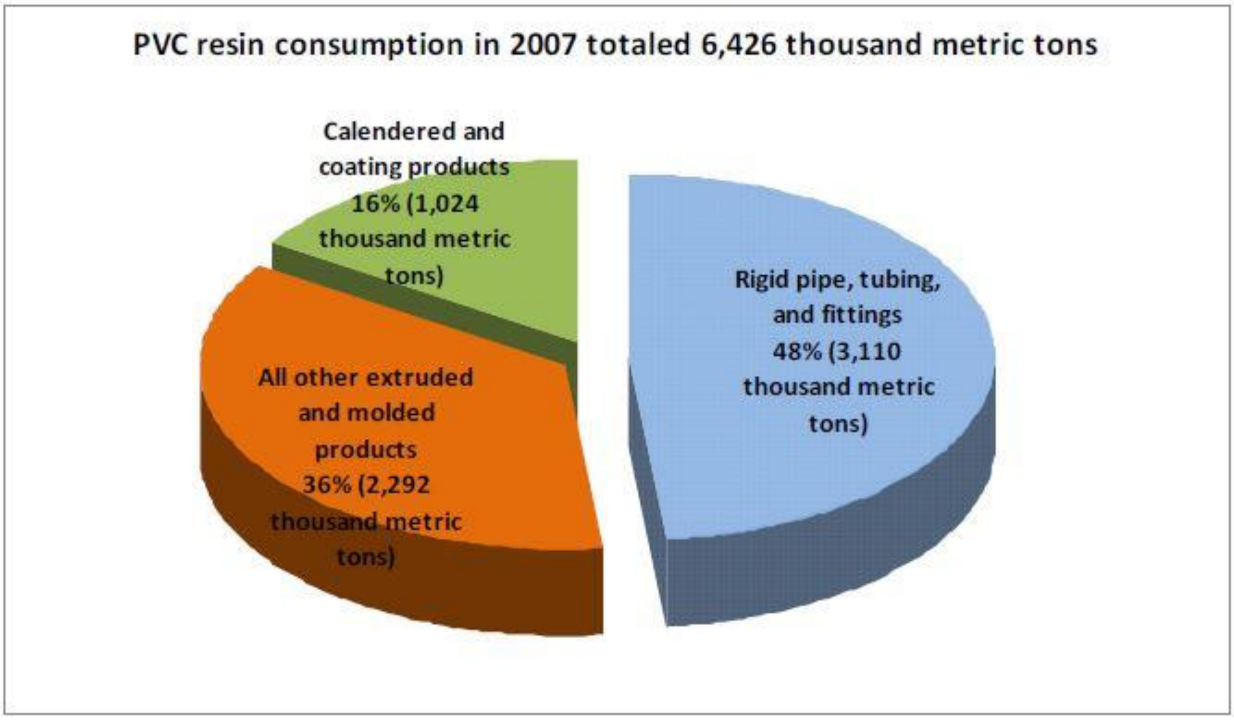


Figure 6: Polyvinyl chloride (PVC) resin consumption in United States and Canada in the year 2007 (Whitfield and Associates based on American chemistry councils monthly statistical Report (PIPS), n.d)

6.2 PRODUCTION AND CONSUMPTION RATE OF POLYVINYL CHLORIDE (PVC) IN CHINA

Polyvinyl chloride (PVC) is the number three (3) most widely produced plastic in the world, followed by polyethene and polypropene. China is ranked the world leading production and consumption of polyvinyl chloride (PVC) in the comity of nations. China production capacity of polyvinyl chloride (PVC) in year 2009 was 9.155 million metric tons (MT), which account for 27% of global production, and the consumption rate stands at 10.62 metric tons (MT), which account for 30% of global consumption. For the past decades (20 years) both consumption and production have increased rapidly. The cumulative average growth rate (CAGR) of production has grown to 14.4%; this growth does not keep pace with the growth in production capacity, which has grown at a rate of nearly 20%. North China is distinctly the largest polyvinyl chloride (PVC) production base in the country, amounting to 42% of total production in 2009.

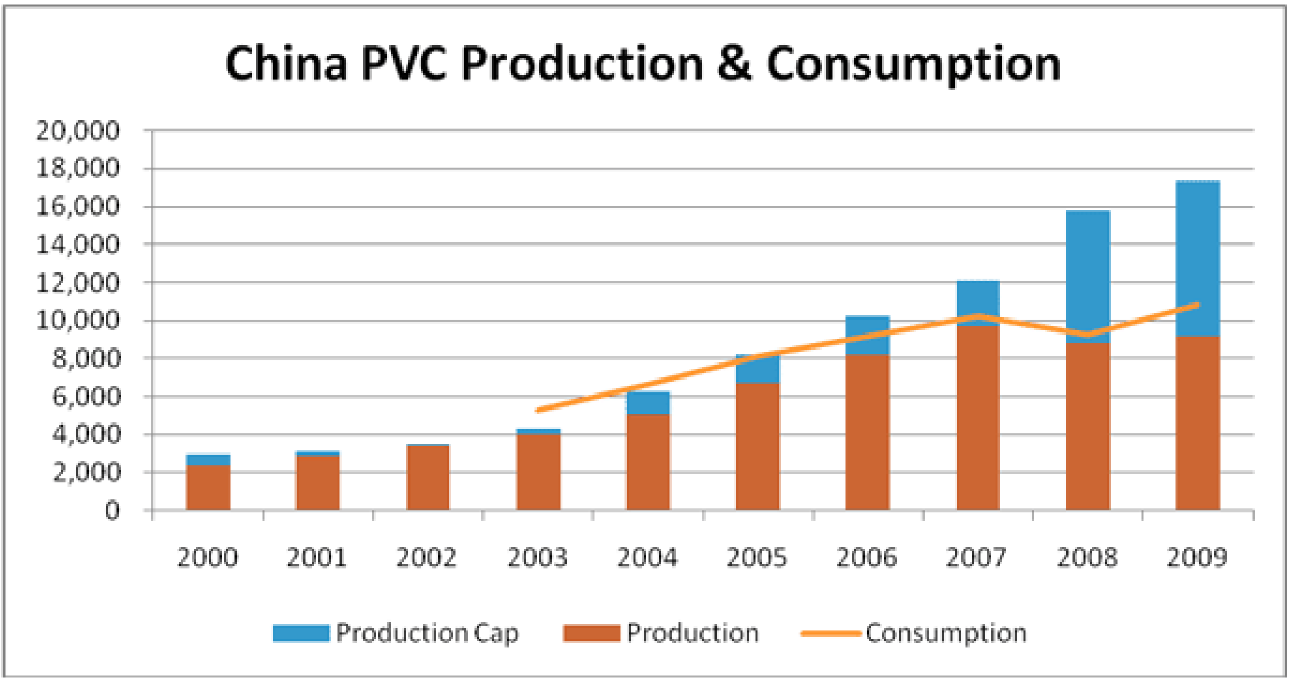


Figure 7: Production cap, production and consumption of PVC in China in thousandth metric tons (Dallan Commodity Exchange, 2011)

Consumption rate has grown rapidly by almost 11% every year from 2003 to 2009 according to the graph shown above in the diagram. Production was generally unable to keep up with demand, due to this event; China relied on imports to satisfy the consumers demand. Most of the domestic polyvinyl chloride (PVC) consumption was used in the production of cable and wire shields, flooring tiles, waterproof membranes, artificial leathers, hoses, window materials, bottles etc. The main consumption areas are in the eastern and southern part of China, though the production area is concentrated in the northern part of the country. The listed provinces together accounted for the 49% of the domestic consumption, the provinces are; Guangdong, Shanghai, Zhejiang and Jiangsu.

6.3 IMPORTS AND EXPORTS CAPACITY OF POLYVINYL CHLORIDE (PVC) IN CHINA

The trend of rapid development of China polyvinyl chloride (PVC) industry, imports and exports of polyvinyl chloride (PVC) has gone through tremendous changes in the last decade. Before the year 2004, China was an importer of polyvinyl chloride (PVC), in 2003 alone it consumed close to six million tons of polyvinyl chloride (PVC), of which 2.3million metric tons (MT) were imported. In spite of that, the anti dumping policy which was implemented against the United states, Russia, Korea, Taiwan, and Japan. This paved way for China domestic polyvinyl chloride (PVC) growth, allowing for greater self-sufficiency and less reliance on imports. The import rate decline in 2008 to 1.13metric tons (MT), the trend amounted to a reversal in high increment in 2009 with almost 74% increase in imports to 195.5metric tons (MT), which create a new record, exports dropped drastically to over half to 275000 tons.

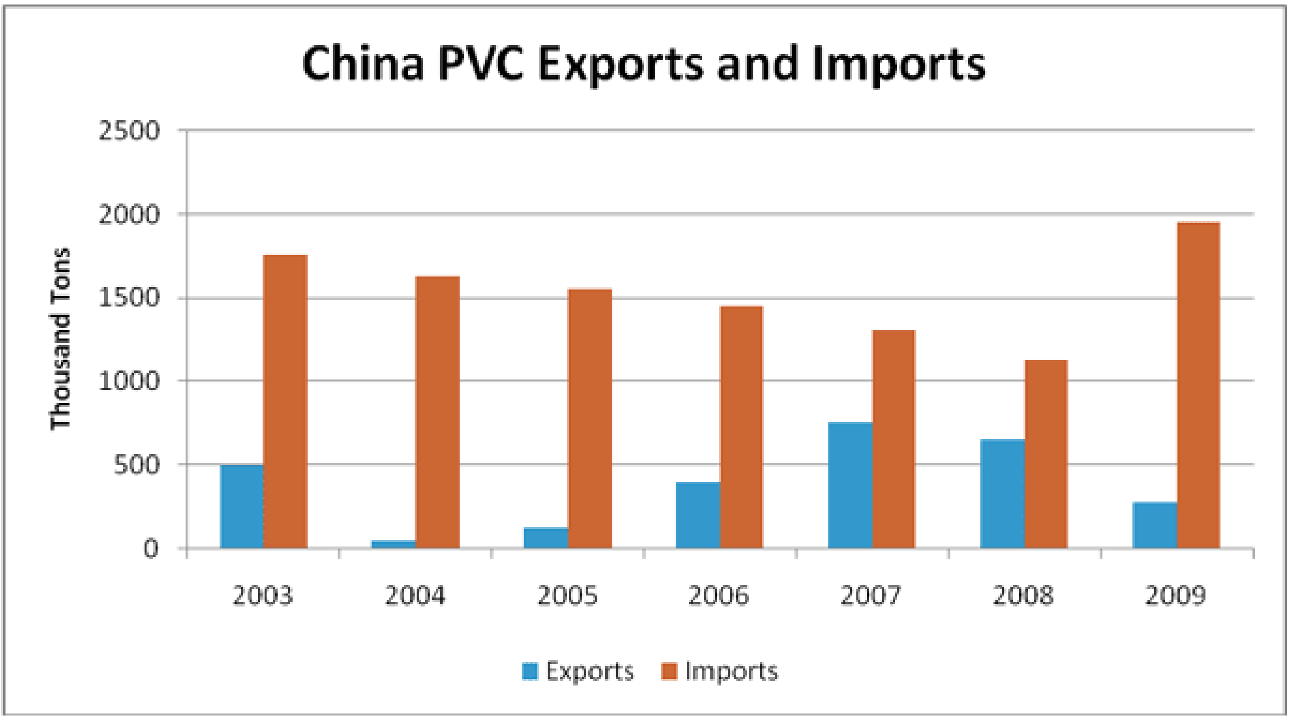


Figure 8: Import and Export capacity of PVC in thousand tons per year in China (Dallan Commodity Exchange, 2011)

In the year 2012, the world total production of polyvinyl chloride (PVC) was amounted to be 54 million tons (source: HIS). This created an increase of 9million tons since 2009. Most of the capacity increments are recorded from China, which is the highest producer and has 44% of the world's capacity production. World current capacity of 24 million tons by far exceeds the Chinese domestic demand of 14million tons, increasing cost of energy and raw materials in recent years. Coal based carbide has been an alternative used for energy generation for producing polyvinyl chloride (PVC) precursor vinyl chloride monomer (VCM) are dominated in China is less competitive. It has no environmental effect on humans and animals, it also reduce manufacturing cost, which is below the naphtha/ethylene route, which are implemented in Europe.

North America has 15% of the world’s polyvinyl chloride (PVC) capacity; plant use capacity has almost reached the period before level crisis. This was as a result of less in improved regional demand for polyvinyl chloride (PVC), the export volume increased instead. More than one-third of North American polyvinyl chloride (PVC) production was exported. The year 2007/2008 marked the year which export accounted for less than 10%. The initial reason for the change cum development can be inferred from the cost benefit along the value added production chain for polyvinyl chloride (PVC) resulting from the shale gas boom. The way the shale gas was being exploited led to discussion of re-industrialization of the USA and calls for the expansion of the domestic petrochemical industry. With reference to the aforementioned event, some expansion in polyvinyl chloride (PVC) is being planned for after the year 2014.

The exploitation of the shale gas reserves in USA lower the cost of ethylene from cracking of ethane and cost benefit was realized on gas based electricity. It also lower the production cost of chlorine as polyvinyl chloride (PVC) precursor by means of chlor-alkali electrolysis, Europe account for 15% of the world polyvinyl chloride (PVC) capacity.

6.4 CONSUMPTION AND EXPORT

The total number of polyvinyl chloride (PVC) consumed in 2012 amounted to 37.4 million tons. Polyvinyl chloride (PVC) is the third largest plastics materials that are consumed worldwide after polyolefin. The average annual market growth of 4.9% was recorded largely in China during the period of 2009 to 2012, China account for the largest single market with 14 million tons; it grew by 3.7 million tons from 2009 to 2012. China import rate was still at 1million tons every year in order to meet up with demand from the consumers. The demand for polyvinyl chloride (PVC) worldwide, rest solely on construction activities. Its application can be felt mostly in pipes and fittings comprise 42%, profiles and hose/tubing comprises 18%, rigid film and sheet comprise 17%, as well as cable which comprise 8%.

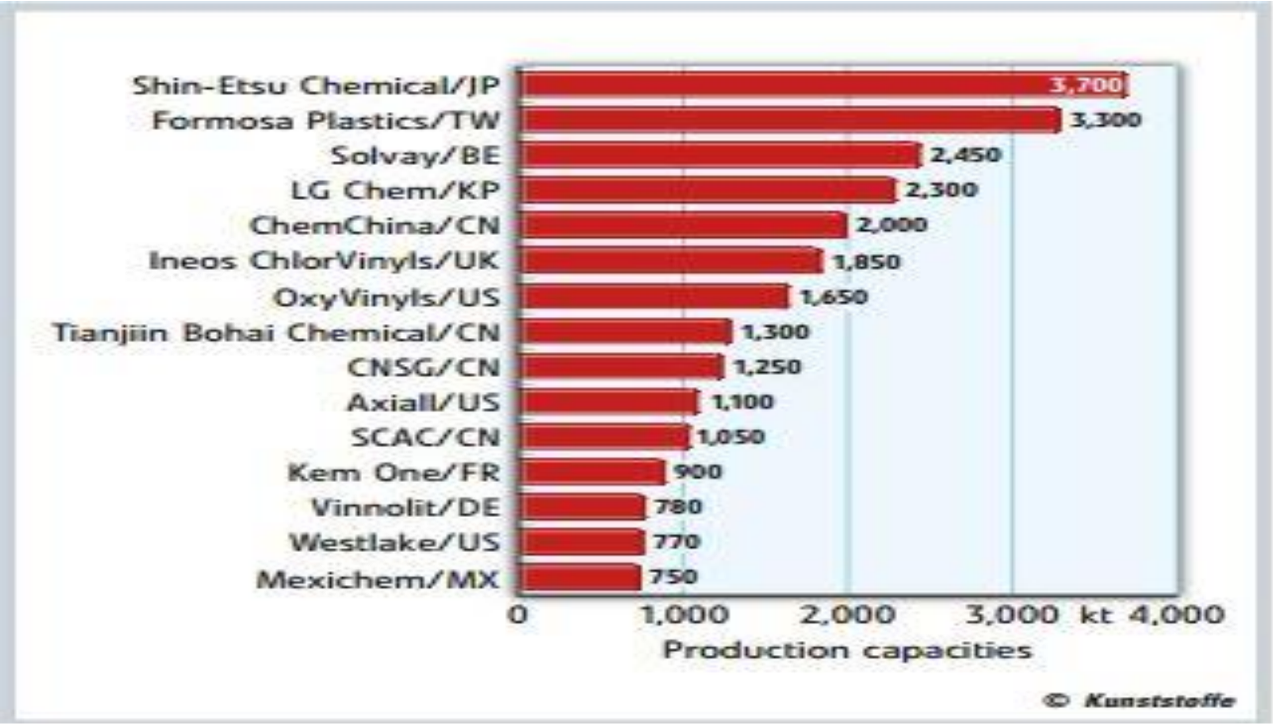


Figure 9: Production capacities of the world's largest producers (Vinnolit 6/2013)

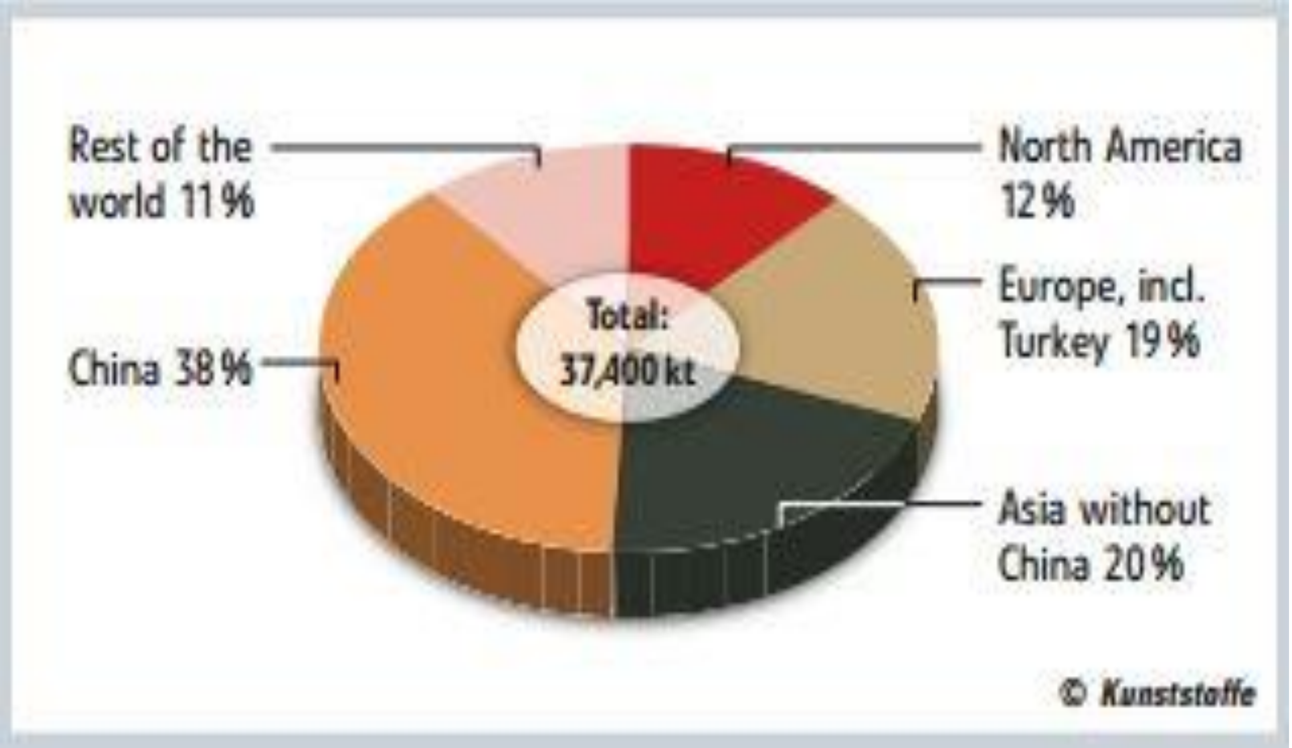


Figure 10: Worldwide PVC consumption in 2012,broken down by region, overall 37.4 million tons (IHS incorp.2014)

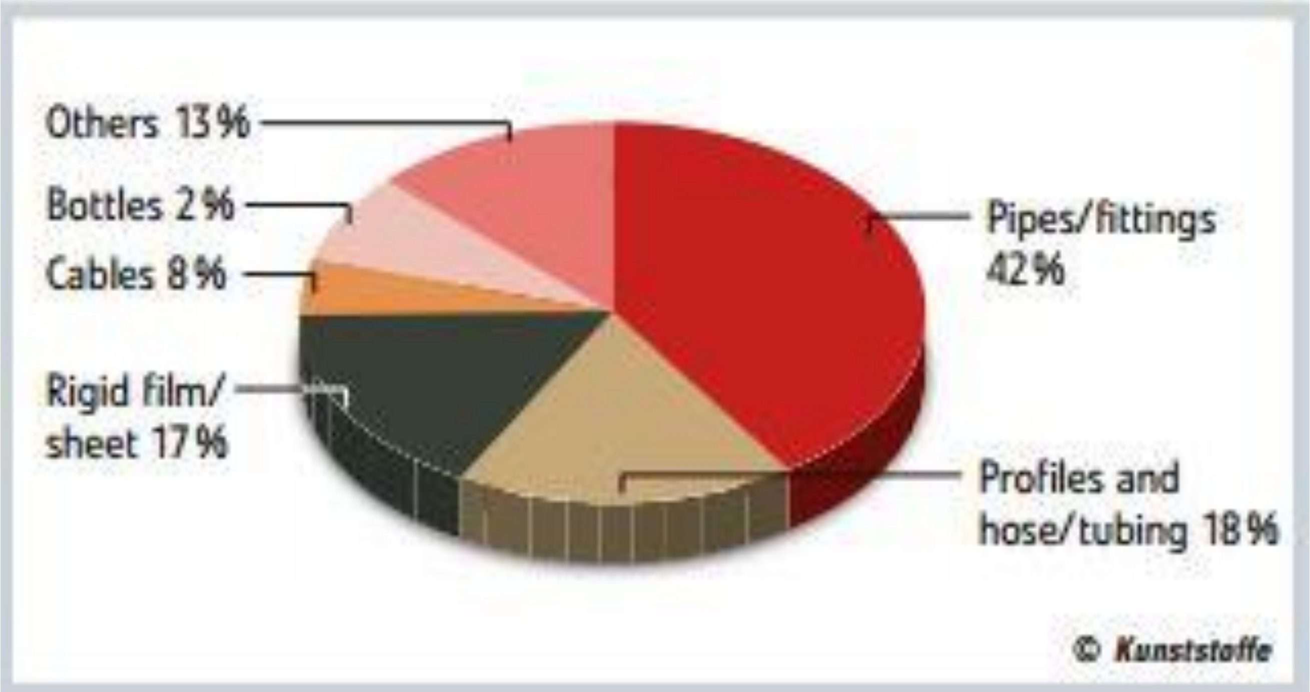


Figure 11: Polyvinyl chloride (PVC) applications around the world in 2012 (ihs incorp.2014)

6.5 COST

The volume cost of raw material of polyvinyl chloride (PVC) polymer input is the purchase cost of a unit volume of the material. Polymer cannot exist without additives, which are why it’s very important to understand the volume cost of polymers and its additives; it determines a particular selection or application to which the polymers are employed.

6.6 DEVELOPMENT OF VOLUME COST PRICE PER KILOGRAME (ton)

In determining the volume cost price per kilogram of raw material input of polyvinyl chloride, the purchase cost of a unit volume of the material must be known. The volume cost of polymers and its additives is very essential when choosing it in some particular application.

Volume Cost (Rs/Litre)=Purchase Cost (Rs/Kg) x Density (Kg/Litre)

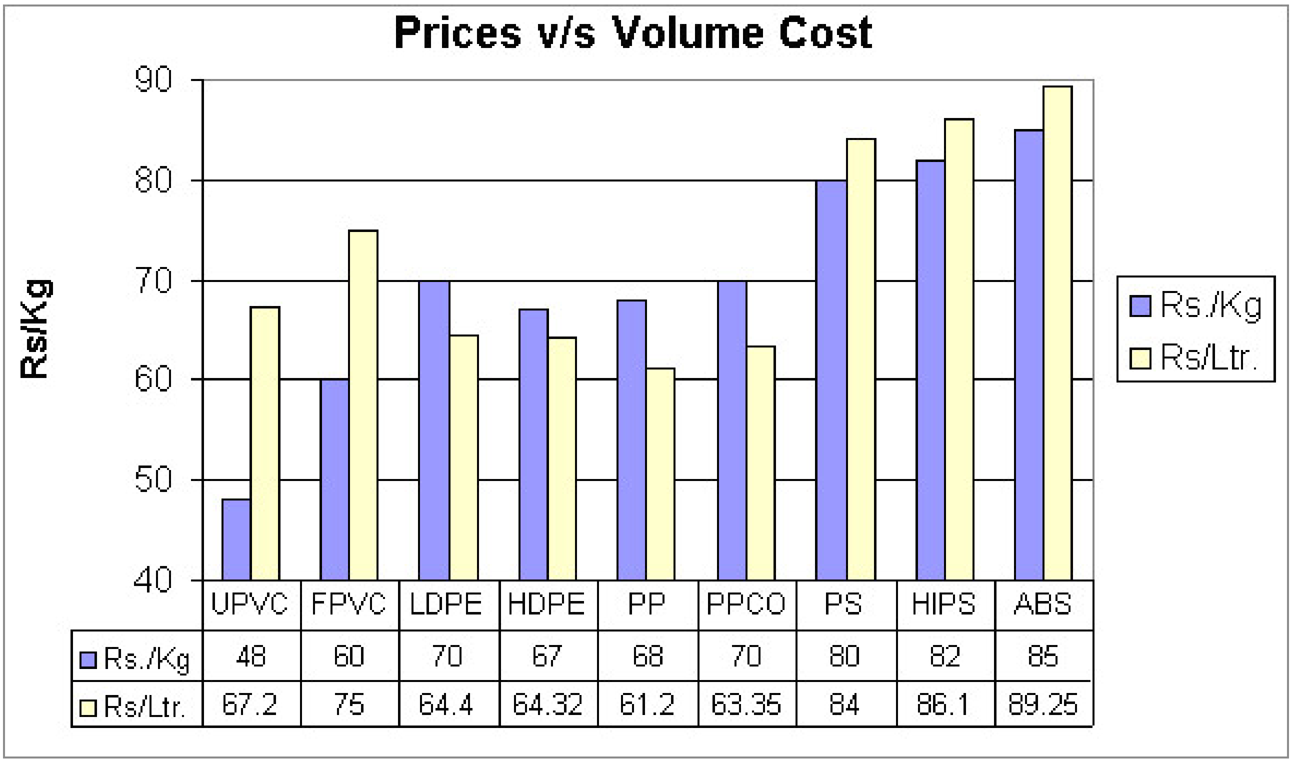
Price is the most determinant factor that designers consider before specifying a certain polymer as a material of construction or design. Though price varies from time to time due to fluctuation of exchange rates in the world markets. The currency of transaction is the rupee, which is used mainly in India. Which is one Indian Rupee equivalent to 0.014€.

The following are the prices of commodity thermoplastics:

Table 2: Prices of different commodities thermoplastics

Polymer	Abbreviation	Price (Rs./Kg.)
Unplasticized PVC	UPVC	48
Plasticised PVC	FPVC	60
Low Density Polyethylene	LDPE	70
High Density Polyethylene	HDPE	67
Polypropylene Homopolymer	PP	68
Polypropylene Copolymer	PPCO	70
Polystyrene	PS	80
High Impact Polystyrene	HIPS	82
Acrylonitrile Butadiene Styrene	ABS	85

When talking about the density of a polymer, it always refers to the polymer in a gelled and fused form or sample, which must not be mistaken or taken for bulk density. Bulk density refers to the apparent density of the powdered polymer form of which it is sold and measured before processing. The rate of flow of polymer granules through hopper throat of the extruder machine, melting, sticking and other storage consideration have relevance with bulk density. Particle size and shape determine bulk density change, while density of a polymer is constant. The graph below is volume cost graph-showing polypropylene as the cheapest polymer.



	UPVC	FPVC	LDPE	HDPE	PP	PPCO	PS	HIPS	ABS
■ Rs./Kg	48	60	70	67	68	70	80	82	85
□ Rs/Ltr.	67.2	75	64.4	64.32	61.2	63.35	84	86.1	89.25

Figure 12: Smartech Global solution Ltd (2014)

6.7 SIGNIFICANCE OF VOLUME COST TO THE PLASTIC MANUFACTU RERS

In the compounding of polymer with additives, volume cost must be put into consideration inorder to achieve desired result. More often, the density of the final product change considerably, due to the mineral fillers that are added just to reduce cost. Volume cost and its implication must be understood properly before deciding cost reduction exercises. The price of polymer are determine either per piece (in mouldings) or per unit length (cables, pipes and tapes manufacturing). Pricing and costing techniques determine fixed volumes of polymers. Since the plastic or polyvinyl chloride (PVC) raw materials are purchased per unit weight, the cost calculation will be done on the basis of per kilogram. This calls for the finished products to be priced and sold on weight per piece. The issue of price reduction or discount will depend on competition within the market mostly by other sellers of same polymer products. The tables shown below depict the volume cost of similar polymers since the practical aspect of the laboratory work is similar to the theoretical part of the write up.

Table 3: Volume cost of polyvinyl chloride (PVC) formulation for PVC pipes

Volume Costs of PVC Formulations for PVC Pipes											
			0 PHR Filler			**10 PHR Filler**			**20 PHR Filler**		
Ingredient	**Price** Rs/Kg	**Density** Kg/Ltr.	**PHR** Kgs.	**Cost** Rs.	**Volume**Ltrs.	**PHR** Kgs.	**Cost** Rs.	**Volume** Ltrs.	**PHR** Kgs.	**Cost** Rs.	**Volume** Ltrs.
PVC Resin K67	48	1.38	100.0	4,800	72.46	100	4,800	72.46	100	.4,800	72.46
TBLS	120	7.2	0.8	96	0.11	0.8	96	0.11	0.9	108	0.13
DBLS	140	4.5	0.5	70	0.11	0.5	70	0.11	0.6	84	0.13
Lead Stearate	100	2.1	0.4	40	0.19	0.4	40	0.19	0.5	50	0.24
Ca. Stearate	80	1.1	0.4	32	0.36	0.4	32	0.36	0.5	40	0.45
Filler	10	2.7	0.0	0	0.00	10	100	3.70	20	200	7.41
Lubricant	140	0.95	0.3	42	0.32	0.3	42	0.32	0.4	56	0.42
TiO2	130	5.6	0.6	78	0.11	0.6	78	0.11	0.6	78	0.11
Carbon Black	50	0.98	0.1	5	0.10	0.1	5	0.10	0.1	5	0.10
Totals			**103.1**	**5,163**	**73.77**	**113.1**	**5,263**	**77.47**	**123.6**	**5,421**	**81.45**
Formulation Cost				**50.08**	**Density**		**46.53**	**Density**		**43.86**	**Density**
Volume Costs				**69.99**	**1.398**		**67.94**	**1.460**		**66.55**	**1.517**
			30 PHR Filler			**40 PHR Filler**			**50 PHR Filler**		
Ingredient	**Price** Rs/Kg	**Density** Kg/Ltr.	**PHR** Kgs.	**Cost** Rs.	**Volume** Ltrs.	**PHR** Kgs.	**Cost** Rs.	**Volume** Ltrs.	**PHR** Kgs.	**Cost** Rs.	**Volume** Ltrs.
PVC Resin K67	48	1.38	100.0	4,800	72.46	100	4,800	72.46	100	4,800	72.46
TBLS	120	7.2	0.9	108	0.13	1	120	0.14	1	120	0.14
DBLS	140	4.5	0.6	84	0.13	0.65	91	0.14	0.65	91	0.14
Lead Stearate	100	2.1	0.5	50	0.24	0.45	45	0.21	0.45	45	0.21
Ca. Stearate	80	1.1	0.5	40	0.45	0.55	44	0.50	0.55	44	0.50
Filler	10	2.7	30.0	300	11.11	40	400	14.81	50	500	18.52
Lubricant	140	0.95	0.4	56	0.42	0.5	70	0.53	0.5	70	0.53
TiO2	130	5.6	0.6	78	0.11	0.6	78	0.11	0.6	78	0.11
Carbon Black	50	0.98	0.1	5	0.10	0.1	5	0.10	0.1	5	0.10
Totals			**133.6**	**5,521**	**85.16**	**143.9**	**.5,653**	**89.01**	**153.9**	**5,753**	**92.72**
Formulation Cost				**41.32**	**Density**		**39.30**	**Density**		**37.39**	**Density**
Volume Costs				**64.83**	**1.569**		**63.51**	**1.616**		**62.05**	**1.659**

Table 4: Summary of costs per hundred parts of resins (PHR) of similar polymers

Summary						
	0 PHR	**10 PHR**	**20 PHR**	**30 PHR**	**40 PHR**	**50 PHR**
Formulation Cost Rs/Kg	Rs.50.08	Rs.46.53	Rs.43.86	Rs.41.32	Rs.39.30	Rs.37.39
Volume Cost Rs/Ltr.	Rs.69.99	Rs.67.94	Rs.66.55	Rs.64.83	Rs.63.51	Rs.62.05
% Reduction in Cost/Kg		7.08%	12.42%	17.48%	21.53%	25.33%
% Reduction in Cost/Ltr		2.94%	4.91%	7.37%	9.2	11.35%

7. COMPARISON OF POLYVINYL CHLORIDE (PVC) TO SOME OTHER MATERIALS

Polyvinyl chloride (PVC) can be compared with a lot of materials ranging from polymers, woods, composites, etc. Their physical, chemical and mechanical properties have to be investigated and noted. The following are some of the materials that are discussed as follows:

7.1 POLYVINYL CHLORIDE (PVC) COMPARED WITH POLYPROPENE (PP) AND ACRYLONITRILE BUTADIENE STYRENE (ABS)

There are very important differences between polyvinyl chloride (PVC) and polypropene (PP). Polypropene (PP) is a neutral plastic with density of 0.910g/cm^3. It contains only two elements: carbon (C) and hydrogen (H). The percentage of chlorine (Cl) in polyvinyl chloride (PVC) by weight is 30% in relation with its basic structure; the composition of polyvinyl chloride (PVC) in petroleum is just 40%. Its reliance on petroleum is minimal; therefore, it is referred to as natural resource plastic. Chlorine and other halogens are harmful to human life and environment, it must not be inhale or ingested due to health implications.

The burning or incinerations of polyvinyl chloride (PVC) either knowingly or accidentally, produce poisonous and toxic byproducts like dioxins, chlorocarbons and hydrochloric acid. In the case of polypropene (PP) when it undergoes complete combustion, it decomposes into carbon dioxide and water. Unlike polyethene (PE), polystyrene (PS) and polypropene (PP) which are petroleum dependent. Polyvinyl chloride (PVC) is essentially not stable to heat thereby making it expose to decomposition during processing, and it has a density of 1.36g/cm^3. Polypropene (PP) can withstand heat under extreme conditions; it will only decompose into lower molecular weight paraffin's, which are in agreement with the base material. Polyvinyl chloride (PVC) in its basic form needs a large amount of lead to stabilize it, due to the poisonous nature of lead, it has been agreed that it should be phased out in production of polyvinyl chloride (PVC) because of its health issue on human and other creatures. The effect of lead is felt in polyvinyl chloride (PVC) either during the life cycle of the product or after its disposal. That is why lead and other heavy metals are not employed in the manufacture of polypropene (PP) sheets.

The monomer unit called vinyl chloride which forms a building blocks of polyvinyl chloride (PVC) is very toxic and poisonous, strict guidelines have been put in place for its handling, transporting and ways of storage. Many studies, symposium and lectures have been held on its health implication on workers and people living around the plants. Polypropene (PP) sheet can be manufactured from propylene monomer which act also as building blocks of polypropene (PP), which is a safe gas gotten from the waste byproduct of petroleum fractions in the fractional distillation column, it was often flare to the atmosphere, thereby causing greenhouse gas emission. As more polypropene sheets are manufactured from this propene gas, less of it will be emitted to the atmosphere and this reduced the greenhouse gas emission effect.

It can be inferred that polypropene is 100% recyclable, compared to polyvinyl chloride (PVC), which is not 100% recyclable due to the nature of its chemical compositions and the additives it contains.

7.2 POLYVINYL CHLORIDE (PVC) COMPARED WITH ACRYLONITRILE BUTADIENE STYRENE (ABS)

The density of acrylonitrile butadiene styrene (ABS) is between 1.0-1.05g/cm^3. Both polyvinyl chloride (PVC) and acrylonitrile butadiene styrene (ABS) pipes are resistant virtually to acids, salts and alkalis in nature, but they are not resistant to aromatic and chlorinated hydrocarbons. They can both be used as surface and submersible means of conveying fluids in pipes. When acrylonitrile butadiene styrene (ABS) pipe is used by exposing it to the sun, it will be deformed and acrylonitrile butadiene styrene (ABS) got affected by ultraviolet ray that degrade the quality of the pipe. That prompted for a research that suggest for the coating of the acrylonitrile butadiene styrene (ABS) pipes with some pigments called latex paints, which will prevent the ultra-violet (UV) radiation from destroying the pipe surface. The additives known as Plasticisers contained in polyvinyl chloride (PVC) makes it to be flexible and somewhat soft, but a purple primer will be needed when joining it together with another polyvinyl chloride (PVC). Acrylonitrile butadiene styrene is very easy to install without primer purple being employed.

Purple primer is a specially blended form of solvent made to soften and swell polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC) pipes and fittings. The purpose that the purple primers serve is to penetrate the surfaces (both outer and inner) of the pipe and produce a stronger and better joint.

7.3 POLYVINYL CHLORIDE (PVC) COMPARED WITH HIGH DENSITY POLYETHYLENE (HDPE)

The density of high-density polyethene (HDPE) is within the range of 0.93 to 0.97g/cm3 compared with that of polyvinyl chloride (PVC), which is between 1.3-1.45g/cm^3 (rigid) and 1.1-1.35g/cm^3 (flexible). Both have some characteristics in common, but an important differences which cannot be overlooked. The two (2) materials are light in weight, do not corrode and can withstand chemical and bacterial build up during use. Polyvinyl chloride (PVC) and polyethylene (PE) have different applications in different facet of life.
Polyvinyl chloride (PVC) is cheap and durable, being a vinyl polymer used in construction for building. Its lightweight and strength give it the advantage used in producing underground and surface pipes. It can also be used in trenchless installation due to its strength.
High-density polyethylene (HDPE) is a polyethylene of the thermoplastic type that is made from petroleum, with higher strength, harder and can withstand high temperature. High-density polyethylene (HDPE) is suitable in underground piping system because it reduces and absorb shock waves and surges that can affect the installed system. They resist pressure at the joint parts, and have abrasion and heat resistant. Due to the durability and low cost of high-density polyethylene, it is utilized as containers for creams, liquid soaps, gels etc.

Polyvinyl chloride (PVC) and High-density polyethylene (HDPE) are strong and durable, but their strength and other properties vary. Their pressure capacities are not the same in pipe stress design. For the pressure rating to be the same with that of polyvinyl chloride (PVC) pipes, the wall of the High-density polyethylene (HDPE) pipe must be made 2.5times thicker than polyvinyl chloride (PVC) pipes.

7.4 POLYVINYL CHLORIDE (PVC) COMPARED WITH ELASTOMERS AND RUBBER

Elastomer usually falls into the category of thermoset and thermoplastic materials. In this context, the two (2) elastomers are mainly; Natural and synthetic rubber.

The density of rubber depends on the type which studies will be based on. Hard rubber has a density of 1200kg/m^3, while soft commercial rubber has a density of 1100kg/m^3 respectively.

Natural rubber is also referred to as Indian rubber with botanical name called hevea brasiliensis, which is an elastomer (elastic hydrocarbon polymer). The natural rubber is gotten from latex in a milky form from the rubber tree plants. The tapped rubber gotten by incision from the bark of the tree is further refined to give it the required properties needed for usable rubber. It is used in manufacture of hoses, footwear, foam mattress, toys etc.

Synthetic rubber is mostly made of raw materials derived from coal, oil, natural gas, petroleum and acetylene. Most of them are polymers that contain more than one monomer. The change in composition of synthetic rubber might alter or improve its properties desired for use. Styrene butadiene rubber (SBR) is mostly employed elastomer because of its low cost and good properties it displays. Its area of application is usually in the manufacture of tires.

7.5 POLYVINYL CHLORIDE (PVC) COMPARED WITH CERAMICS

Ceramics exist in different forms as organic and inorganic materials that are essential in day-to-day use. The ceramic type to be mentioned in this work will be the floor tile, which is inorganic in nature. The density of a floor tile will depend on its moisture absorption rate. If the moisture absorption rate is less, its density or weight will surely increase, and it is within the range of 2790-3070kg/m^3. Furthermore, as the weight or density increases, it becomes even stronger in strength. The process by which ceramic are made to its finish end is called ceramic glazing.

Ceramic glazing is addition of vitreous coating materials to ceramics, and its primary purposes are for decoration as well as protection when put in use. The type of atoms bonding and the way the atoms are packed will determine the strength of a ceramic material; this can be termed atomic scale structure. Virtually all ceramics are made up of two (2) or more elements that forms a compound. All atoms in ceramic materials are bind together by a chemical bond. The most well known chemical bonds for ceramic materials are mostly covalent and ionic bonds. In the case of metal, metallic bond are employed. The covalent and ionic bonding is much stronger when atoms are bond together by these two (2) methods than the metallic bonding, that is the reason why ceramics are brittle materials and metal are ductile.

The properties listed below make ceramic to be employed in different applications and walks of life. Most ceramics are:

- Hard
- Brittle
- Wear-resistant
- Refractory
- Thermal insulators
- Electrical insulators
- Oxidation resistant
- Prone to thermal shock
- Chemically stable

Polyvinyl chloride (PVC) is distinct from ceramics in the sense that they don’t share most of the properties of ceramics. Though, the bonds that hold atoms in the polymer molecules together in polyvinyl chloride (PVC), is the covalent bond.

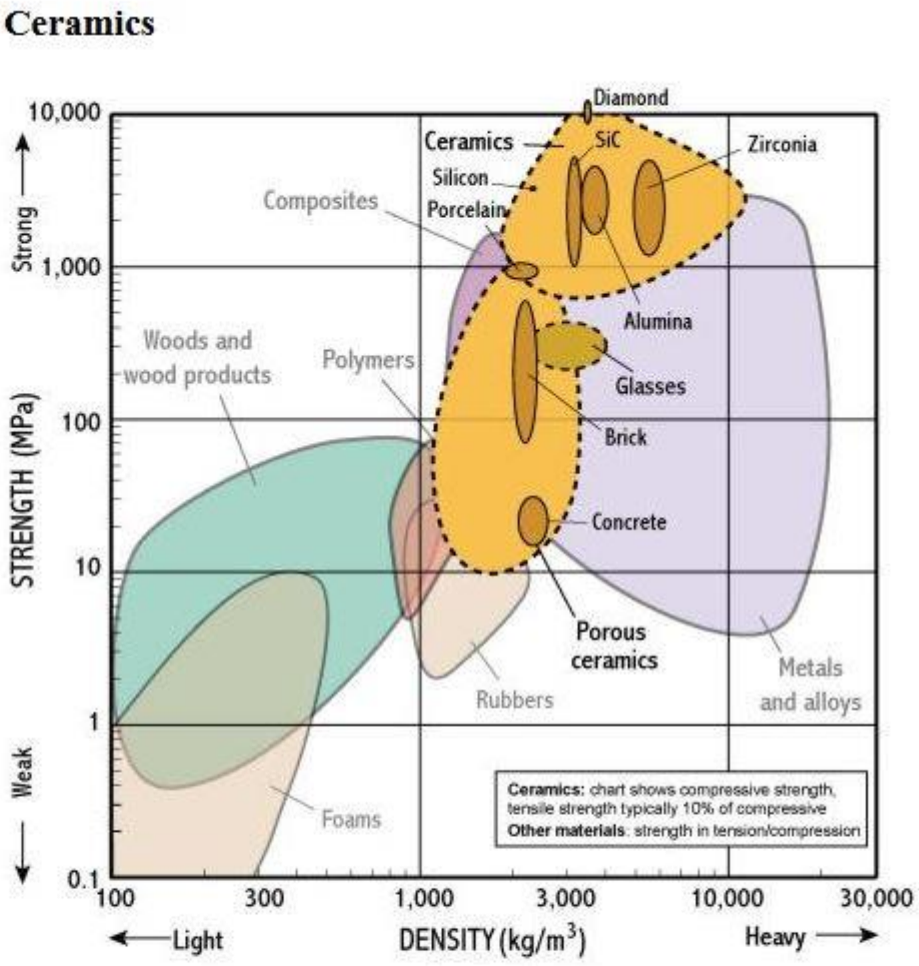


Figure 13: Compressive strength and tensile strength of ceramics

7.6 POLYVINYL CHLORIDE (PVC) BENEFITS OVER OTHER MATERIALS

In most of the present world applications of these days, polyvinyl chloride (PVC) is been used as a substitute in traditional building materials such as metal, wood, concrete and clay. The ability of polyvinyl chloride (PVC) to be employed in varieties of ways makes it to gain popularity in building and other fields. The cost effectiveness and the history of use to which it is put into makes it has an edge over other polymers in building sector. In 2006 almost 60% of the European polyvinyl chloride production was used by the construction sector which makes it the sought after polymers.

Polyvinyl chloride (PVC) versatility makes it one of the most popular and widely used plastics in construction and building. It is also used to transport drinking water, wastewater and sewage pipes, window frames and rails, wall coverings, floor tiles and as insulator for cables and various applications in engineering and day to day use equipment's, as it provide replacements or alternatives to known traditional materials such as metal, wood, rubber and glass. Polyvinyl chloride (PVC) products are mostly lighter in weight, cost less and give many performance advantages (versatility). The following are the advantages as explained below:

7.6.1 STRENGTH AND LIGHT WEIGHT

Polyvinyl chloride (PVC) ability to resist abrasion during impact with external body, lightweight, good mechanical strength coupled with toughness is the edge it has over other materials. These technical advantages make it to be a very good choice in building and construction applications:

7.6.2 EASE OF INSTALLATION

Polyvinyl chloride (PVC) can be easily cut into various shapes, depending on the use to which it will be used for and where it is needed. It can also be welded together or joined together by different means of joining techniques. Its lightweight makes it convenient in manual handling during installation in construction and building sectors. During its installation in buildings or construction sites, it causes little or no danger of injuries.

7.6.3 DURABILITY

The ability of polyvinyl chloride to resist harsh weather, that is; colour change, texture, composition and its form (weathering), corrosion, shock and abrasion makes it the preferred material for both indoor and outdoor long life products. Due to the longevity in use during its application, it accounts for 85% of the polyvinyl chloride (PVC) production used in building and construction sectors. More than 75% of polyvinyl chloride (PVC) will have a lifespan of more than 40 years, depending on the use it was subjected to, the normal potential life span of service is actually 100 years. In window profiles and cable insulations, it was indicated that 60% of the polyvinyl chloride used would have lifespan of more than 40 years.

7.6.4 COST EFFECTIVENESS

Polyvinyl chloride (PVC) has been users choice for many years mostly in construction and building sector, due to its technical and physical properties that gives good result without spending much money for its purchase, and better-cost performance benefit. As a result of the properties like durability, lifespan and little maintenance of polyvinyl chloride (PVC), that is why it is competitive in terms of price.

8. EXPERIMENTAL WORK AND RESULTS

Polyvinyl chloride (PVC) of three (3) different types with listed below qualities were provided by PRIMO OY PRIMO FINLAND AB upon request during visitation to the factory in heinola by me and my supervisor Mariann Holmberg.

- NORVINYL^{TM} S6045: A low molecular weight and low porosity vinyl chloride homopolymer, which was produced by suspension process in the factory.
- NORVINYL^{TM} S6545: A medium molecular weight, with high bulk density and low porosity vinyl chloride homopolymer that was produced by suspension process.
- NORVINYL^{TM} 6261: A medium to low molecular weight vinyl chloride homopolymer that was produced by the process of suspension in the factory.

The detailed information and typical properties of the above mentioned NORVINYLS (PVCs) could be gotten from the appendix.

The K-values that expresses the viscosity estimate of the statistical molecular mass of polymeric material used in producing poly vinyl chloride (PVC) of different properties are also mentioned in the appendix. The k-values of the above mentioned polyvinyl chlorides (PVCs) are; 60, 65 and 62 respectively.

The different polyvinyl chlorides (PVCs) materials were delivered in sheets. Upon receiving the sheets of polyvinyl chloride, a die in form of a dog bone was designed and used to cut out the test piece by the computer numerical control machine (CNC) by drilled cut. The different sheets were cut in the same shapes and reading values. Though two (2) cutting methods were provided as options, but the drilled cut was later chosen. The two (2) are:

- Water cut (laser type)
- Drilled cut

Figure 14: Dog-bone diagram drawn with solid works software

8.1 PREPARATION OF POLYVINYL CHLORIDES (PVCs) FOR TEST.

Each dog bone cut shaped polyvinyl chloride (PVCs), the test were properly conducted at a test speed of 5,100mm/min according to ISO 1133 standard. Seven (7) range of temperatures reading was chosen in order to get accurate results and test dog-bone dimension are 165 x 19 x 0.83 was taken to the drilling machine to drill a hole at the far end of the test piece in order to suspend it inside the heating oven.

The different dog bone test pieces was differentiated and denoted with numbers written on it as 1, 2 and 3 in order not to cause mix up. A thin long iron was passed through the hole drilled at the ends of the dog bone shaped polyvinyl chlorides (PVCs) for easy suspension inside an oven in order to heat up the dog bones.

The thermometer that was built with the oven was giving conflicting temperatures readings due to its long time use. I was later told by Erland Nyroth to improvise by mounting a thermometer inside the oven and at the same time use the infrared thermometer to know the temperature readings inside the oven and compare the readings with the mounted thermometer inside the oven. The dog bone shaped polyvinyl chlorides (PVCs) 1, 2 and 3 was heated to a temperature of 23, 38.7, 49.8, 60.7, 75.2 and 80.1°C at time 30, 60 and 90 minutes respectively. After the subsequent heating to the desired listed temperatures and predetermined time. Each dog bone shaped polyvinyl chlorides (PVCs) are removed and the temperature and time is written on it to avoid mix up during the test.

The reason for not getting a rounded figure for the temperature readings was due to the irregular malfunction of the designed thermometer on the oven. The improvised thermometer readings was agreed to be used.

8.2 TESTOMETRIC TEST OF DIFFERENT POLYVINYL CHLORIDES (PVCs)

Testometric universal testing machine is commonly used in industries and manufacturing world for testing physical and mechanical properties, to give fast proper evaluation of the materials and products.

Different polyvinyl chlorides (PVCs) sheets which has been into the dog bone shape were heated in the oven at different temperatures and time will need to undergo loading force inorder to know their mechanical and physical behavior when subjected to tension force when gripped at both ends on the testometric universal machine.

Each of the heated dog bone shaped polyvinyl chloride (PVC) which was left cooled were mounted subsequently on the testometric machine by holding both ends by the grips of the machine, with the aid of the installed software connected to the computer, the test piece was set into tension. With further increment of the tension, the dog bone shaped polyvinyl chloride will break when it attains its breaking point, and the mechanical properties curve are displayed on the stress-strain graph which will be shown of different dog bones at different temperatures and time. Below are the results for different dog bone shaped polyvinyl chlorides (PVCs):

Figure 15: Dog-bone mounted on a grip being tested with a testometric tensile testing machine (Arcada plastic technology laboratory, January 2015)

Figure 16: Suspended dog-bones and improvised thermometer placed inside the heater in the Arcada plastic laboratory (December 2014).

8.3 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 TESTED AT DIFFERENT TEMPERATURE

In order to test and compare results, different dog-bones were cut out by drilled cut with the computer numerical control machine (CNC). The polyvinyl chlorides (PVC) materials were produced by PRIMO OY in form of sheets, and the dog-bones undergo heating in the oven at different temperatures and time. It was done to obtain the mechanical data of the dog-bone such as tensile strength, elongation, stress, strain, young modulus, deformation, etc. Below are the table, graph and picture of the polyvinyl chlorides (PVCs) 1, 2 and 3 after the experiments.

8.4 POLYVINYL CHLORIDE (PVC) 1,2 AND 3 AT ROOM TEMPERATURE

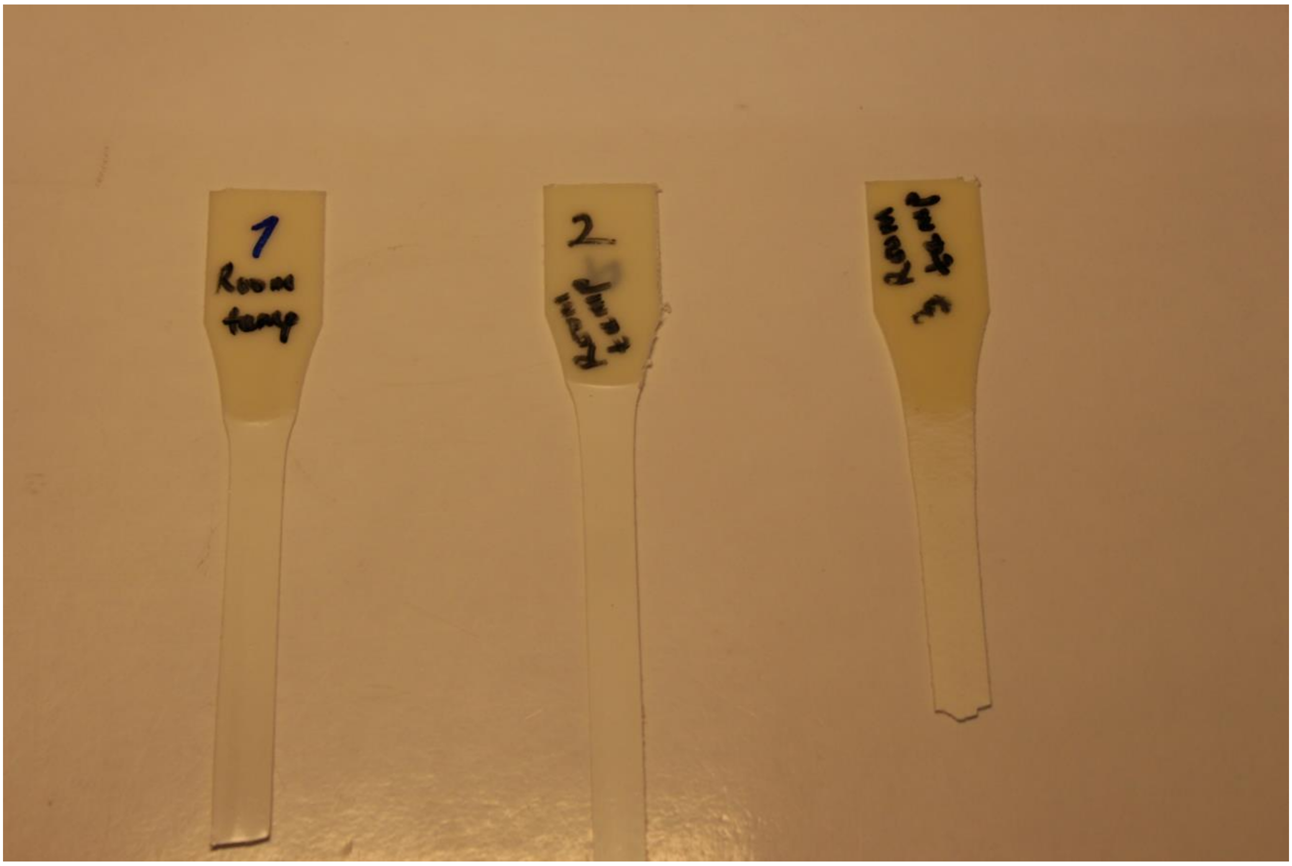


Figure 17: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

At room temperature 23°C, the polyvinyl chloride 1 and 2 do not show any laminar change on the surface when it was subjected to loading on the testometric tensile testing machine, and both 1and 2 also has a smooth edge at the break point. And both elongations have a high value. While polyvinyl chloride (PVC) 3 shows a crossed delaminated surface when subjected to load on same machine, and its break point edge is rough as shown in the diagram in figure 17 above. Polyvinyl chloride (PVC) 3 also has a low elongation value at break point compared to 1 and 2 in the graph on the appendix page.

8.5 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 38.7°C FOR 30 MINUTES.

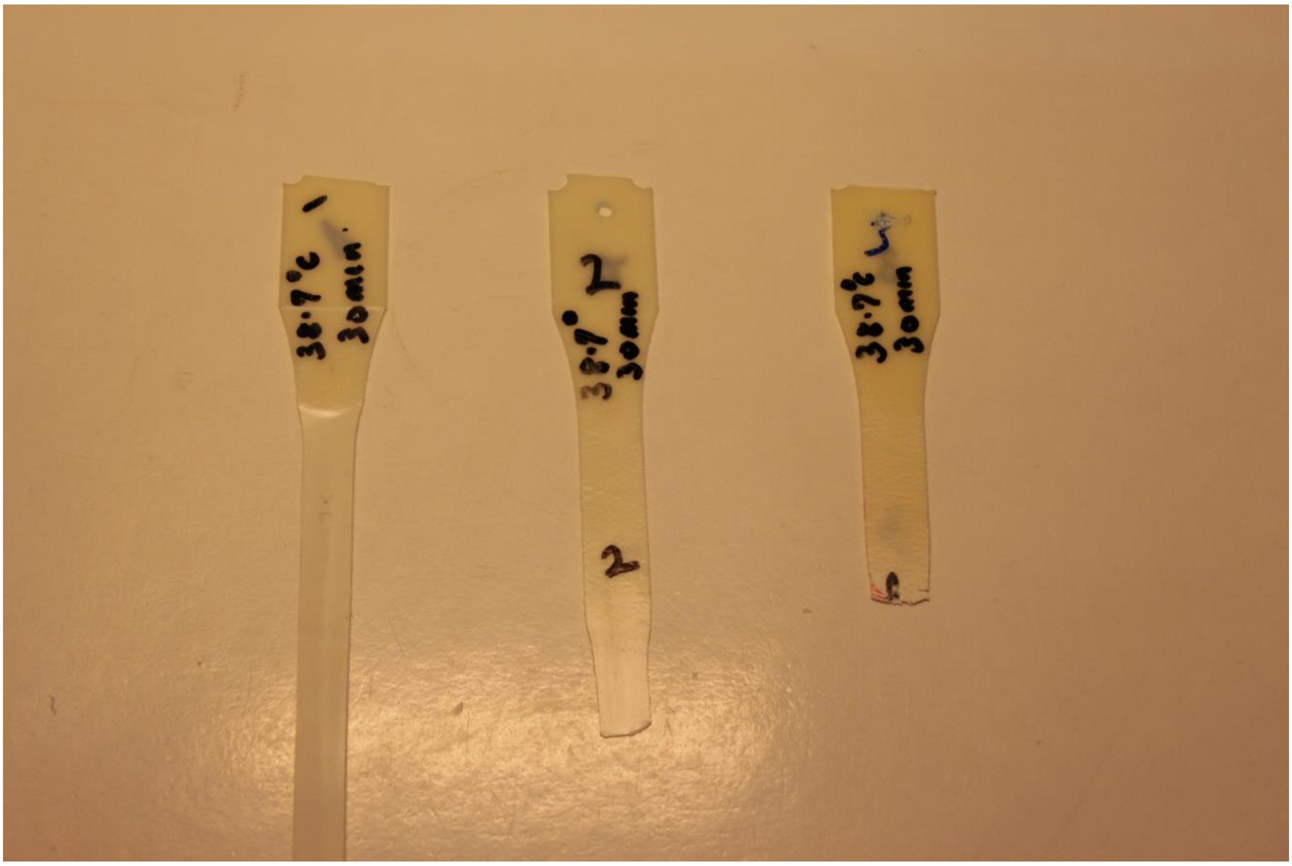


Figure 18: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 38.7°C for 30 minutes. Polyvinyl chlorides (PVC) 1 and 2 show high elongation when subjected to loading on the testometric tensile testing machine before reaching breaking point, but polyvinyl chloride (PVC) 2 and 3 shows delamination on the dog-bone surfaces, while polyvinyl chloride (PVC) 1 has smooth surface and rough edges at the break point as illustrated in the diagram in figure 18 above.

8.6 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 49.8°C FOR 30 MINUTES.

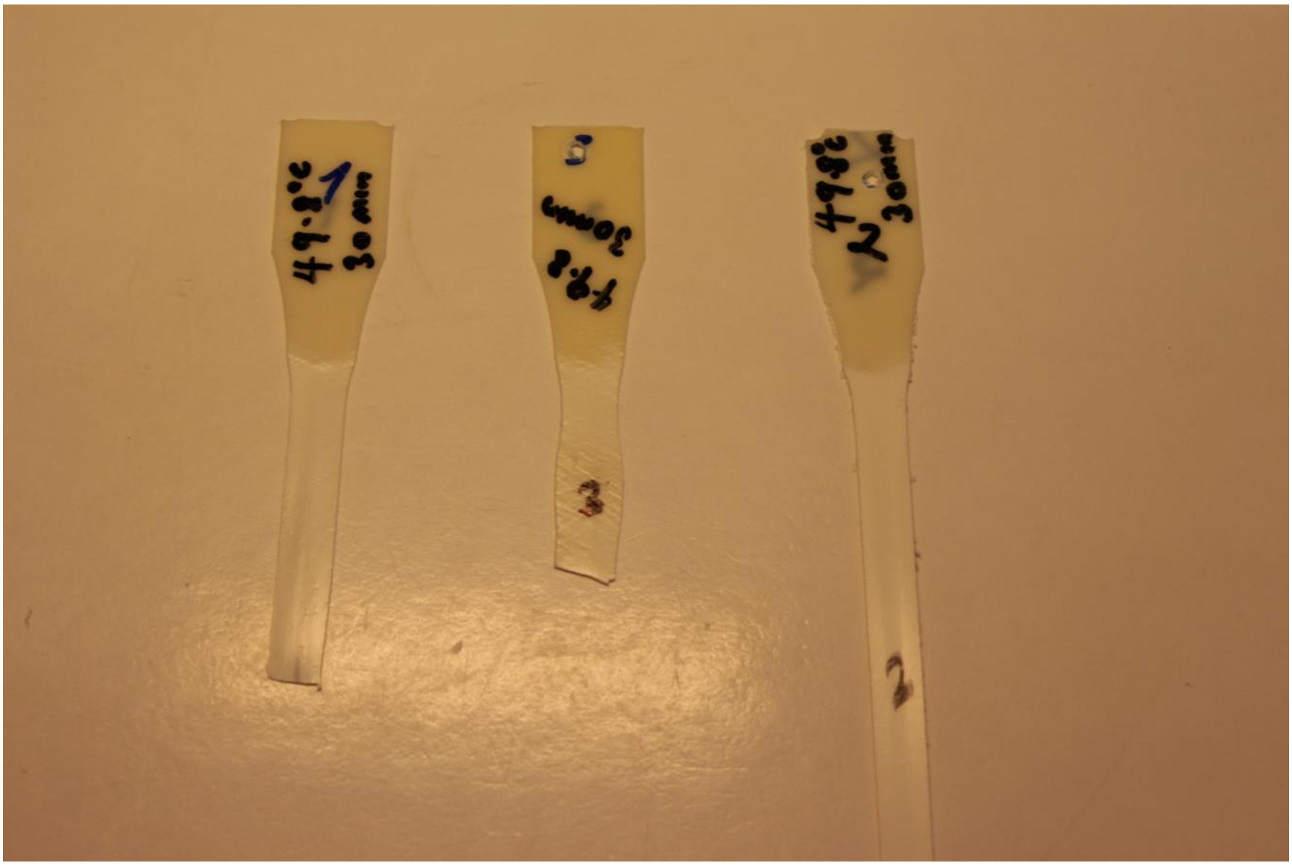


Figure 19: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under the light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 49.8°C for 30 minutes. Polyvinyl chloride (PVC) 3 show a visible delamination on the surface, while 1 and 2 shows smooth surfaces with smooth edge cut at the break points as shown in the diagram in figure 19 above. Polyvinyl chloride (PVC) 1 and 2 shows high elongation, while 3 is the least at the break point when subjected to loading on the testometric tensile testing machine as shown in the graph on the appendix page.

8.7 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 60.7°C FOR 30 MINUTES.

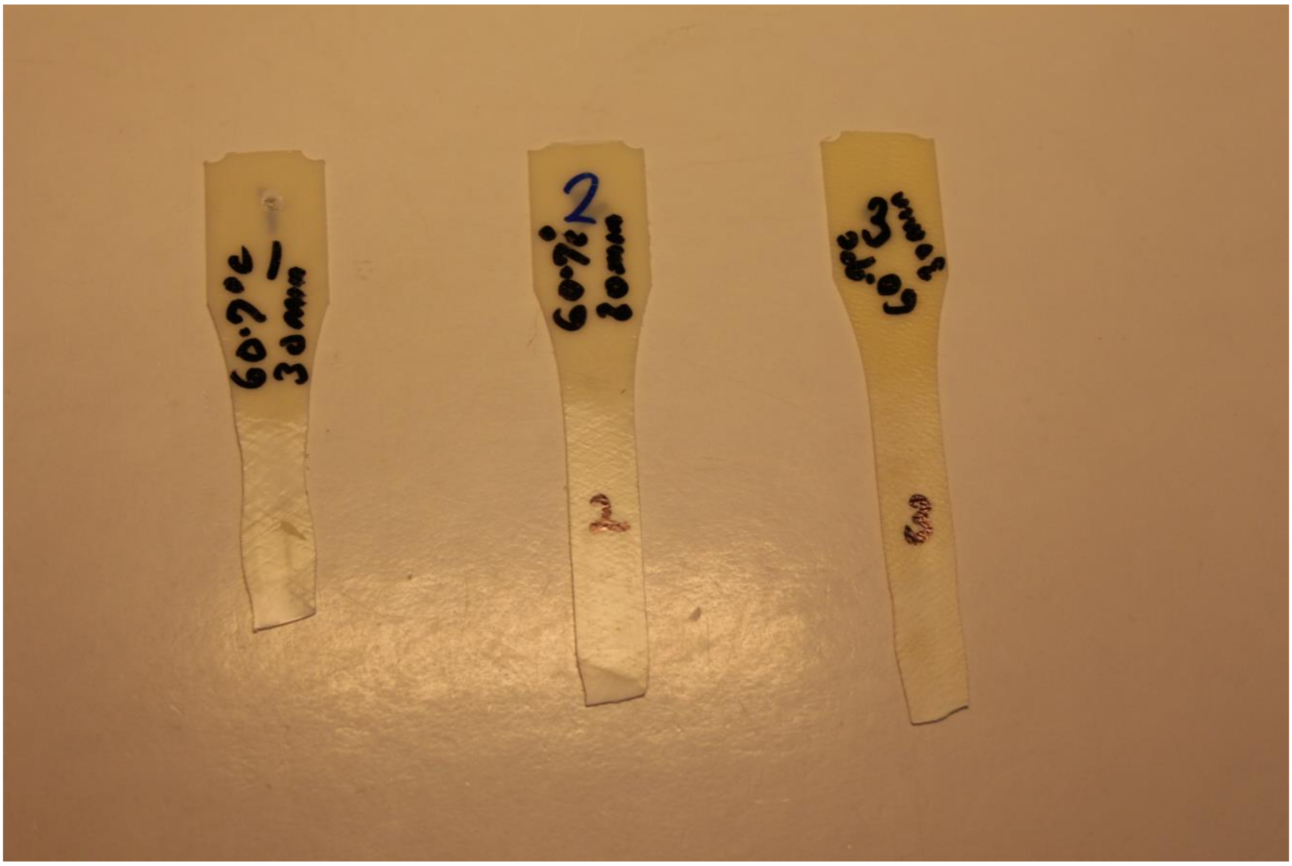


Figure 20: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 60.7°C for 30 minutes. All the polyvinyl chlorides (PVC) mentioned and shown above indicate sign of delamination surfaces, all the polyvinyl chloride (PVC) samples have smooth edges at the break point when subjected to loading on the testometric tensile testing machine as shown in the figure 20 above. But polyvinyl chloride (PVC) 2 shows the highest elongation followed by 1, and then 3 were the least elongated as shown in the graph on the appendix page.

8.8 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 75.2°C FOR 30 MINUTES.

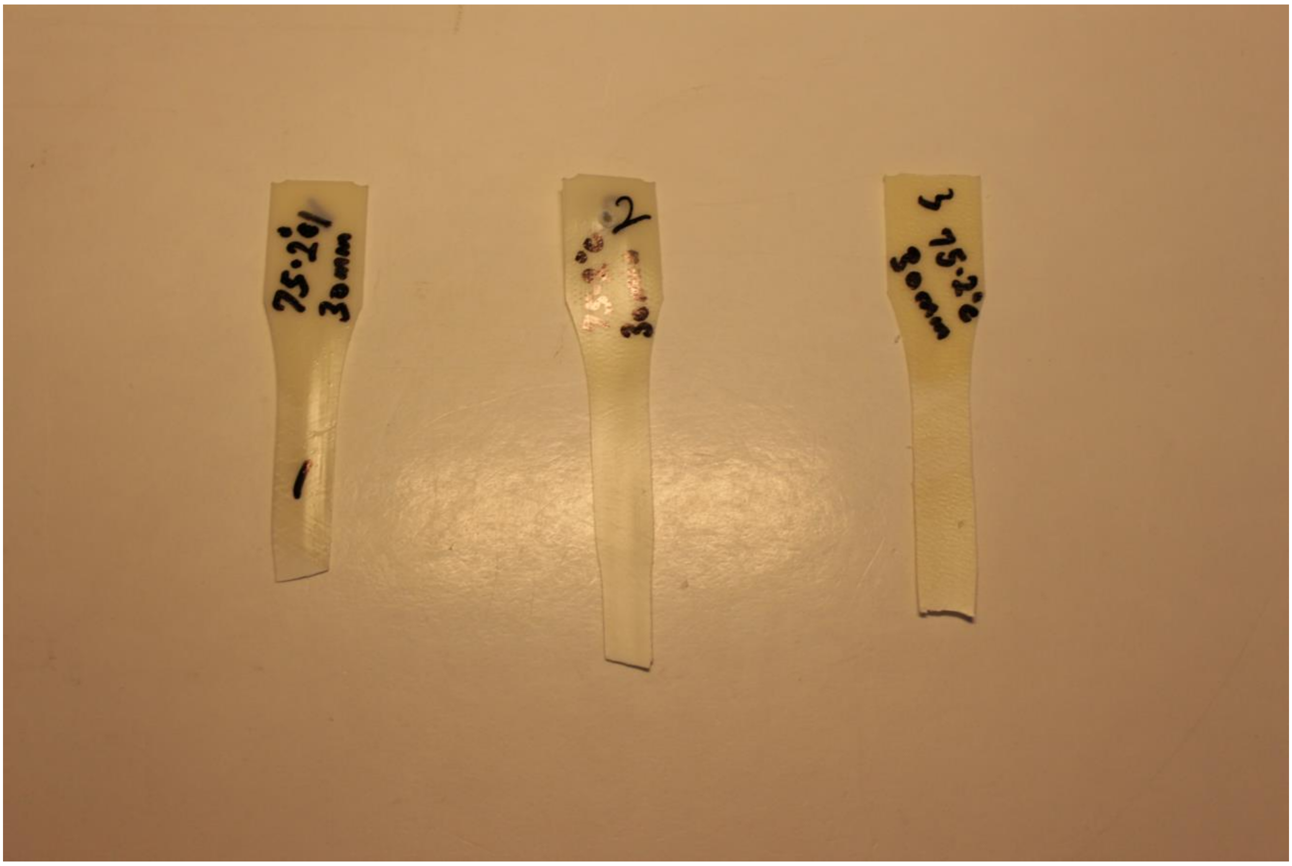


Figure 21: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 75.2°C for 30 minutes. All shows a sign of delamination on their surfaces due to loading on the testometric tensile testing machine, polyvinyl chloride (PVC) 1 and 2 has smooth edges, while the edge of 3 is slightly rough as illustrated in the diagram in figure 21 above. According to the graph on the appendix page, the elongation is highest in polyvinyl chloride (PVC) 2, followed by 3 and the least is 1.

8.9 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 80.1°C FOR 30 MINUTES.

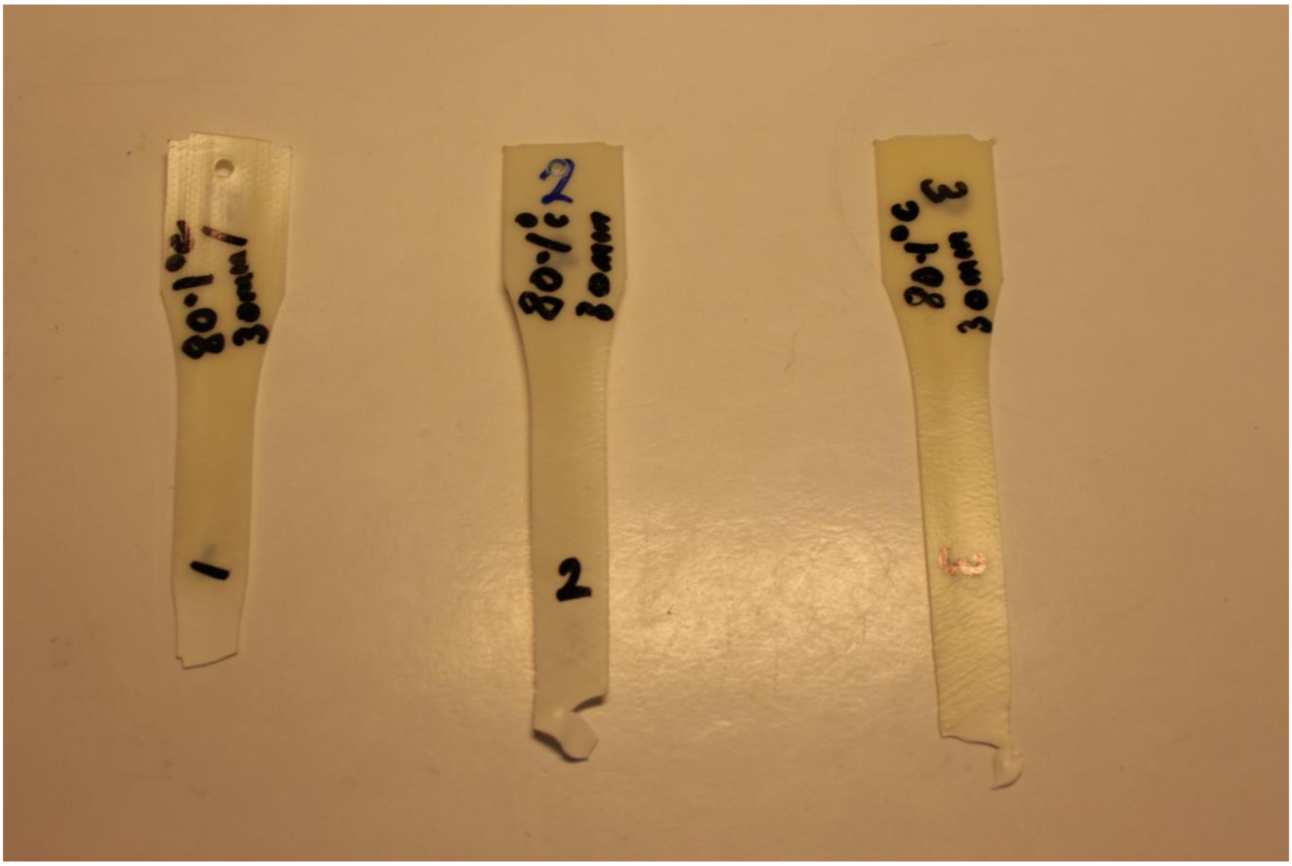


Figure 22: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 80.1°C for 30 minutes. Delamination was well noticed on polyvinyl chloride (PVC) 3 when viewed under the light. The remaining two (2) polyvinyl chlorides (PVC) were not so visible. Polyvinyl chloride (PVC) 2 and 3 has rough edge at the break points, and 1 has smooth edge cut at the break point as illustrated in the diagram in figure 22 above. According to the graph on the appendix page, the elongation is highest in polyvinyl chloride (PVC) 2, and then followed 1 and the least was 3 when subjected to loading on the testometric tensile testing machine.

8.9.1 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 38.7°C FOR 60 MINUTES.

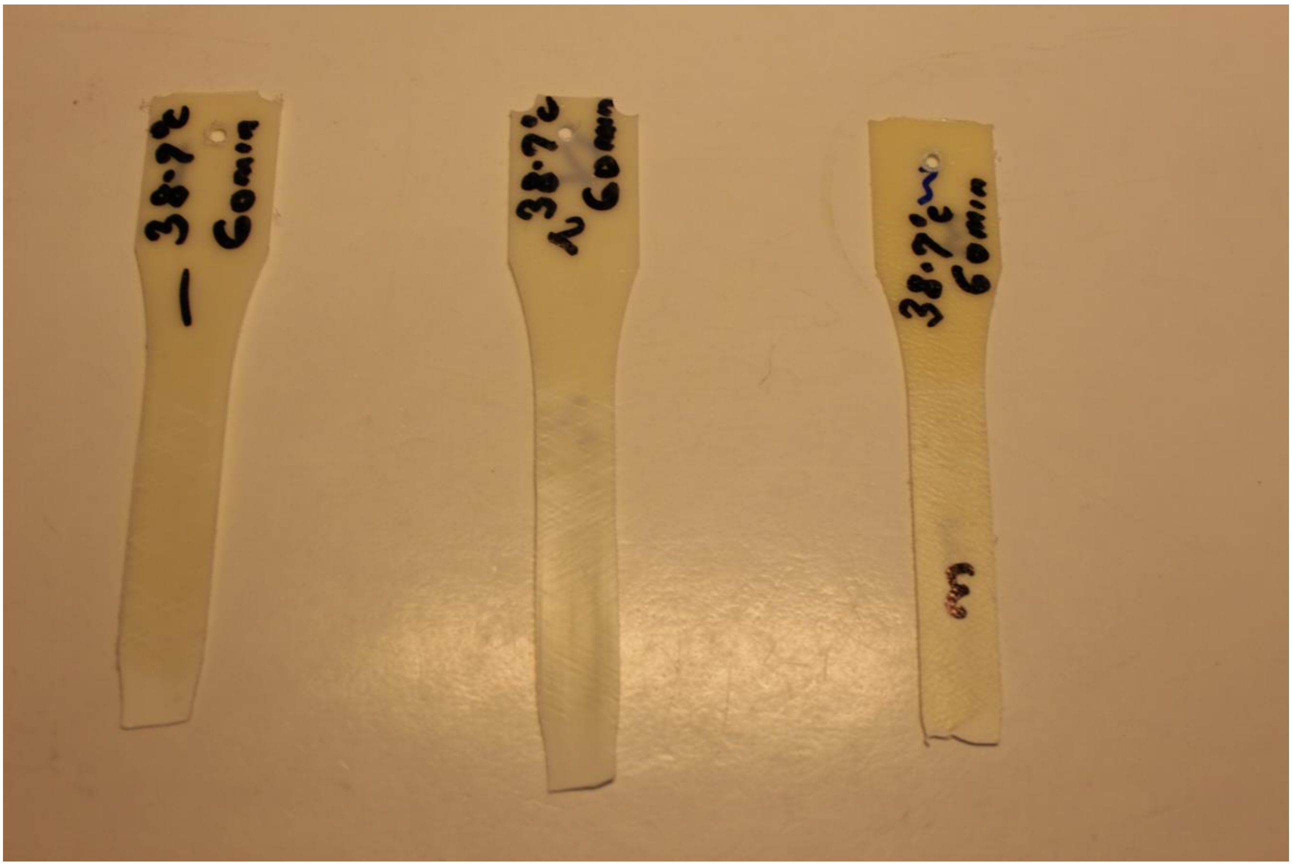


Figure 23: Pictorial view 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 38.7°C for 60 minutes. All the three (3) polyvinyl chlorides (PVC), shows a delaminated surface on the diagram when viewed under the light, and all the edges are smooth as shown in figure 23 above. The elongation is highest in polyvinyl chloride (PVC) 1, and then followed by 2 and the least was 3 when subjected to loading on the testometric tensile testing machine in the plastic laboratory as shown in the graph on the appendix page.

8.9.2 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 49.8°C FOR 60 MINUTES.

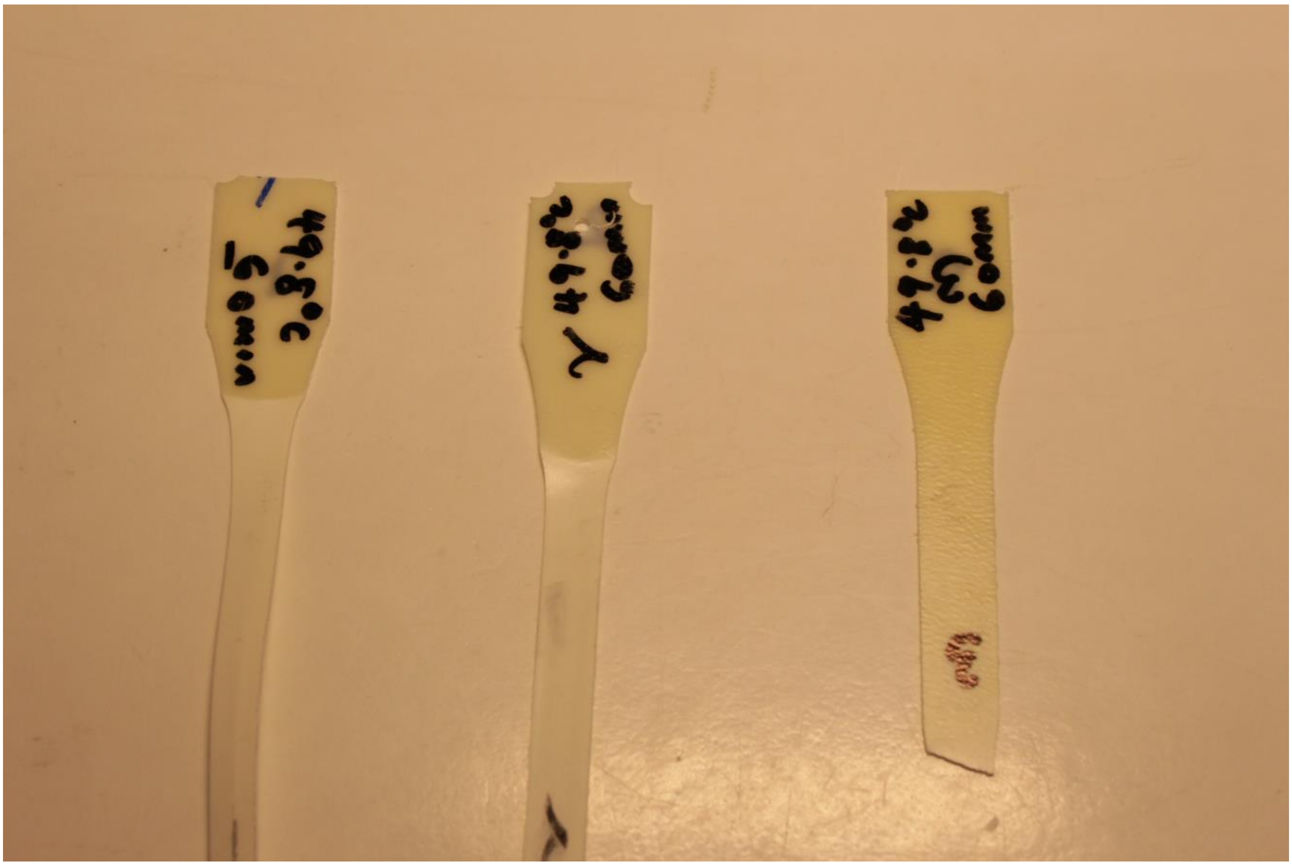


Figure 24: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 49.8°C for 60 minutes. Polyvinyl chloride (PVC) 1 and 2 has smooth surfaces, while 3 have delaminated surface, and smooth edge at the break point when subjected to load on the testometric tensile testing machine in the laboratory as shown in the diagram in figure 24 above. And polyvinyl chloride 1 has the highest elongation followed by 2, and 3 has the least elongation at break point as shown on the graph on the appendix page.

8.9.3 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 60.7°C FOR 60 MINUTES.

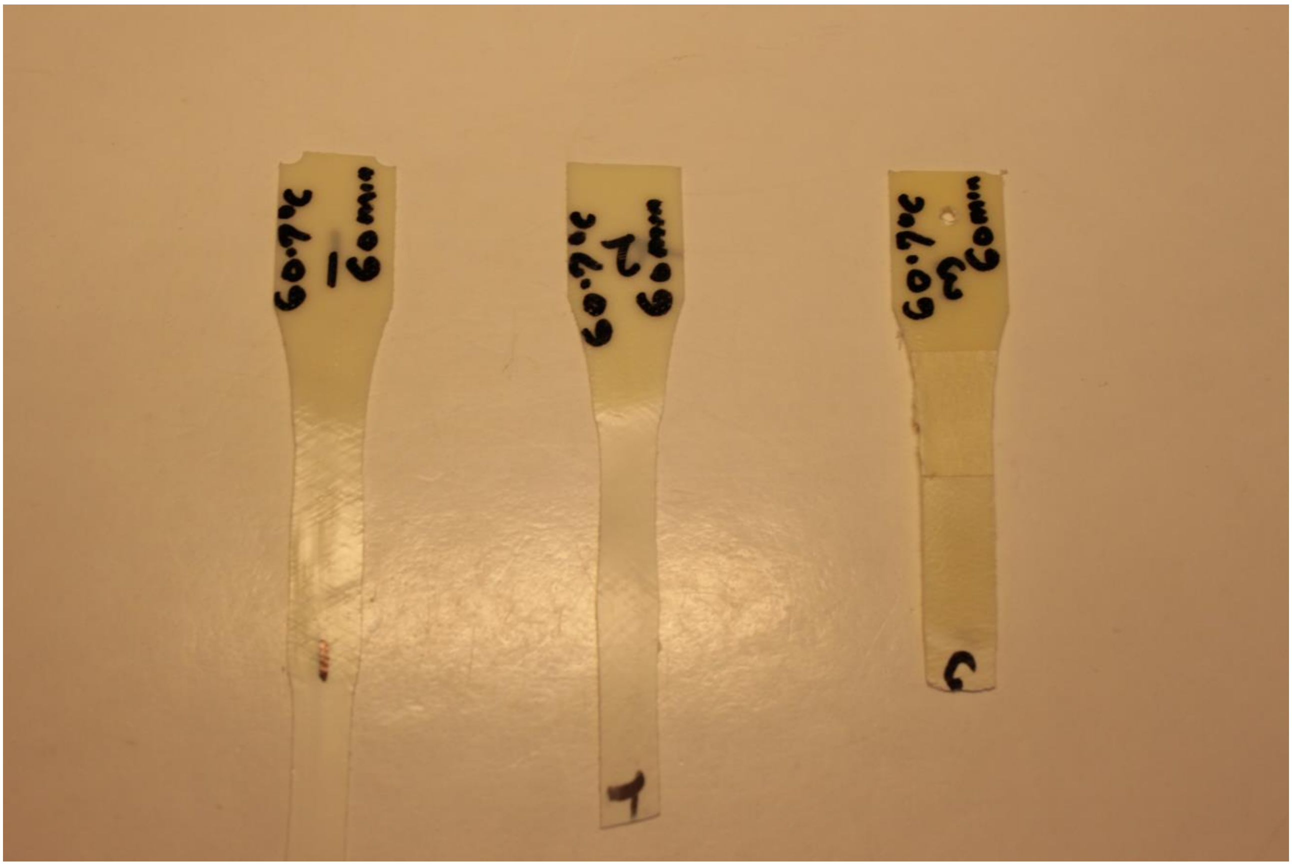


Figure 25 : Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 60.7°C for 60 minutes. The three (3) polyvinyl chlorides (PVCs) when subjected to loading on the testometric tensile testing machine has all surfaces delaminated and all the edges are smooth at the break point as illustrated in figure 25 above. Polyvinyl chloride (PVC) 2 has the highest elongation at break point, followed by 1 and the least was 3 as shown in the graph on the appendix page.

8.9.4 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 75.2°C FOR 60 MINUTES.

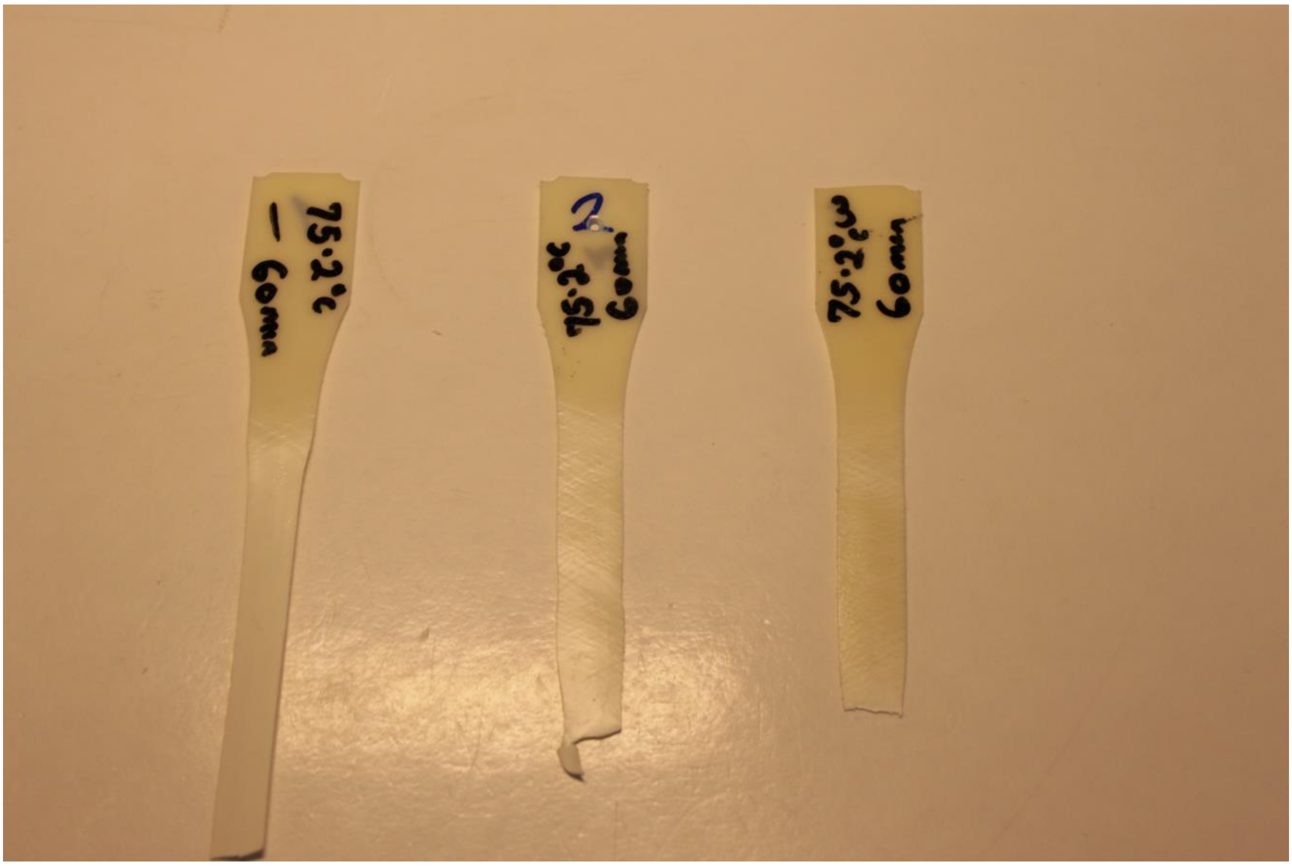


Figure 26: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 75.2°C for 60 minutes. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine has delaminated surfaces that is most noticeable in 2 and 3. The edges of 1 and 3 are smooth, while that of 2 is slightly rough or irregular as illustrated in the figure 26 above. Elongation at break point is highest in polyvinyl chloride 1, followed by 2 and least in 3 as depicted on the graph at the appendix page.

8.9.5 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 80.1°C FOR 60 MINUTES.

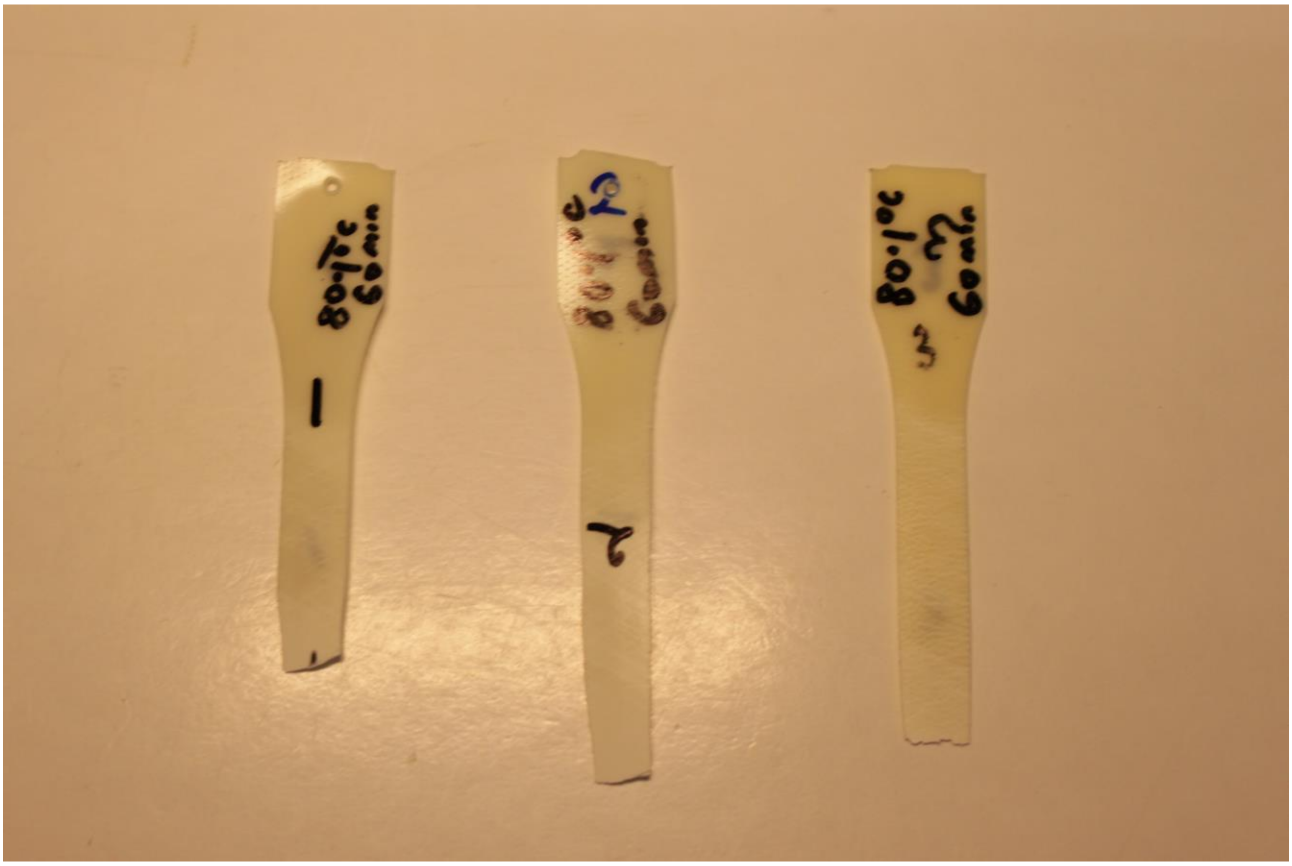


Figure 27: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 80.1°C for 60 minutes. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine has delaminated surfaces which is most noticeable in 3 and least noticeable in 1 and 2. The edges of 1 and 2 are smooth, while that of 3 is rough as illustrated in the figure 27 above. Elongation at break point is highest in polyvinyl chloride 2, followed by 3 and least in 1 as in the graph on appendix page.

8.9.6 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 38.7°C FOR 90 MINUTES.

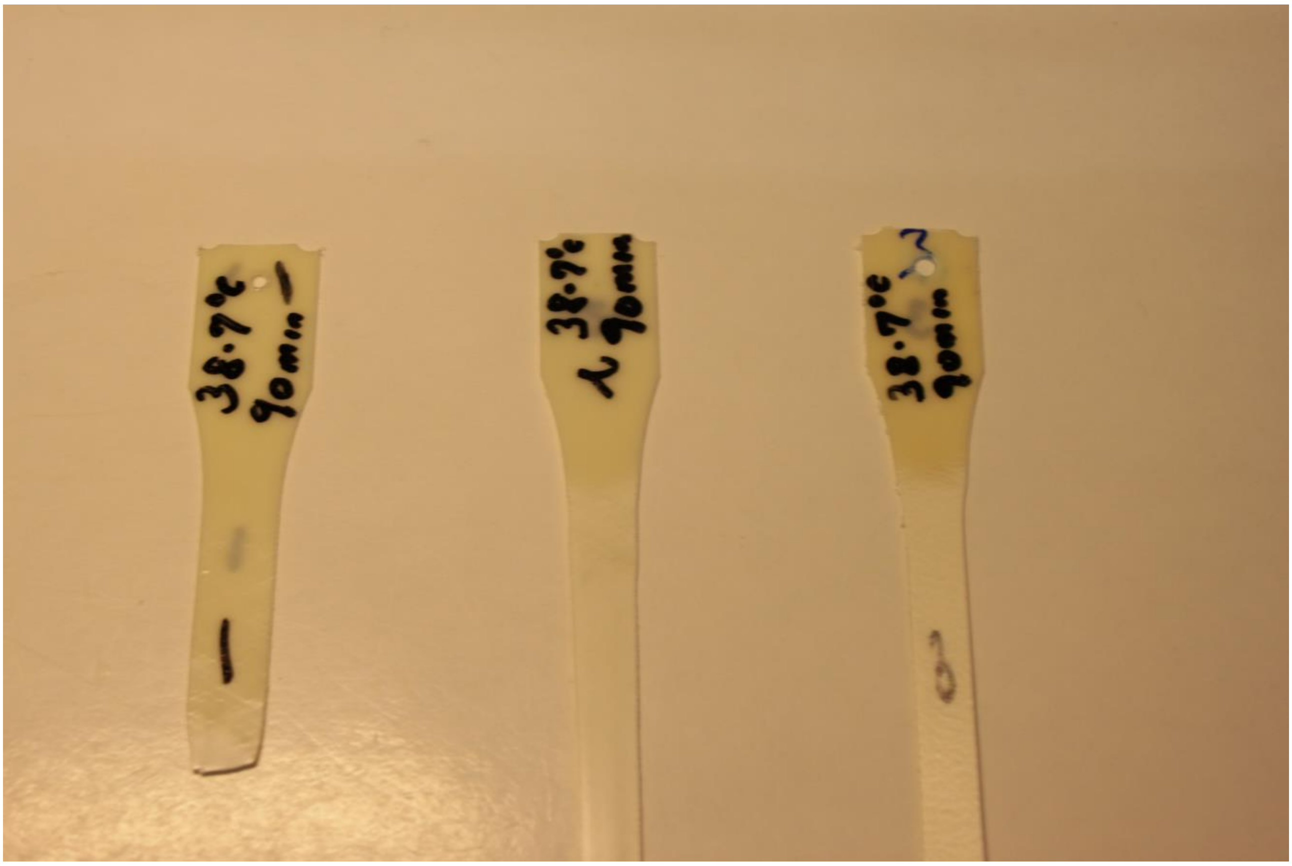


Figure 28: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 38.7°C for 90 minutes. Polyvinyl chloride (PVC) 1, 2 and 3 were subjected to loading on the testometric tensile testing machine in the plastic laboratory has all surfaces delaminated which is most noticeable in 1, and least noticeable in 2 and 3. The edges of I, 2 and 3 polyvinyl chlorides (PVC) are all smooth as shown in the diagram of figure 28 above. Elongation at break point is highest in polyvinyl chloride 3, followed by 2 and least in 1 as depicted on the appendix page.

8.9.7 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 49.8°C FOR 90 MINUTES.

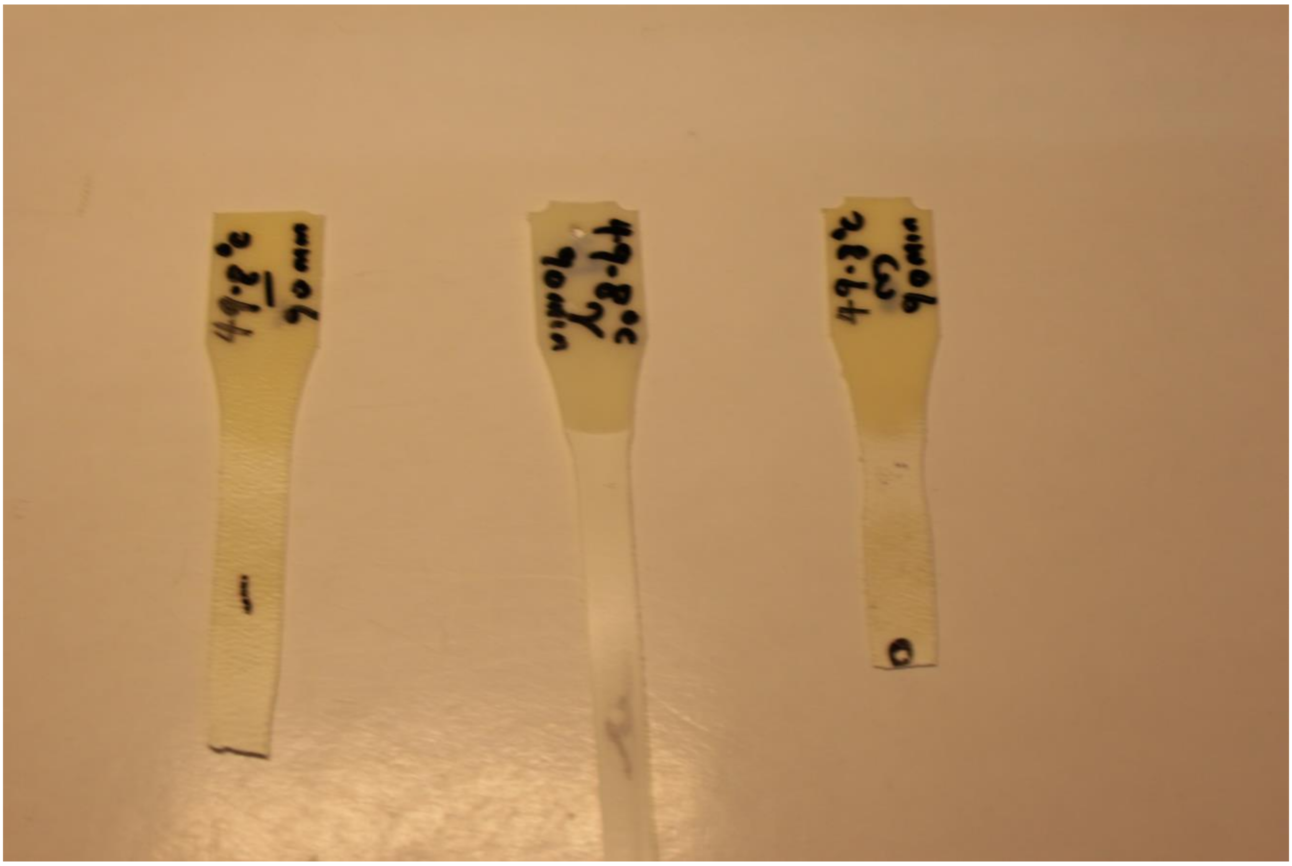


Figure 29: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 49.8°C for 90 minutes. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine in the plastic laboratory has all surfaces delaminated which is most noticeable in 1 and 3, and least noticeable in 2. The edges of I, 2 and 3 polyvinyl chlorides (PVC) are all smooth, it is illustrated on the graph in figure 29 above. Elongation at break point is highest in polyvinyl chloride 2 (PVC 2), followed by 3 and least elongation in 1, it can be found on the graph at the appendix page.

8.9.8 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 60.7°C FOR 90 MINUTES.

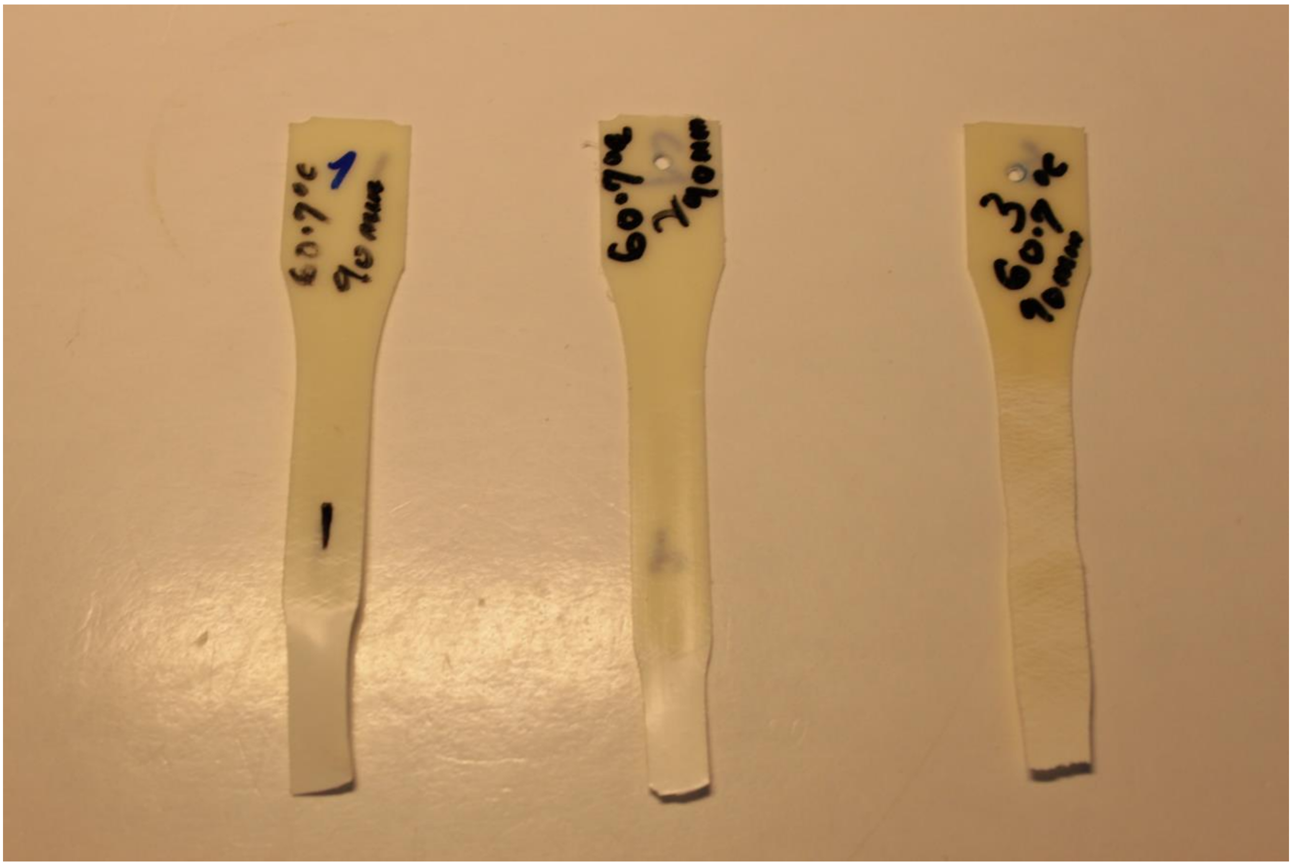


Figure 30: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 60.7°C for 90 minutes in the oven. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine in the plastic laboratory has all surfaces delaminated which is most noticeable in polyvinyl chloride (PVC) 1, and least noticeable in 2 and 3 when viewed under the light in figure 30. The edge of polyvinyl chloride (PVC) is smooth at the break point, 2 and 3 polyvinyl chlorides (PVCs) edges are all rough at the break point. Elongation at break point is highest in polyvinyl chloride 3 (PVC), followed by 1 and least in 2 as illustrated on the appendix page.

8.9.9 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 75.2°C FOR 90 MINUTES.

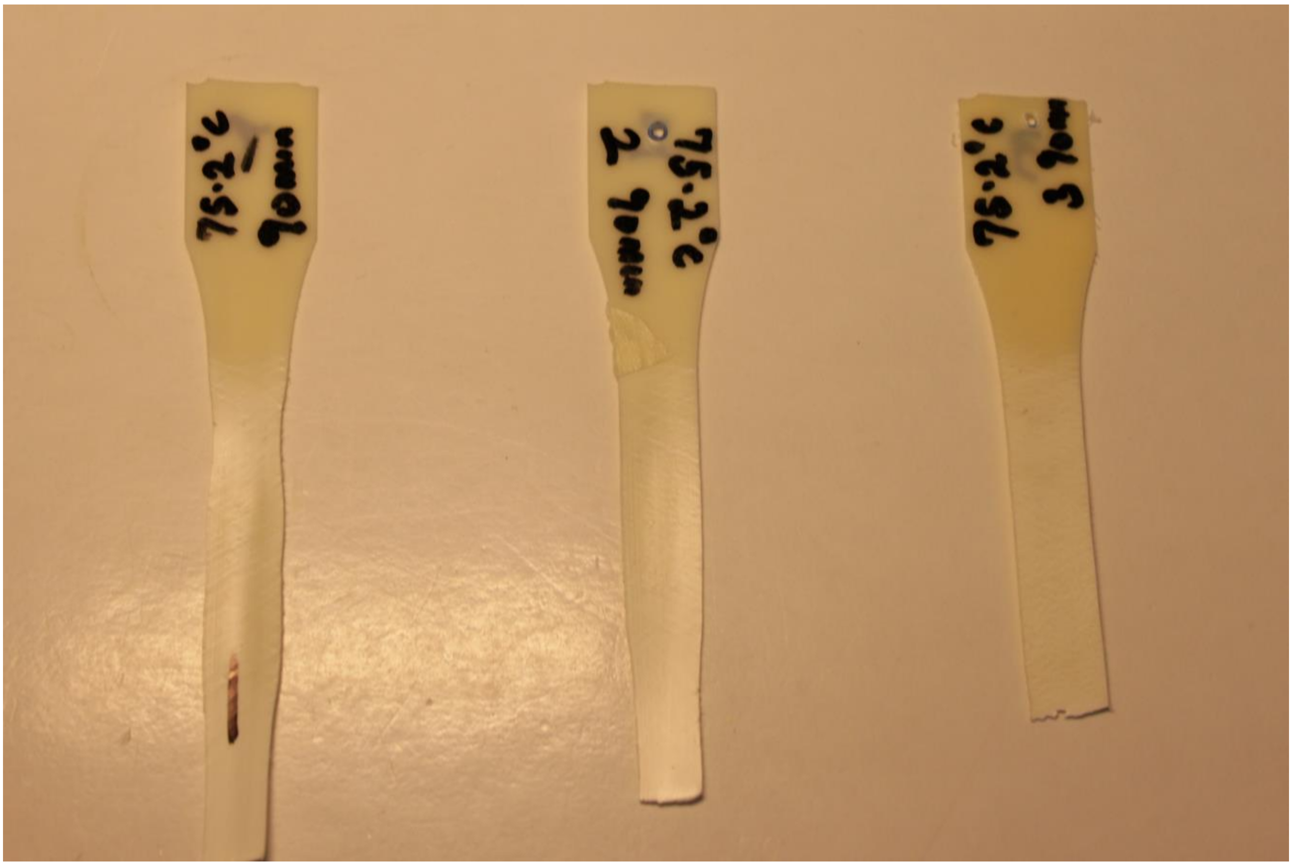


Figure 31: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 60.7°C for 90 minutes in the oven in plastic laboratory. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine in the plastic laboratory, has all delaminated surfaces which is noticeable in polyvinyl chloride (PVC) 1, 2 and 3 when viewed under the light as illustrated in the above diagram in figure 31. The edge of polyvinyl chloride (PVC) is smooth at the break point 1, and slightly rough at 2, but rough at 3. Elongation at break point is highest in polyvinyl chloride (PVC) 1, followed by 2 and least in 3 as shown on the graph on the appendix page.

8.1.0.0 POLYVINYL CHLORIDE (PVC) 1, 2 AND 3 HEATED AT TEMPERATURE 80.1°C FOR 90 MINUTES.

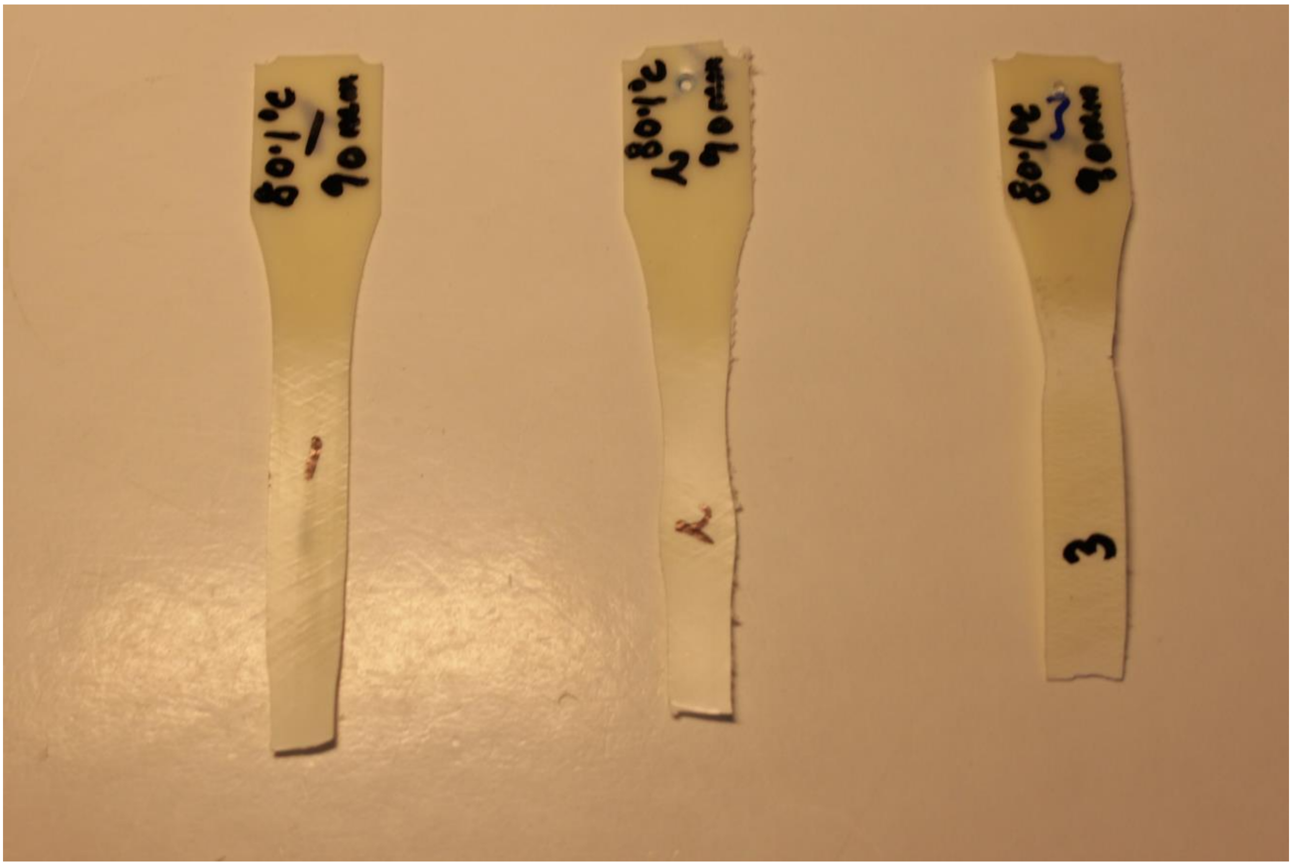


Figure 32: Pictorial view of 1, 2, and 3 polyvinyl chloride (PVC) when viewed under light

Polyvinyl chloride (PVC) 1, 2 and 3 were heated at temperature 80.1°C for 90 minutes in the oven in plastic laboratory. Polyvinyl chloride (PVC) 1, 2 and 3 when subjected to loading on the testometric tensile testing machine in the plastic laboratory has all surfaces delaminated, which are noticeable in polyvinyl chloride (PVC) 1, 2 and 3 when viewed under the light as shown in the figure 32 above. The edges of polyvinyl chloride (PVC) 1, 2 and 3 are all smooth at the break points. Elongation at break point is highest in polyvinyl chloride (PVC) 2, followed by 1 and least in 3 in the graph on the appendix page.

9. RESULTS

9.1 CUTTING METHODS

Table 5: Computer numerical control (CNC) milled cut and water cut (WC) laser methods of cutting polyvinyl strips into dog-bone shapes

CUTTING (PVC)	CNC (Computer numeric.cont.)	WC (water cut or laser)
1	Good	Poor
2	Good	Poor
3	Good	Poor

9.2 DELAMINATION

9.2.1 DELAMINATION AT ROOM TEMPERATURE (23°C)

For the following tables and analysis, the conditions of the polyvinyl chlorides (PVCs), such as poor, fair and good will be represented with the figures; 1, 2 and 3 respectively. That is;

1= Poor, 2= Fair and 3= Good.

Table 6: Polyvinyl chloride (PVC) 1, 2 and 3 delamination natures at room temperature (23°C)

PVC (1)	PVC (2)	PVC (3)	ROOM TEMP. (°C)
Poor	Poor	Fair	23

9.2.2 DELAMINATION AT 30 MINUTES

Table 7: Nature of delamination of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 30 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Poor	Good	Good	30	38.7
Poor	Poor	Good	30	49.8
Good	Good	Good	30	60.7
Good	Fair	Fair	30	75.2
Good	Fair	Good	30	80.1

9.2.3 DELAMINATION AT 60 MINUTES

Table 8: Nature of delamination of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 60 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Fair	Good	Good	60	38.7
Poor	Poor	Good	60	49.8
Good	Fair	Fair	60	60.7
Fair	Good	Good	60	75.2
Fair	Fair	Good	60	80.1

9.2.4 DELAMINATION AT 90 MINUTES

Table 9: Nature of delamination of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 90 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Fair	Fair	Good	90	38.7
Good	Poor	Good	90	49.8
Fair	Fair	Good	90	60.7
Good	Fair	Fair	90	75.2
Good	Fair	Fair	90	80.1

9.3 SMOOTHNESS

9.3.1 SMOOTHNESS AT ROOM TEMPERATURE (23°C)

Table 10: Nature of smoothness of polyvinyl chlorides (PVCs) 1, 2 and 3 at room temperature (23°C)

PVC (1)	PVC (2)	PVC (3)	ROOM TEMP. (°C)
Good	Good	Fair	23

9.3.2 SMOOTHNESS AT 30 MINUTES

Table 11: Nature of smoothness of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 30 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Good	Poor	Poor	30	38.7
Good	Good	Poor	30	49.8
Poor	Poor	Poor	30	60.7
Poor	Fair	Poor	30	75.2
Good	Fair	Poor	30	80.1

9.3.3 SMOOTHNESS AT 60 MINUTES

Table 12: Nature of smoothness of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 60 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Poor	Poor	Poor	60	38.7
Good	Good	Poor	60	49.8
Poor	Fair	Poor	60	60.7
Fair	Poor	Poor	60	75.2
Fair	Fair	Poor	60	80.1

9.3.4 SMOOTHNESS AT 90 MINUTES

Table 13: Nature of smoothness of polyvinyl chlorides (PVCs) 1, 2 and 3 at different temperatures when heated for 90 minutes

PVC (1)	PVC (2)	PVC (3)	TIME (minutes)	TEMP. (°C)
Fair	Fair	Fair	90	38.7
Poor	Good	Poor	90	49.8
Fair	Fair	Poor	90	60.7
Poor	Poor	Poor	90	75.2
Poor	Poor	Fair	90	80.1

9.3.5 POLYVINYL CHLORIDE (PVC) 1 AT DELAMINATION

Table 14: Temperature / natures of polyvinyl chloride 1 (PVC 1) at heating time of 30, 60 and 90 minutes for delamination

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	1	2	2
49.8	1	1	3
60.7	3	3	2
75.2	3	2	3
80.1	3	2	3

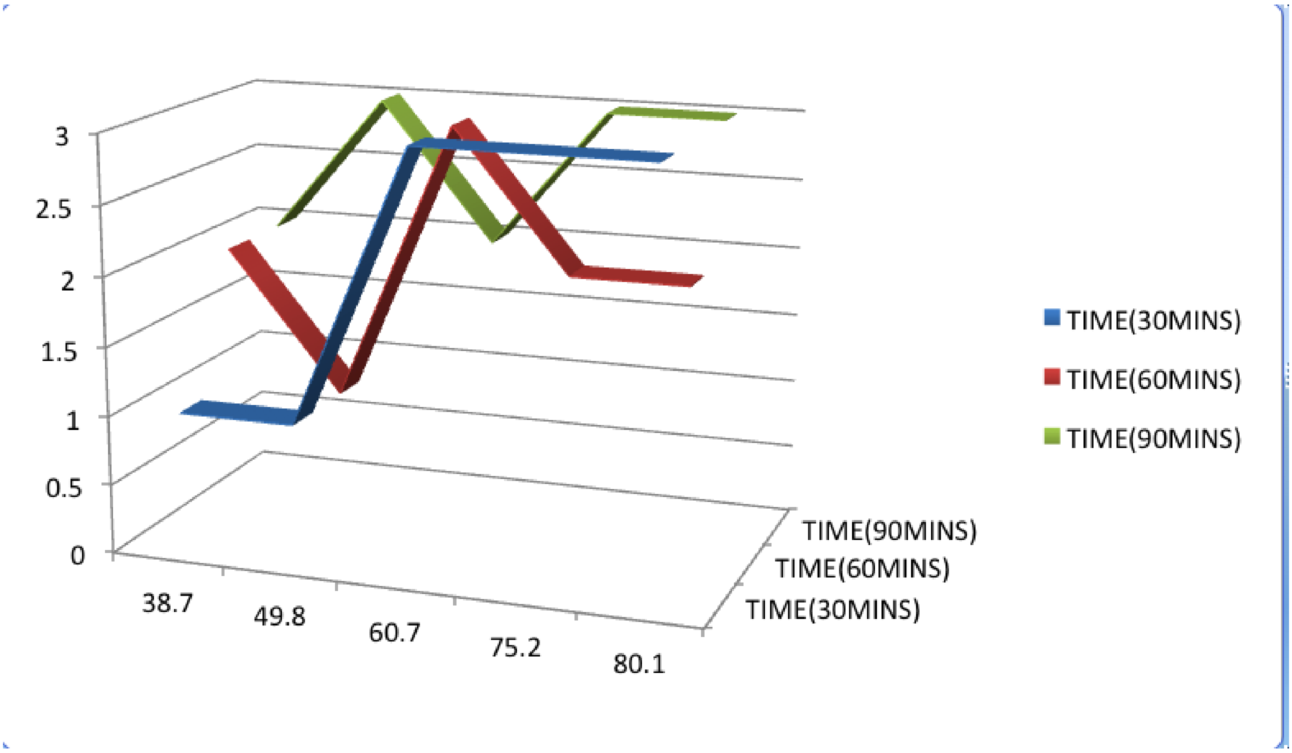


Figure 33: 3D-Graph of temperature/nature of polyvinyl chloride 1 (PVC 1) at delamination

From the above table and 3-dimensional graph of polyvinyl chloride 1(PVC 1), the delamination was not noticed at the initial (38.7°C) and second temperature (49.8°C) when subjected to loading on the testometric-testing machine. As the temperature increases, the values of the delamination increase and remain the same till it get to temperature of 80.1°C at heating time of 30 minutes.

At heating time of 60 minutes at different temperatures, the delaminations were noticed and disappear. As the temperature was further increased, it shown complete delamination and further heating reduced the delaminated nature to fair.

Further heating for 90 minutes shows that for the first 3 temperatures, the delamination nature fluctuates. At the last 2 temperatures of 75.2°C and 80.1°C, the delamination was excellently noticed. It has impact on delamination when the temperature is increased due to the percentage of the additives and this gives irregular steeping of the values on the graphs.

9.3.6 POLYVINYL CHLORIDE (PVC) 2 AT DELAMINATION

Table 15: Temperature / natures of polyvinyl chloride 2 (PVC 2) at heating time of 30, 60 and 90 minutes for delamination

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	3	3	2
49.8	1	1	1
60.7	3	2	2
75.2	2	3	2
80.1	2	2	2

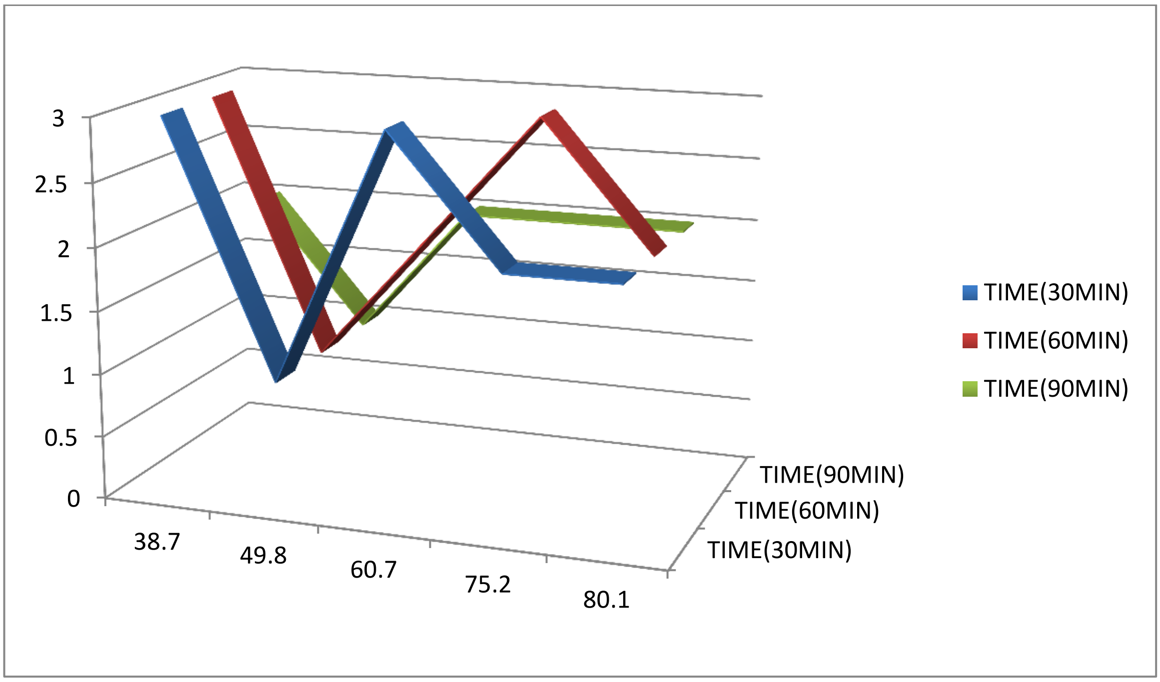


Figure 34: 3D-Graph of temperature/nature of polyvinyl chloride 2 (PVC 2) at delamination

As seen from the above table and 3-dimensional graph of polyvinyl chloride 2(PVC 2), the delamination was completely noticed at the initial temperature (38.7°C), it was not noticed at temperature of 49.8°C when subjected to loading on the testometric-testing machine. As the temperature increases, the delamination increase and reduced when it got to temperature of 75.2°C.The delamination remain the same till it get to temperature of 80.1°C at heating time of 30 minutes.

At heating time of 60 minutes at different temperatures for different polyvinyl chloride (PVC) as illustrated in the table and graph, the delamination's were noticed and disappear. As the temperature was further increased, it shown little delamination and further heating depict complete delamination. At temperature of 80.1°C, the delaminated nature was fair.

Further heating for 90 minutes at 38.7°C shows the delamination to be fairly noticed. At 49.8°C, the delamination was not felt. When the remaining polyvinyl chlorides (PVCs) was heated at temperatures of 60.7°C, 75.2°C and 80.1°C respectively, the delaminated nature remain fairly the same. Additives percentage will determine how the polyvinyl chloride (PVC) will behave when subjected to heat and loading.

9.3.7 POLYVINYL CHLORIDE (PVC) 3 AT DELAMINATION

Table 16: Temperature / natures of polyvinyl chloride 3 (PVC 3) at heating time of 30, 60 and 90 minutes for delamination

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	3	3	3
49.8	3	3	3
60.7	3	2	3
75.2	2	3	2
80.1	3	3	2

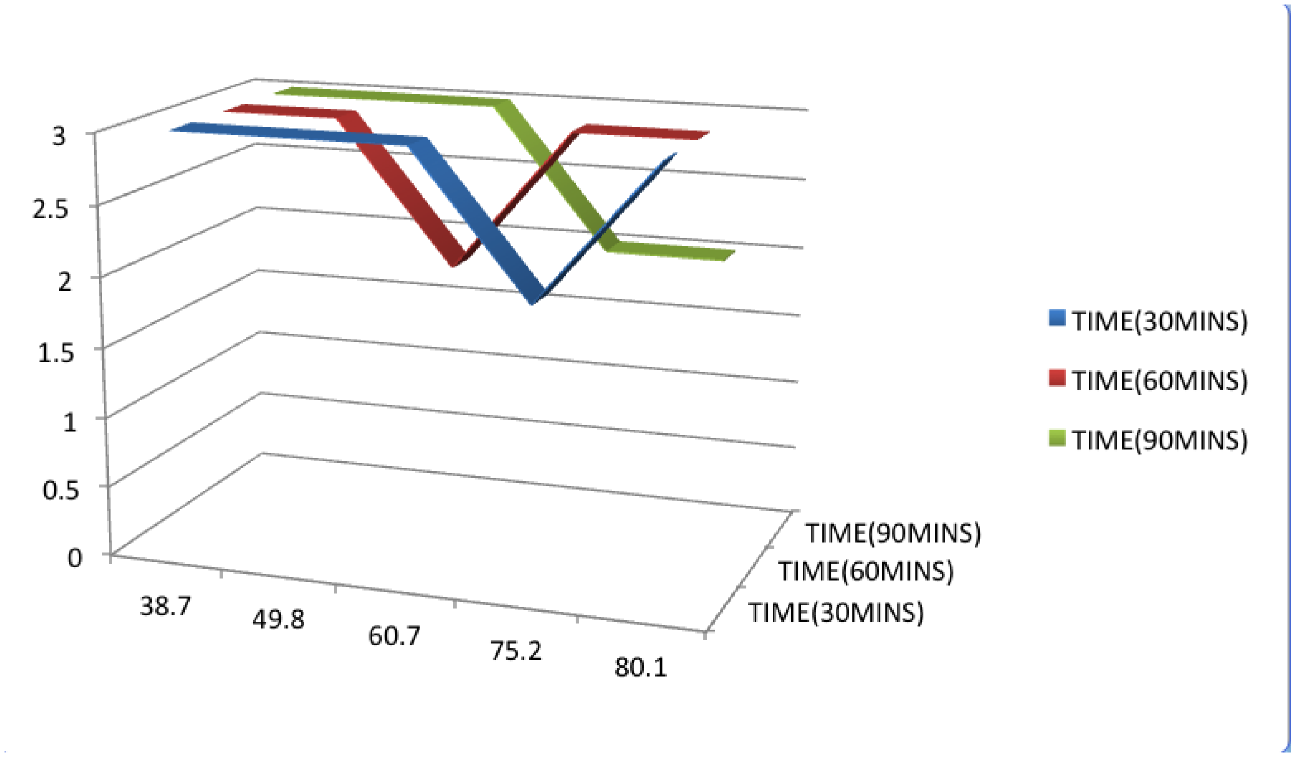


Figure 35: 3D -Graph of temperature/nature of polyvinyl chloride 3 (PVC 3) at delamination

As illustrated from the above table and 3-dimensional graph of polyvinyl chloride 3 (PVC 3), the delamination was completely noticed at the temperatures 38.7°C, 49.8°C and 60.7°C for the three (3) polyvinyl chloride 3 (PVC 3). It was fairly noticed at temperature of 75.2°C. As the temperature increases to 80.1°C, the delamination increased and was clearly visible. The nature of the whole delamination was noticed as each heated polyvinyl chlorides (PVCs) at different temperatures was subjected to load on the testometric tensile testing machine.

At heating time of 60 minutes at different temperatures for different polyvinyl chlorides (PVCs), as illustrated in the table and graph above. The delamination's were easily noticed at the first, second and third temperatures. As the temperature was further increased, it shown little (fair) delamination for the rest temperatures of 75.2°C and 80.1° when subjected to load on the testometric tensile testing machine.

Continuous heating for 90 minutes at temperatures of 38.7°C, 49.8°C and 60.7°C shows the delamination to be perfectly noticed. At temperatures 75.2°C and 80.1°C, the delamination was fairly noticed when subjected to load on the testometric tensile testing machine.

9.3.8 POLYVINYL CHLORIDE (PVC) 1 AT SMOOTHNESS

Table 17: Temperature / natures of polyvinyl chloride 1 (PVC 1) at heating time of 30, 60 and 90 minutes for smoothness

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	3	1	2
49.8	3	3	1
60.7	1	1	2
75.2	1	2	1
80.1	3	2	1

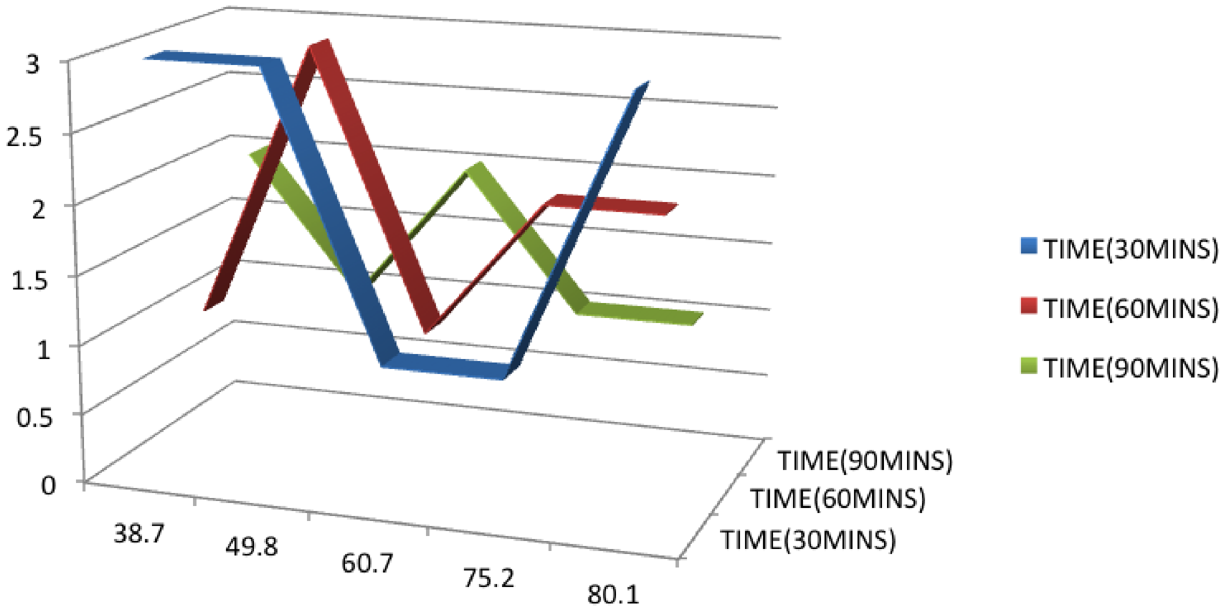


Figure 36: 3D-Graph of temperature/nature of polyvinyl chloride 1 (PVC 1) at smoothness

As illustrated from the above table and 3-dimensional graph of polyvinyl chloride 1 (PVC 1), the smoothness was completely noticed at the temperatures 38.7°C and 49.8°C for the two (2) polyvinyl chlorides 1 (PVC 1) for 30 minutes. The smoothness was poor at temperature of 60.7°C and 75.2°C. As the temperature increases to 80.1°C, the polyvinyl chloride smoothness was noticed at the given temperature when subjected to load on the testometric tensile testing machine.

At heating time of 60 minutes, at different temperatures for different polyvinyl chlorides (PVCs), as illustrated in the table and graph above. The natures of the polyvinyl chlorides (PVCs) smoothness were fluctuating from poor to good and later diminished to poor. Further temperature increase for the rest polyvinyl chloride 1(PVC 1) from temperature 75.2°C and 80.1°C make the smoothness appear fair when subjected to load on the testometric tensile testing machine.

Continuous heating for 90 minutes at temperatures of 38.7°C shows the smoothness to be fairly noticed. It later diminished to poor for polyvinyl chloride 1(PVC 1) at 49.8°C, and at temperatures 60.7°C, the smoothness was fair. Further temperature increment reduced the smoothness nature to poor for the rest two (2) temperatures when subjected to load on the testometric tensile testing machine.

9.3.9 POLYVINYL CHLORIDE (PVC) 2 AT SMOOTHNESS

Table 18 : Temperature / natures of polyvinyl chloride 2 (PVC 2) at heating time of 30, 60 and 90 minutes for smoothness

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	1	1	2
49.8	3	3	3
60.7	1	2	2
75.2	2	1	1
80.1	2	2	1

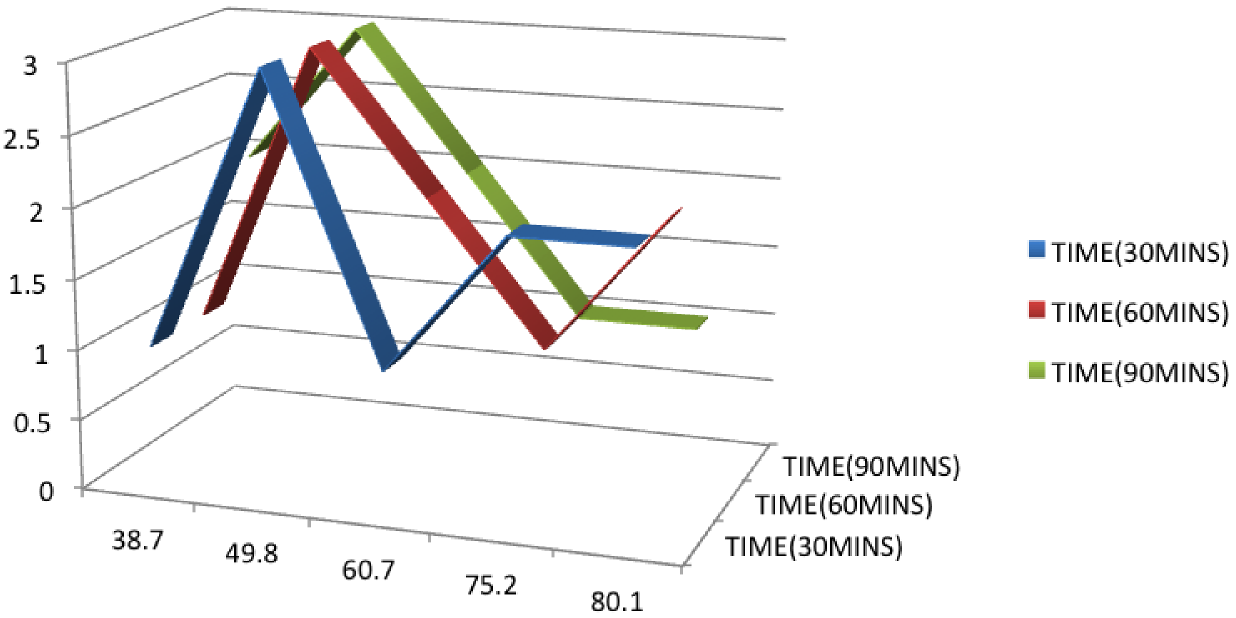


Figure 37: 3D-graph of temperature/nature of polyvinyl chloride 2 (PVC 2) at smoothness

As illustrated from the above table and 3-dimensional graph of polyvinyl chloride 2 (PVC 2), the smoothness was completely unnoticed at the temperatures 38.7°C. At temperature of 49.8°C, the smoothness was perfectly noticed. But at 60.7°C for polyvinyl chloride 2 (PVC 2) heated for 30 minutes, the smoothness was perfectly poor. For the two (2) polyvinyl chlorides 2 (PVC 2) for 30 minutes at temperatures of 75.2°C and 80.1°C, The smoothness was fairly noticed. All these are as a result of subjecting it to loads on the testometric tensile testing machine.

At heating time of 60 minutes at different temperatures for different polyvinyl chlorides 2 (PVCs 2), as illustrated in the table and 3-D graph above. The natures of the polyvinyl chlorides (PVCs) smoothness were fluctuating from poor to good and later diminished to fair. Further temperature increase for the rest polyvinyl chloride 2 (PVC 2) from temperature 75.2°C and 80.1°C make the smoothness appear from poor to fair when subjected to load on the testometric tensile testing machine.

Continuous heating for 90 minutes at temperatures of 38.7°C shows the smoothness to be fairly noticed. For polyvinyl chloride 2 (PVC 2) at temperature 49.8°C, the smoothness was easily noticed. At 60.7°C for 90 minutes, the smoothness was fair. Further heating of the two (2) polyvinyl chlorides (PVCs 2) at temperatures of 75.2°C and 80.1°C for 90 minutes shows both smoothness to be poor. All the results were based on the subjection to loading on the testometric tensile testing machine.

9.4.0 POLYVINYL CHLORIDE (PVC) 3 AT SMOOTHNESS

Table 19: Temperature / natures of polyvinyl chloride 3 (PVC 3) at heating time of 30, 60 and 90 minutes for smoothness

TEMPERATURE (°C)	TIME (30MINS)	TIME (60MINS)	TIME (90MINS)
38.7	1	1	2
49.8	1	1	1
60.7	1	1	1
75.2	1	1	1
80.1	1	1	2

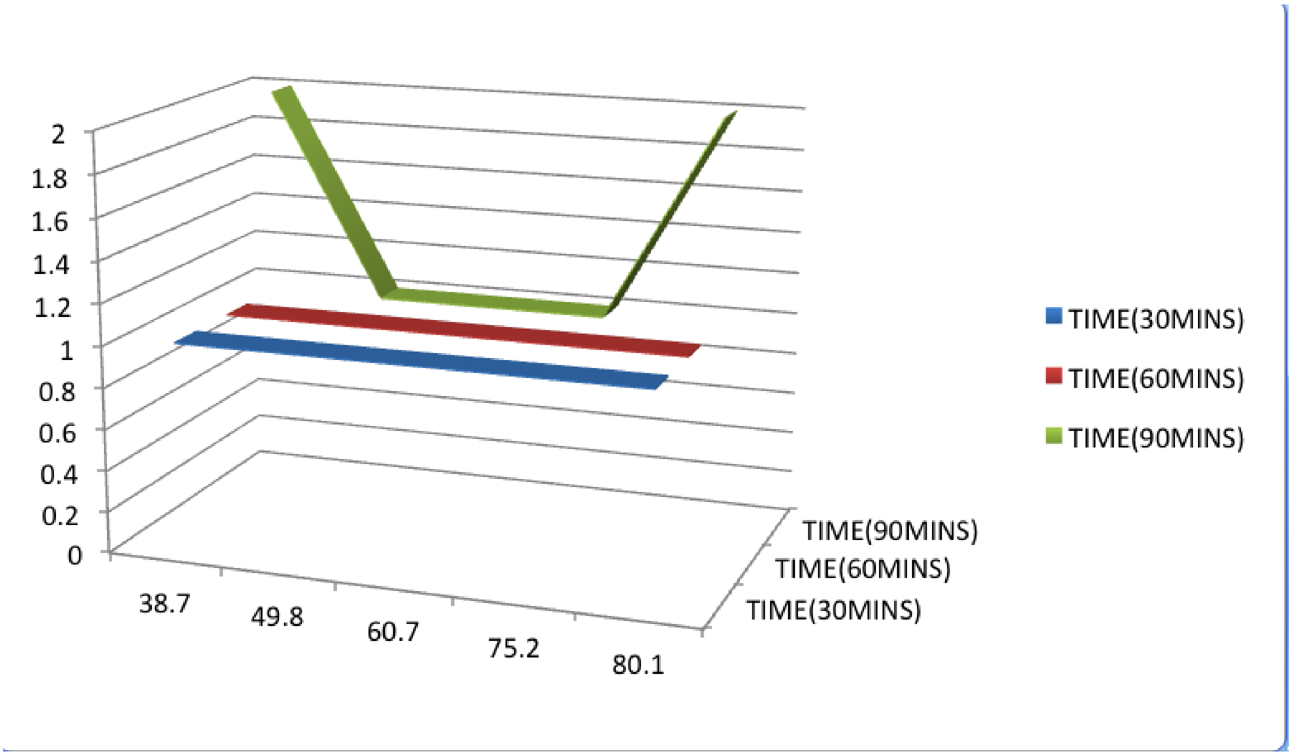


Figure 38: 3D-Graph of temperature/nature of polyvinyl chloride 3 (PVC 3) at smoothness

As illustrated from the above table and 3-dimensional graph of polyvinyl chloride 3 (PVC 3), the smoothness was completely unnoticed for the whole temperatures for the 30 minutes and 60 minutes heating.

At Heating time 90 minutes for polyvinyl chloride 3(PVC 3), the smoothness was fairly noticed at 38.7°. Polyvinyl chlorides 3 (PVC 3) at different temperatures of 49.8°C, 60.7°C, and 75.2°C smoothness were very poor. Further heating of the polyvinyl chloride 3 (PVC 3) at 80.1°C shows the smoothness to be fairly noticed.

10. CONCLUSION

In the course of the thesis work of mechanical and structural changes of polyvinyl chloride (PVC) when subjected to heating, two (2) methods of cutting was provided to cut out strips of three (3) polyvinyl chlorides (PVCs) of different additives into dog-bone shapes. The two (2) methods of cutting are; milled cut and water or laser cut.

The milled cut was chosen due to the nature of the polyvinyl chloride (PVC) strips, which are easy to cut on the computer numerical control machine with a well-designed die.

The mechanical properties of the three (3) polyvinyl chlorides (PVCs); Norvinyl S6045, Norvinyl S6045 and Norvinyl S6545 depends on the percentage (%) of the additives that made up the Polyvinyl chloride (PVC) strips. The stress-strain testometric tables and graphs shows the mechanical properties like elongation at yield, peak and break point when heated and taken to the testometric-testing machine. The stresses and strains at each point when the loads are increased are indicated on the graphs before and after the material shear or fail.

The structural aspect is the appearance of the nature of the material when it is drawn or subjected to loading on the testometric machine. More often than not, polyvinyl chloride (PVC) has shining or delaminated surface appearance due to the changes in the lattice arrangement of the atoms that bind the polymer together due to heating and application of load force on the testometric tensile testing machine. That is, the heat and load which it is subjected to cause it to maintain or change its surface nature.

In conclusion, temperatures, time of heating and additives have a tremendous part to play in the behavior and use of polyvinyl chlorides (PVC). For the proper usage of the polyvinyl chloride (PVC) materials, it must not be subjected to too high temperatures and heavy loadings in order not to fail and be used properly.

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APPENDICIES

APPENDIX 1

1/4

POLYVINYL CHLORIDE (PVC)
CHEMICAL RESISTANCE DATA

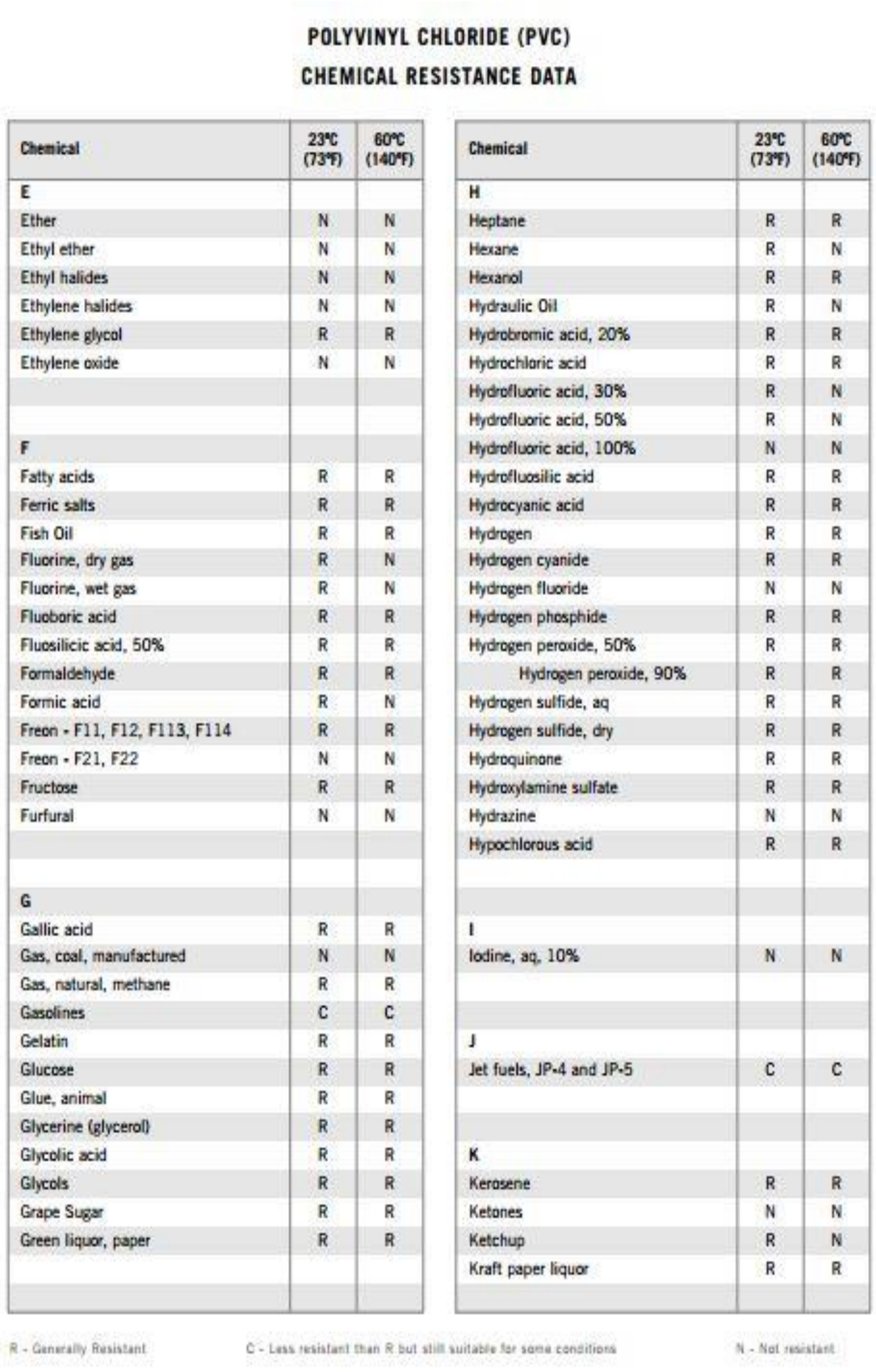
Chemical	23°C (73°F)	60°C (140°F)
C		
Cadmium Cyanide	R	R
Calcium salts	R	R
except Calcium bisulfide	N	N
Calcium hypochlorite, 30%	R	R
Calcium hydroxide	R	R
Calcium Nitrate	R	R
Calcium Oxide	R	R
Calcium Sulfate	R	R
Camphor	R	N
Cane sugar liquors	R	R
Carbon disulfide	N	N
Carbon dioxide	R	R
Carbon dioxide, aq	R	R
Carbon monoxide	R	R
Carbitol	R	N
Carbon tetrachloride	R	N
Carbonic Acid	R	R
Castor oil	R	R
Caustic potash, (potassium hydroxide), 50%	R	R
Caustic soda, (sodium hydroxide), < 40%	R	R
Cellosolve	R	N
Cellosolve acetate	R	N
Chloral hydrate	R	R
Chloramine, dilute	R	N
Chloric acid, 20%	R	R
Chlorine, gas, dry	C	N
Chlorine, gas, wet	N	N
Chlorine, liquid	N	N
Chlorine water	R	R
Chloracetic acid, 50%	R	R
Chloroacetyl Chloride	R	N
Chlorobenzene	N	N
Chlorobenzyl chloride	N	N
Chloroform	N	N
Chloropicrin	N	N
Chlorosulfonic acid	R	N
Chromic acid, 10%	R	R
Chromic acid, 30%	R	R
Chromic acid, 40%	R	C

Chemical	23°C (73°F)	60°C (140°F)
Chromic acid, 50%	N	N
Chromium potassium sulfate	R	N
Citric acid	R	R
Coconut oil	R	R
Coffee	R	R
Coke oven gas	R	R
Copper acetate	R	N
Copper salts, aq	R	R
Corn oil	R	R
Corn syrup	R	R
Cottonseed oil	R	R
Cresote	N	N
Cresol, 90%	N	N
Cresylic acid, 50%	R	R
Croton aldehyde	N	N
Crude oil, sour	R	R
Cupric Salts, aq	R	R
Cyclohexane	N	N
Cyclohexanol	N	N
Cyclohexanone	N	N
D		
Detergents, aq	R	R
Dextrin	R	R
Dextrose	R	R
Dibutoxyethyl phthalate	N	N
Diesel fuels	R	R
Diethylamine	N	N
Diethyl Ether	R	N
Disodium phosphate	R	R
Diglycolic acid	R	R
Dioxane -1,4	N	N
Dimethylamine	R	R
Dimethyl formamide	N	N
Dibutyl phthalate	N	N
Dibutyl sebacate	R	N
Dichlorobenzene	N	N
Dichloroethylene	N	N

R - Generally Resistant

C - Less resistant than R but still suitable for some conditions

N - Not resistant

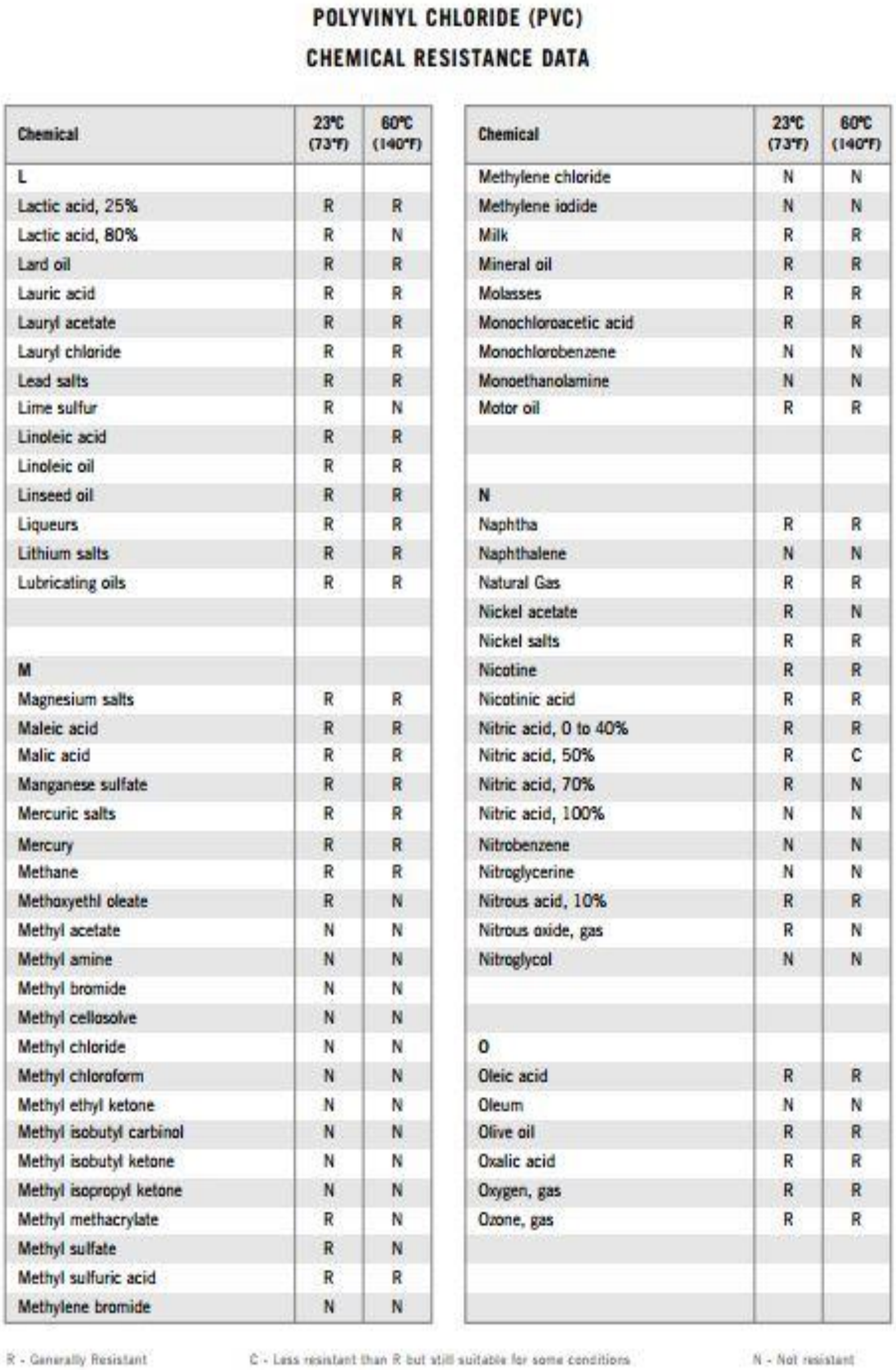


POLYVINYL CHLORIDE (PVC)
CHEMICAL RESISTANCE DATA

Chemical	23°C (73°F)	60°C (140°F)
E		
Ether	N	N
Ethyl ether	N	N
Ethyl halides	N	N
Ethylene halides	N	N
Ethylene glycol	R	R
Ethylene oxide	N	N
F		
Fatty acids	R	R
Ferric salts	R	R
Fish Oil	R	R
Fluorine, dry gas	R	N
Fluorine, wet gas	R	N
Fluoboric acid	R	R
Fluosilicic acid, 50%	R	R
Formaldehyde	R	R
Formic acid	R	N
Freon - F11, F12, F113, F114	R	R
Freon - F21, F22	N	N
Fructose	R	R
Furfural	N	N
G		
Gallic acid	R	R
Gas, coal, manufactured	N	N
Gas, natural, methane	R	R
Gasolines	C	C
Gelatin	R	R
Glucose	R	R
Glue, animal	R	R
Glycerine (glycerol)	R	R
Glycolic acid	R	R
Glycols	R	R
Grape Sugar	R	R
Green liquor, paper	R	R

Chemical	23°C (73°F)	60°C (140°F)
H		
Heptane	R	R
Hexane	R	N
Hexanol	R	R
Hydraulic Oil	R	N
Hydrobromic acid, 20%	R	R
Hydrochloric acid	R	R
Hydrofluoric acid, 30%	R	N
Hydrofluoric acid, 50%	R	N
Hydrofluoric acid, 100%	N	N
Hydrofluosilic acid	R	R
Hydrocyanic acid	R	R
Hydrogen	R	R
Hydrogen cyanide	R	R
Hydrogen fluoride	N	N
Hydrogen phosphide	R	R
Hydrogen peroxide, 50%	R	R
Hydrogen peroxide, 90%	R	R
Hydrogen sulfide, aq	R	R
Hydrogen sulfide, dry	R	R
Hydroquinone	R	R
Hydroxylamine sulfate	R	R
Hydrazine	N	N
Hypochlorous acid	R	R
I		
Iodine, aq, 10%	N	N
J		
Jet fuels, JP-4 and JP-5	C	C
K		
Kerosene	R	R
Ketones	N	N
Ketchup	R	N
Kraft paper liquor	R	R

R - Generally Resistant C - Less resistant than R but still suitable for some conditions N - Not resistant



POLYVINYL CHLORIDE (PVC)
CHEMICAL RESISTANCE DATA

Chemical	23°C (73°F)	60°C (140°F)
L		
Lactic acid, 25%	R	R
Lactic acid, 80%	R	N
Lard oil	R	R
Lauric acid	R	R
Lauryl acetate	R	R
Lauryl chloride	R	R
Lead salts	R	R
Lime sulfur	R	N
Linoleic acid	R	R
Linoleic oil	R	R
Linseed oil	R	R
Liqueurs	R	R
Lithium salts	R	R
Lubricating oils	R	R
M		
Magnesium salts	R	R
Maleic acid	R	R
Malic acid	R	R
Manganese sulfate	R	R
Mercuric salts	R	R
Mercury	R	R
Methane	R	R
Methoxyethl oleate	R	N
Methyl acetate	N	N
Methyl amine	N	N
Methyl bromide	N	N
Methyl cellosolve	N	N
Methyl chloride	N	N
Methyl chloroform	N	N
Methyl ethyl ketone	N	N
Methyl isobutyl carbinol	N	N
Methyl isobutyl ketone	N	N
Methyl isopropyl ketone	N	N
Methyl methacrylate	R	N
Methyl sulfate	R	N
Methyl sulfuric acid	R	R
Methylene bromide	N	N

Chemical	23°C (73°F)	60°C (140°F)
Methylene chloride	N	N
Methylene iodide	N	N
Milk	R	R
Mineral oil	R	R
Molasses	R	R
Monochloroacetic acid	R	R
Monochlorobenzene	N	N
Monoethanolamine	N	N
Motor oil	R	R
N		
Naphtha	R	R
Naphthalene	N	N
Natural Gas	R	R
Nickel acetate	R	N
Nickel salts	R	R
Nicotine	R	R
Nicotinic acid	R	R
Nitric acid, 0 to 40%	R	R
Nitric acid, 50%	R	C
Nitric acid, 70%	R	N
Nitric acid, 100%	N	N
Nitrobenzene	N	N
Nitroglycerine	N	N
Nitrous acid, 10%	R	R
Nitrous oxide, gas	R	N
Nitroglycol	N	N
O		
Oleic acid	R	R
Oleum	N	N
Olive oil	R	R
Oxalic acid	R	R
Oxygen, gas	R	R
Ozone, gas	R	R

R - Generally Resistant

C - Less resistant than R but still suitable for some conditions

N - Not resistant

POLYVINYL CHLORIDE (PVC)
CHEMICAL RESISTANCE DATA

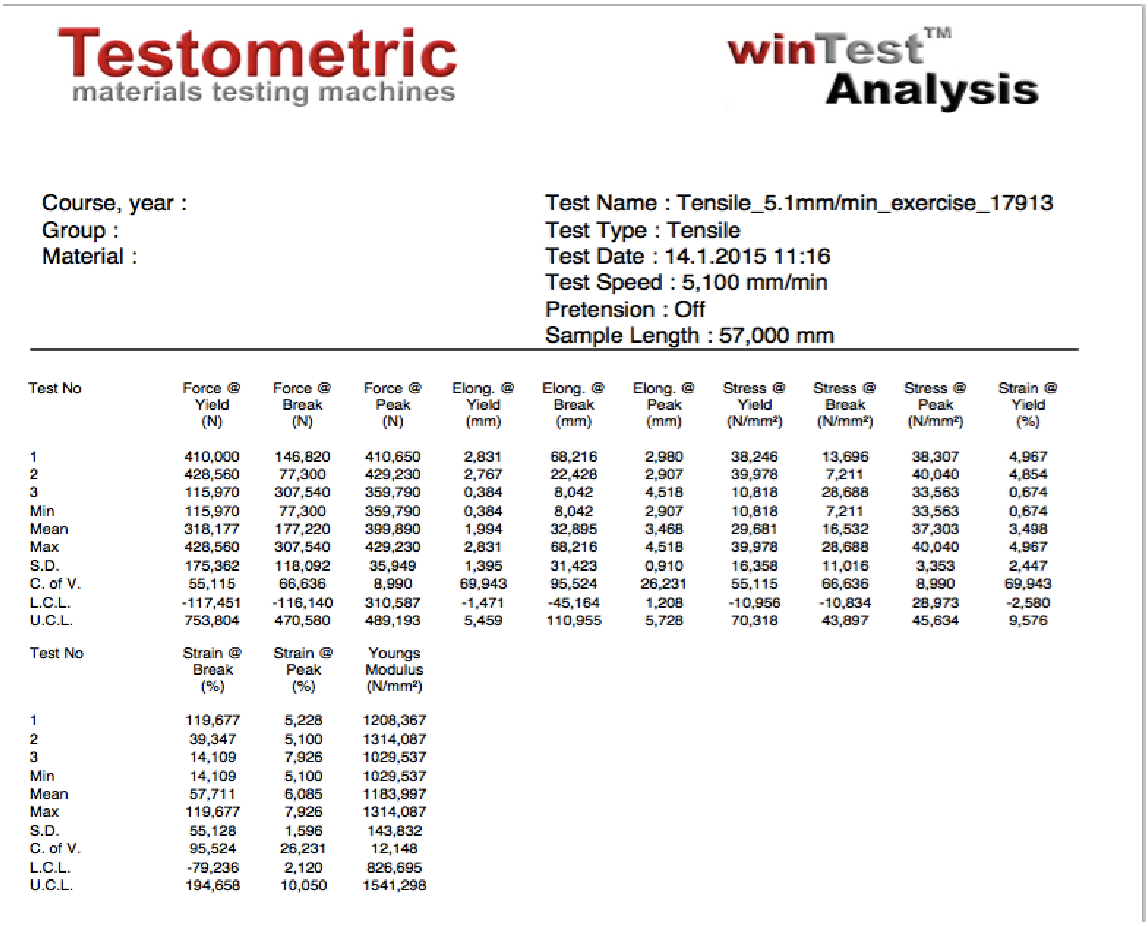
Chemical	23°C (73°F)	60°C (140°F)
P		
Palmitic acid, 10%	R	R
Palmitic acid, 70%	R	N
Paraffin	R	R
Pentane	C	C
Peracetic acid, 40%	R	N
Perchloric acid, 15%	R	N
Perchloric acid, 70%	R	N
Perchloroethylene	C	C
Perphosphate	R	N
Phenol	R	N
Phenylhydrazine	N	N
Phosphoric anhydride	R	N
Phosphoric acid	R	R
Phosphorus, yellow	R	N
Phosphorus, red	R	N
Phosphorus pentoxide	R	N
Phosphorus trichloride	N	N
Photographic chemicals, aq	R	R
Phthalic acid	C	C
Picric acid	N	N
Plating solutions, metal	R	R
Potash	R	R
Potassium amyl xanthate	R	N
Potassium salts, aq	R	R
except Potassium iodide	R	N
Potassium permanganate, 10%	R	R
Potassium permanganate, 25%	R	N
Propane	R	R
Propylene dichloride	N	N
Propylene oxide	N	N
Pyridine	N	N
Pyrogallic acid	R	N
R		
Rayon coagulating bath	R	R

Chemical	23°C (73°F)	60°C (140°F)
S		
Salicylic acid	R	R
Salicylaldehyde	N	N
Selenic acid, aq.	R	R
Silicic acid	R	R
Silicone oil	R	N
Silver salts	R	R
Soaps	R	R
Sodium salts, aq	R	R
except Sodium chlorite	N	N
except Sodium chlorate	R	N
except Sodium hypochlorite	R	N
Stannic chloride	R	R
Stannous chloride	R	R
Starch	R	R
Stearic acid	R	R
Stoddard solvent	N	N
Succinic acid	R	R
Sulfamic acid	N	N
Sulfate & Sulfite liquors	R	R
Sulfur	R	R
Sugars, aq	R	R
Sulfur dioxide, dry	R	R
Sulfur dioxide, wet	R	N
Sulfur trioxide, gas, dry	R	R
Sulfur trioxide, wet	R	N
Sulfuric acid, up to 80%	R	R
Sulfuric acid, 90 to 93%	R	N
Sulfuric acid, 94 to 100%	N	N
Sulfurous acid	R	R
T		
Tall Oil	R	R
Tannic acid	R	R
Tanning liquors	R	R
Tar	N	N
Tartaric acid	R	R
Terpineol	C	C
Tetrachloroethane	C	C

R - Generally Resistant   C - Less resistant than R but still suitable for some conditions   N - Not resistant

APPENDIX 2

1/15



Testometric
materials testing machines

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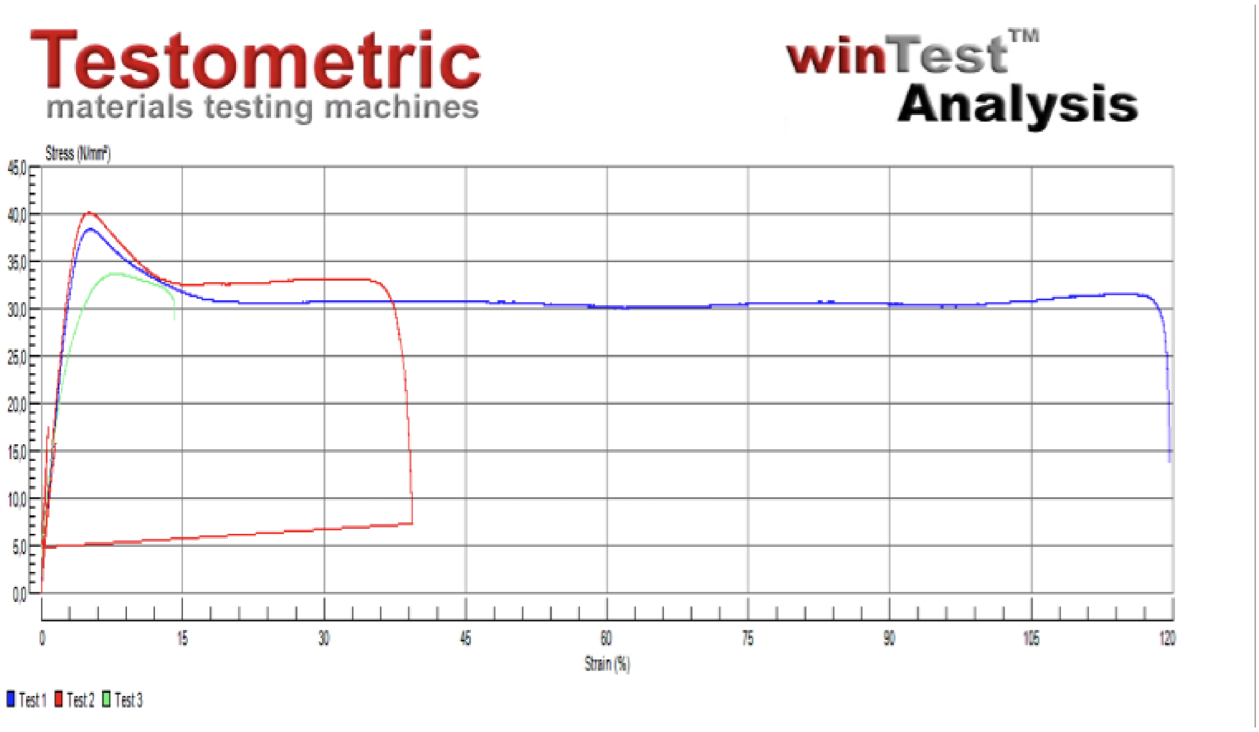
Analysis

Course, year :
Group :
Material :

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 14.1.2015 11:16
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm^2)	Stress @ Break (N/mm^2)	Stress @ Peak (N/mm^2)	Strain @ Yield (%)
1	410,000	146,820	410,650	2,831	68,216	2,980	38,246	13,696	38,307	4,967
2	428,560	77,300	429,230	2,767	22,428	2,907	39,978	7,211	40,040	4,854
3	115,970	307,540	359,790	0,384	8,042	4,518	10,818	28,688	33,563	0,674
Min	115,970	77,300	359,790	0,384	8,042	2,907	10,818	7,211	33,563	0,674
Mean	318,177	177,220	399,890	1,994	32,895	3,468	29,681	16,532	37,303	3,498
Max	428,560	307,540	429,230	2,831	68,216	4,518	39,978	28,688	40,040	4,967
S.D.	175,362	118,092	35,949	1,395	31,423	0,910	16,358	11,016	3,353	2,447
C. of V.	55,115	66,636	8,990	69,943	95,524	26,231	55,115	66,636	8,990	69,943
L.C.L.	-117,451	-116,140	310,587	-1,471	-45,164	1,208	-10,956	-10,834	28,973	-2,580
U.C.L.	753,804	470,580	489,193	5,459	110,955	5,728	70,318	43,897	45,634	9,576

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm^2)
1	119,677	5,228	1208,367
2	39,347	5,100	1314,087
3	14,109	7,926	1029,537
Min	14,109	5,100	1029,537
Mean	57,711	6,085	1183,997
Max	119,677	7,926	1314,087
S.D.	55,128	1,596	143,832
C. of V.	95,524	26,231	12,148
L.C.L.	-79,236	2,120	826,695
U.C.L.	194,658	10,050	1541,298



Testometric
materials testing machines

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Analysis

Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 16.1.2015 11:32
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	414,060	51,380	414,060	2,915	18,286	2,915	38,625	4,793	38,625	5,114
2	385,680	-41,670	385,680	2,707	17,882	2,707	35,978	-3,887	35,978	4,749
3	357,250	-50,290	357,390	2,338	10,236	2,376	33,326	-4,691	33,339	4,102
Min	357,250	-50,290	357,390	2,338	10,236	2,376	33,326	-4,691	33,339	4,102
Mean	385,663	-13,527	385,710	2,653	15,468	2,666	35,976	-1,262	35,980	4,655
Max	414,060	51,380	414,060	2,915	18,286	2,915	38,625	4,793	38,625	5,114
S.D.	28,405	56,376	28,335	0,292	4,536	0,272	2,650	5,259	2,643	0,513
C. of V.	7,365	-416,775	7,346	11,013	29,322	10,196	7,365	-416,775	7,346	11,013
L.C.L.	315,101	-153,573	315,321	1,927	4,201	1,991	29,394	-14,326	29,414	3,381
U.C.L.	456,226	126,520	456,099	3,379	26,735	3,341	42,558	11,802	42,547	5,929

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	32,081	5,114	1129,783
2	31,372	4,749	1187,483
3	17,958	4,168	1176,814
Min	17,958	4,168	1129,783
Mean	27,137	4,677	1164,693
Max	32,081	5,114	1187,483
S.D.	7,957	0,477	30,700
C. of V.	29,322	10,196	2,636
L.C.L.	7,370	3,493	1088,429
U.C.L.	46,904	5,862	1240,957

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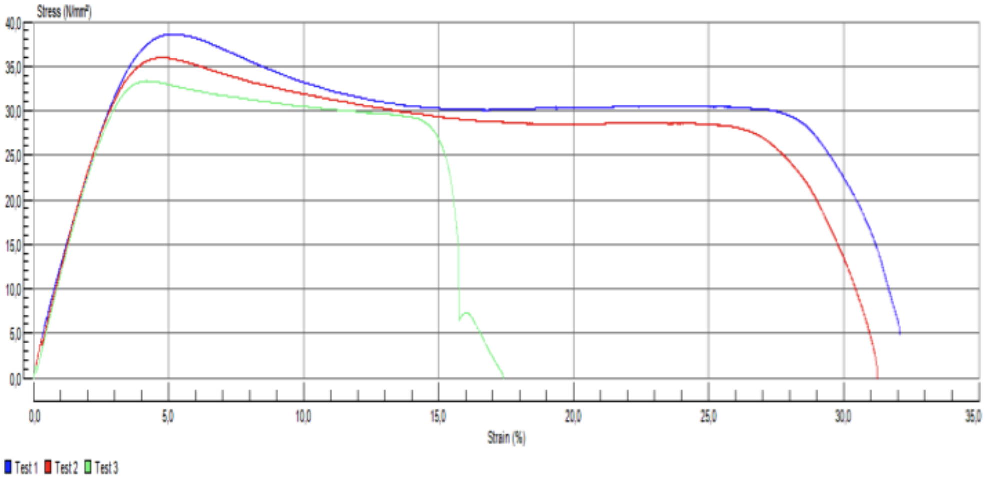

Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 11:42
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	415,130	40,690	415,510	2,805	26,400	2,918	38,725	3,796	38,760	4,921
2	362,120	-54,240	362,760	2,535	48,069	2,670	33,780	-5,060	33,840	4,447
3	368,720	-33,970	369,150	2,455	53,800	2,549	34,396	-3,169	34,436	4,307
Min	362,120	-54,240	362,760	2,455	26,400	2,549	33,780	-5,060	33,840	4,307
Mean	381,990	-15,840	382,473	2,598	42,756	2,712	35,633	-1,478	35,678	4,558
Max	415,130	40,690	415,510	2,805	53,800	2,918	38,725	3,796	38,760	4,921
S.D.	28,889	49,994	28,788	0,183	14,452	0,188	2,695	4,664	2,685	0,322
C. of V.	7,563	-315,622	7,527	7,058	33,801	6,935	7,563	-315,622	7,527	7,058
L.C.L.	310,225	-140,035	310,958	2,143	6,855	2,245	28,939	-13,063	29,007	3,759
U.C.L.	453,756	108,355	453,989	3,054	78,657	3,180	42,328	10,108	42,350	5,358

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	46,316	5,119	1144,930
2	84,332	4,684	1190,188
3	94,386	4,472	1184,200
Min	46,316	4,472	1144,930
Mean	75,011	4,758	1173,106
Max	94,386	5,119	1190,188
S.D.	25,354	0,330	24,584
C. of V.	33,801	6,935	2,096
L.C.L.	12,027	3,939	1112,034
U.C.L.	137,995	5,578	1234,178

Testometric
materials testing machines

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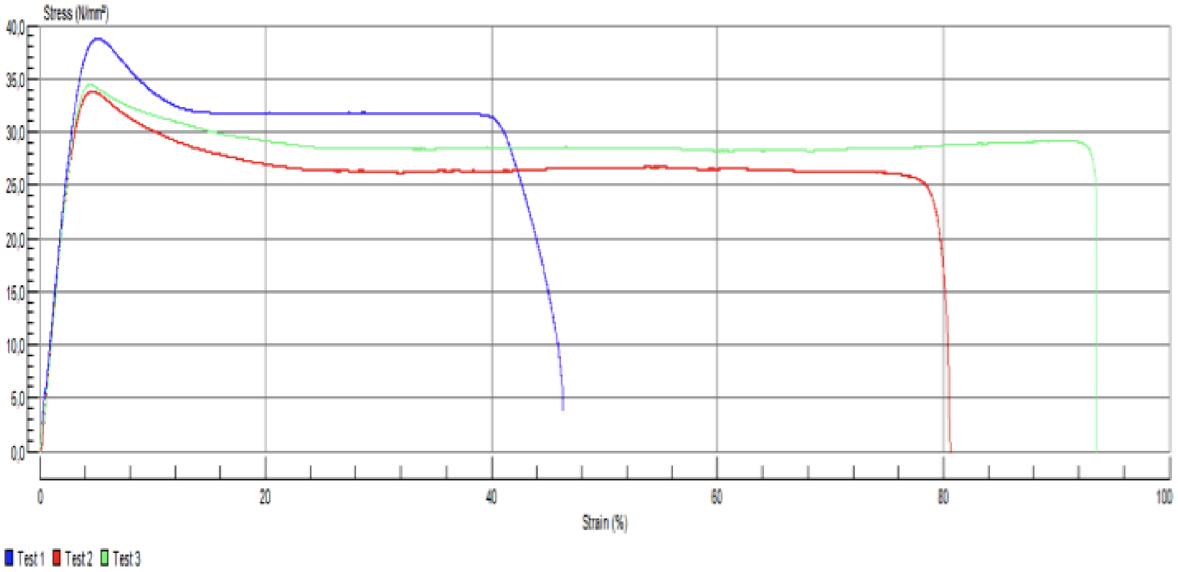
Analysis



Testometric
materials testing machines

winTest™ Analysis

Course, year : Thesis project, 2015
Group : Adelakin
Material : 49.8 deg

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 14.1.2015 12:27
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	395,780	173,980	395,870	2,890	69,550	2,910	36,920	16,229	36,928	5,070
2	142,080	-240,090	142,270	1,467	75,322	1,495	13,254	-22,396	13,271	2,574
3	388,390	37,600	388,390	2,645	20,608	2,645	36,230	3,507	36,230	4,640
Min	142,080	-240,090	142,270	1,467	20,608	1,495	13,254	-22,396	13,271	2,574
Mean	308,750	-9,503	308,843	2,334	55,160	2,350	28,801	-0,887	28,810	4,095
Max	395,780	173,980	395,870	2,890	75,322	2,910	36,920	16,229	36,928	5,070
S.D.	144,388	211,015	144,305	0,761	30,062	0,752	13,469	19,684	13,461	1,335
C. of V.	46,765	-2220,436	46,724	32,595	54,499	32,009	46,765	-2220,436	46,724	32,595
L.C.L.	-49,933	-533,701	-49,635	0,444	-19,518	0,481	-4,658	-49,786	-4,630	0,779
U.C.L.	667,433	514,694	667,321	4,224	129,838	4,219	62,261	48,012	62,250	7,410

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	122,018	5,105	1162,761
2	132,144	2,623	830,184
3	36,154	4,640	1158,296
Min	36,154	2,623	830,184
Mean	96,772	4,123	1050,414
Max	132,144	5,105	1162,761
S.D.	52,740	1,320	190,738
C. of V.	54,499	32,009	18,158
L.C.L.	-34,243	0,845	576,590
U.C.L.	227,787	7,401	1524,238

Testometric
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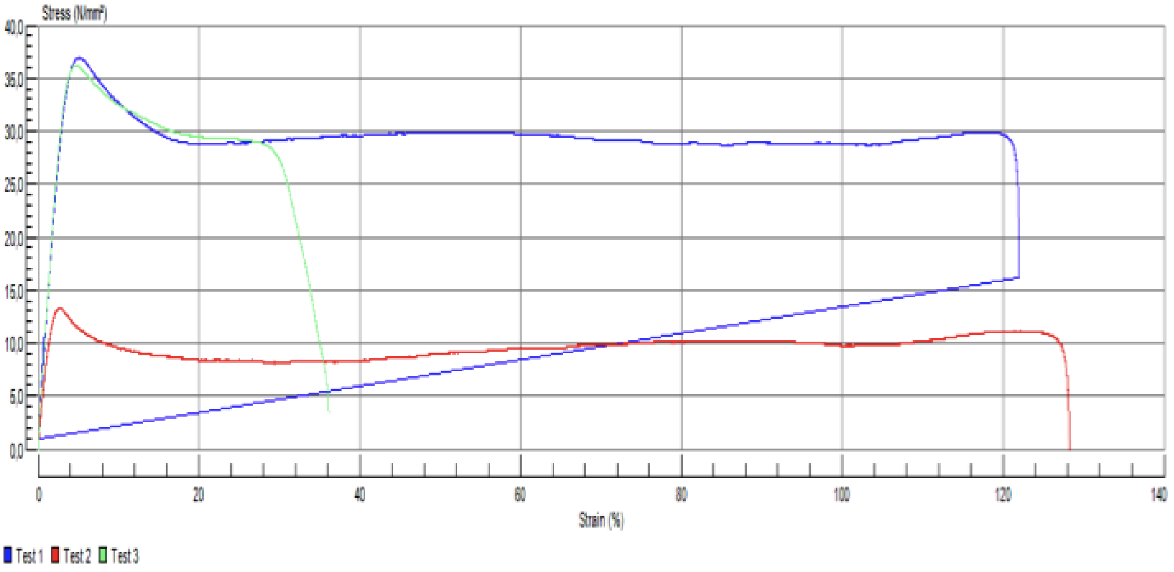

Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 16.1.2015 11:59
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	382,740	319,160	382,740	2,763	118,854	2,763	35,703	29,772	35,703	4,847
2	379,660	227,480	379,660	2,729	72,630	2,729	35,416	21,220	35,416	4,788
3	349,640	-47,370	349,760	2,368	19,031	2,445	32,616	-4,419	32,627	4,154
Min	349,640	-47,370	349,760	2,368	19,031	2,445	32,616	-4,419	32,627	4,154
Mean	370,680	166,423	370,720	2,620	70,172	2,646	34,578	15,525	34,582	4,596
Max	382,740	319,160	382,740	2,763	118,854	2,763	35,703	29,772	35,703	4,847
S.D.	18,286	190,741	18,217	0,219	49,957	0,175	1,706	17,793	1,699	0,384
C. of V.	4,933	114,612	4,914	8,355	71,192	6,600	4,933	114,612	4,914	8,355
L.C.L.	325,254	-307,408	325,466	2,076	-53,929	2,212	30,341	-28,676	30,361	3,642
U.C.L.	416,106	640,255	415,974	3,164	194,273	3,079	38,816	59,725	38,804	5,550

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	208,516	4,847	1156,554
2	127,421	4,788	1173,212
3	33,388	4,289	1188,724
Min	33,388	4,289	1156,554
Mean	123,108	4,642	1172,830
Max	208,516	4,847	1188,724
S.D.	87,644	0,306	16,088
C. of V.	71,192	6,600	1,372
L.C.L.	-94,613	3,881	1132,864
U.C.L.	340,829	5,403	1212,796

Testometric
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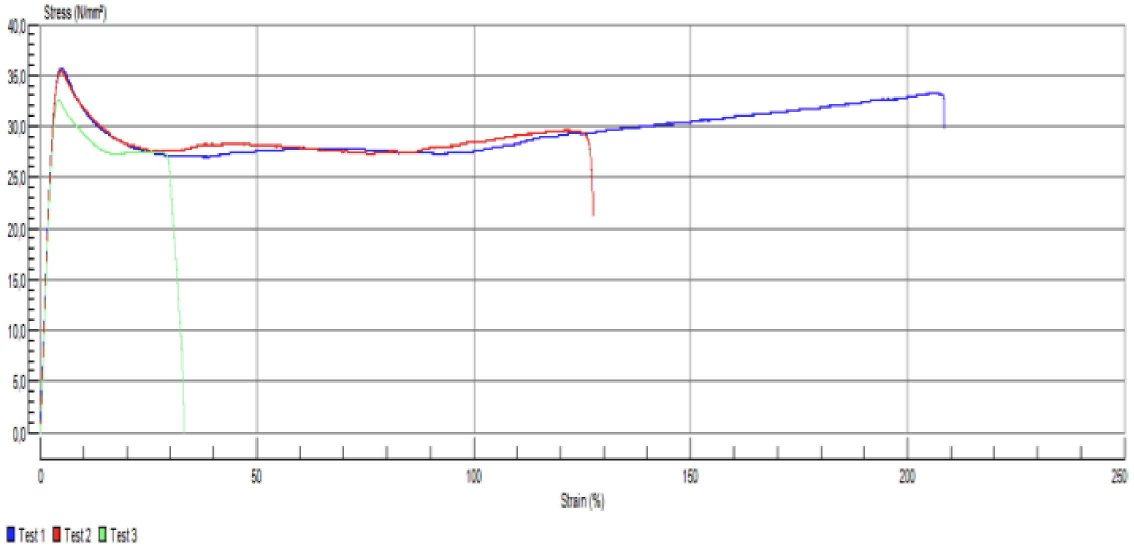
Analysis



Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 12:29
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	360,500	232,640	360,780	2,655	15,256	2,734	33,629	21,701	33,655	4,658
2	389,200	288,930	390,930	2,774	92,858	2,945	36,306	26,952	36,467	4,867
3	95,170	257,600	378,560	0,512	18,527	2,750	8,878	24,030	35,313	0,898
Min	95,170	232,640	360,780	0,512	15,256	2,734	8,878	21,701	33,655	0,898
Mean	281,623	259,723	376,757	1,980	42,214	2,810	26,271	24,228	35,145	3,474
Max	389,200	288,930	390,930	2,774	92,858	2,945	36,306	26,952	36,467	4,867
S.D.	162,110	28,205	15,156	1,273	43,890	0,117	15,122	2,631	1,414	2,233
C. of V.	57,563	10,860	4,023	64,282	103,971	4,181	57,563	10,860	4,023	64,282
L.C.L.	-121,084	189,657	339,107	-1,182	-66,816	2,518	-11,295	17,692	31,633	-2,074
U.C.L.	684,331	329,789	414,406	5,143	151,243	3,101	63,837	30,764	38,657	9,022

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	26,765	4,796	1144,720
2	162,909	5,167	1157,905
3	32,504	4,825	1092,636
Min	26,765	4,796	1092,636
Mean	74,059	4,929	1131,754
Max	162,909	5,167	1157,905
S.D.	77,000	0,206	34,513
C. of V.	103,971	4,181	3,049
L.C.L.	-117,221	4,417	1046,019
U.C.L.	265,339	5,441	1217,488

Testometric
materials testing machines

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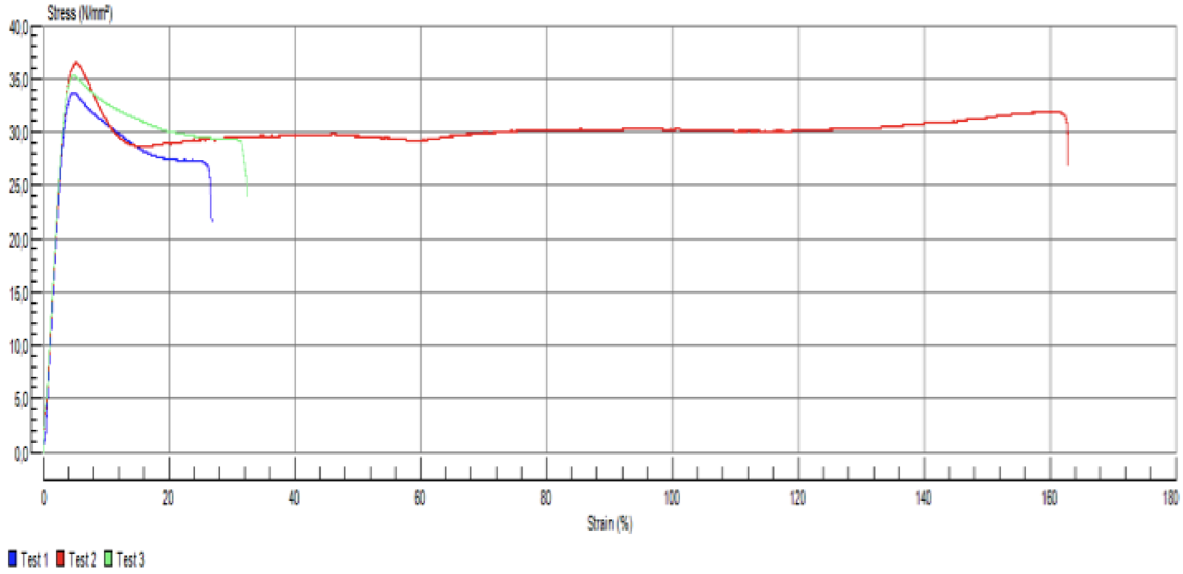
Analysis



Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC_1,2,3

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 14.1.2015 13:45
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	418,030	48,630	418,590	3,070	18,570	3,183	38,995	4,536	39,048	5,386
2	398,560	-33,400	398,560	3,105	19,418	3,105	37,179	-3,116	37,179	5,447
3	381,560	-26,420	381,560	2,907	17,800	2,907	35,593	-2,465	35,593	5,100
Min	381,560	-33,400	381,560	2,907	17,800	2,907	35,593	-3,116	35,593	5,100
Mean	399,383	-3,730	399,570	3,027	18,596	3,065	37,256	-0,348	37,273	5,311
Max	418,030	48,630	418,590	3,105	19,418	3,183	38,995	4,536	39,048	5,447
S.D.	18,249	45,479	18,536	0,106	0,809	0,142	1,702	4,242	1,729	0,185
C. of V.	4,569	-1219,281	4,639	3,491	4,352	4,642	4,569	-1219,281	4,639	3,491
L.C.L.	354,050	-116,708	353,524	2,765	16,586	2,712	33,027	-10,887	32,978	4,851
U.C.L.	444,717	109,248	445,616	3,290	20,606	3,418	41,485	10,191	41,569	5,772

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	32,579	5,584	1109,640
2	34,067	5,447	1087,123
3	31,228	5,100	1069,851
Min	31,228	5,100	1069,851
Mean	32,625	5,377	1088,871
Max	34,067	5,584	1109,640
S.D.	1,420	0,250	19,952
C. of V.	4,352	4,642	1,832
L.C.L.	29,097	4,757	1039,307
U.C.L.	36,152	5,997	1138,436

Testometric
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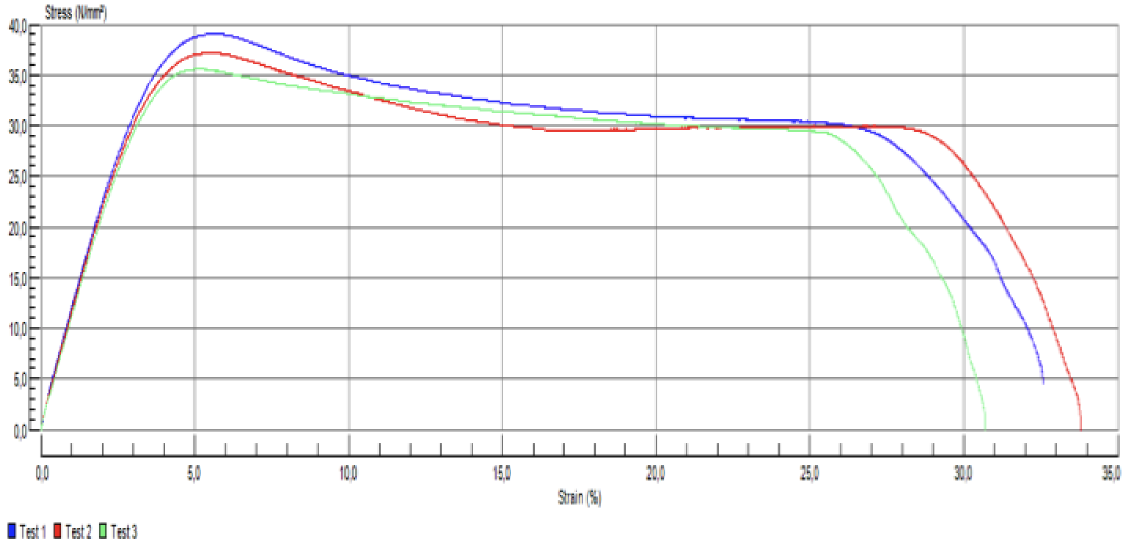
Analysis



Testometric
materials testing machines

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Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 16.1.2015 13:19
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	431,630	51,820	432,080	3,180	32,918	3,290	40,264	4,834	40,306	5,579
2	414,350	-21,100	414,460	3,188	54,103	3,207	38,652	-1,968	38,662	5,593
3	397,770	300,280	397,770	2,944	8,070	2,944	37,105	28,011	37,105	5,165
Min	397,770	-21,100	397,770	2,944	8,070	2,944	37,105	-1,968	37,105	5,165
Mean	414,583	110,333	414,770	3,104	31,697	3,147	38,674	10,292	38,691	5,446
Max	431,630	300,280	432,080	3,188	54,103	3,290	40,264	28,011	40,306	5,593
S.D.	16,931	168,491	17,157	0,139	23,041	0,181	1,579	15,717	1,600	0,243
C. of V.	4,084	152,711	4,137	4,466	72,691	5,740	4,084	152,711	4,137	4,466
L.C.L.	372,523	-308,226	372,149	2,760	-25,540	2,698	34,750	-28,752	34,715	4,841
U.C.L.	456,643	528,892	457,391	3,448	88,934	3,596	42,597	49,337	42,667	6,050

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	57,751	5,772	1109,419
2	94,918	5,626	1108,365
3	14,158	5,165	1144,430
Min	14,158	5,165	1108,365
Mean	55,609	5,521	1120,738
Max	94,918	5,772	1144,430
S.D.	40,422	0,317	20,525
C. of V.	72,691	5,740	1,831
L.C.L.	-44,807	4,734	1069,752
U.C.L.	156,025	6,308	1171,724

Testometric
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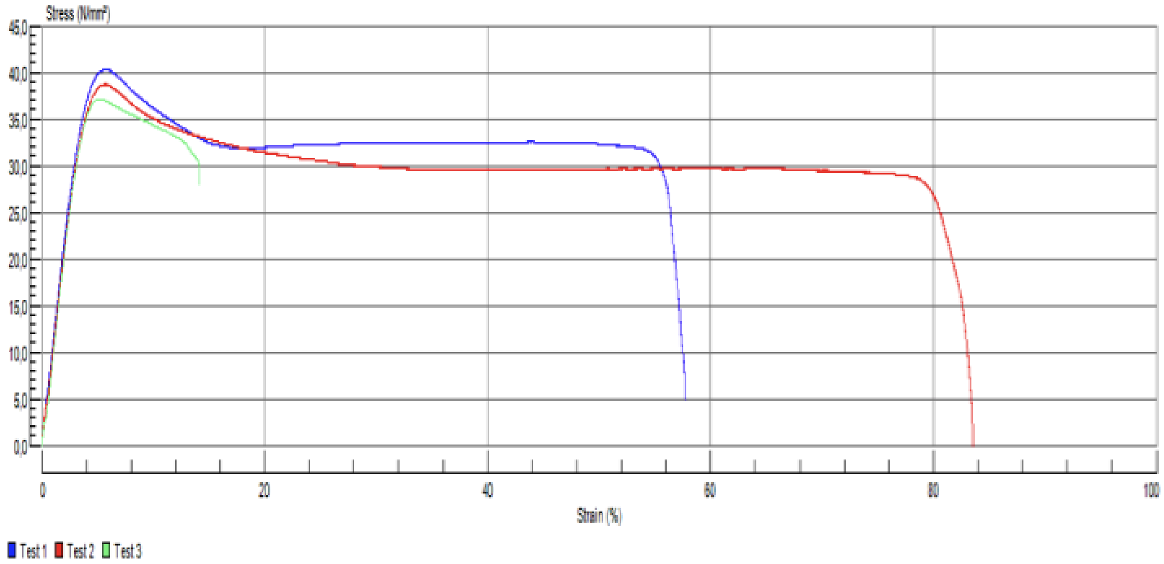
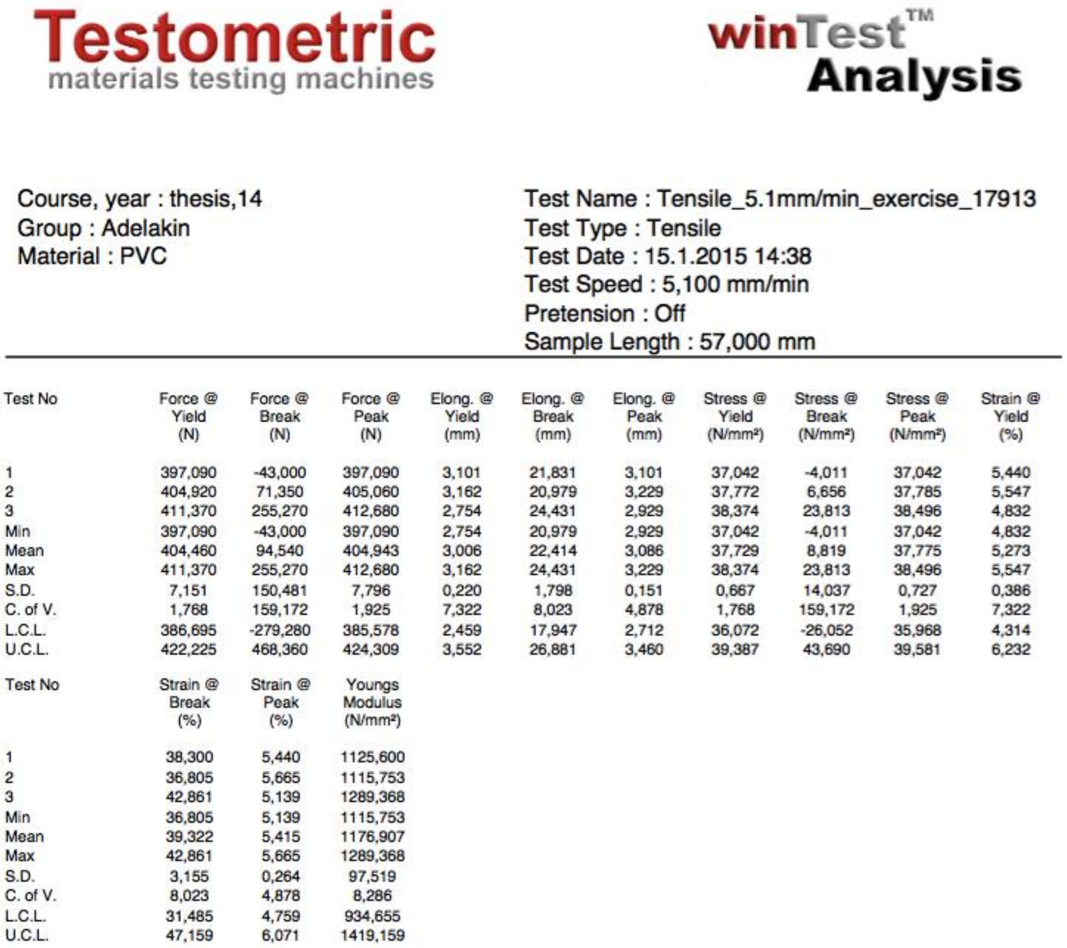
Analysis





Testometric
materials testing machines

winTest™
Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 14:38
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm^2)	Stress @ Break (N/mm^2)	Stress @ Peak (N/mm^2)	Strain @ Yield (%)
1	397,090	-43,000	397,090	3,101	21,831	3,101	37,042	-4,011	37,042	5,440
2	404,920	71,350	405,060	3,162	20,979	3,229	37,772	6,656	37,785	5,547
3	411,370	255,270	412,680	2,754	24,431	2,929	38,374	23,813	38,496	4,832
Min	397,090	-43,000	397,090	2,754	20,979	2,929	37,042	-4,011	37,042	4,832
Mean	404,460	94,540	404,943	3,006	22,414	3,086	37,729	8,819	37,775	5,273
Max	411,370	255,270	412,680	3,162	24,431	3,229	38,374	23,813	38,496	5,547
S.D.	7,151	150,481	7,796	0,220	1,798	0,151	0,667	14,037	0,727	0,386
C. of V.	1,768	159,172	1,925	7,322	8,023	4,878	1,768	159,172	1,925	7,322
L.C.L.	386,695	-279,280	385,578	2,459	17,947	2,712	36,072	-26,052	35,968	4,314
U.C.L.	422,225	468,360	424,309	3,552	26,881	3,460	39,387	43,690	39,581	6,232

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm^2)
1	38,300	5,440	1125,600
2	36,805	5,665	1115,753
3	42,861	5,139	1289,368
Min	36,805	5,139	1115,753
Mean	39,322	5,415	1176,907
Max	42,861	5,665	1289,368
S.D.	3,155	0,264	97,519
C. of V.	8,023	4,878	8,286
L.C.L.	31,485	4,759	934,655
U.C.L.	47,159	6,071	1419,159

Testometric
materials testing machines

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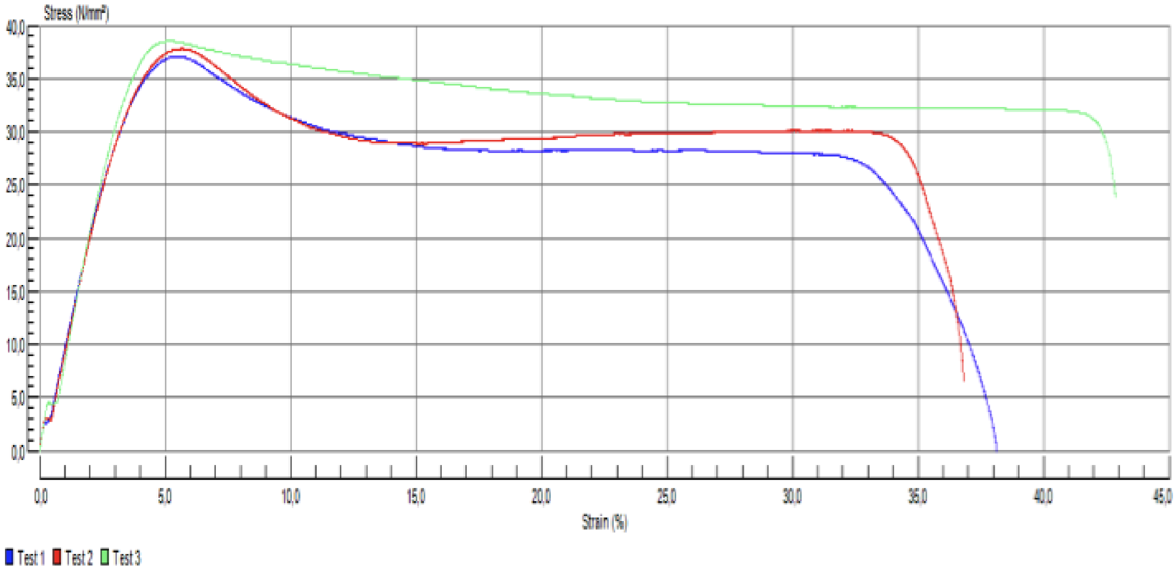
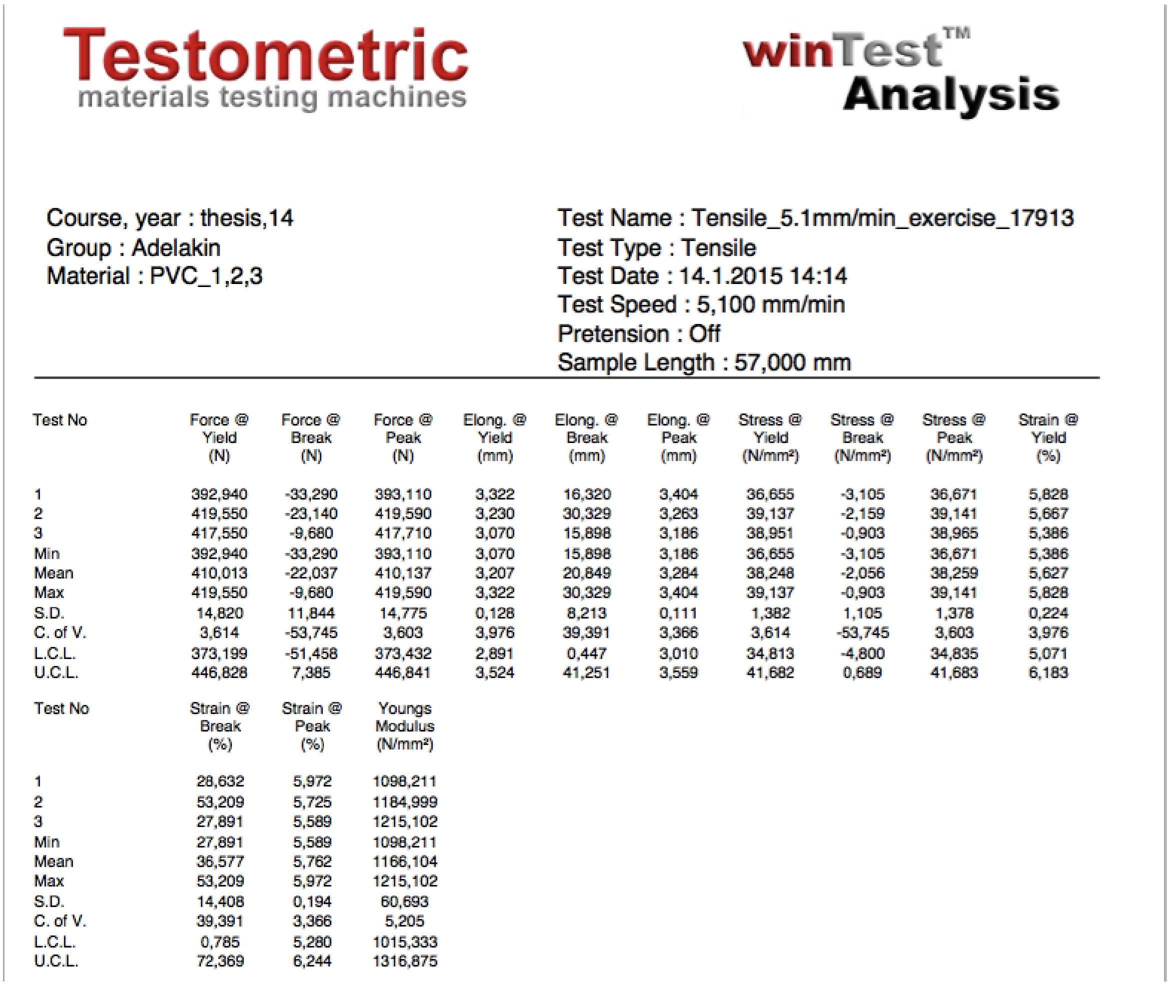
Analysis





Testometric
materials testing machines

winTest™ Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC_1,2,3

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 14.1.2015 14:14
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	392,940	-33,290	393,110	3,322	16,320	3,404	36,655	-3,105	36,671	5,828
2	419,550	-23,140	419,590	3,230	30,329	3,263	39,137	-2,159	39,141	5,667
3	417,550	-9,680	417,710	3,070	15,898	3,186	38,951	-0,903	38,965	5,386
Min	392,940	-33,290	393,110	3,070	15,898	3,186	36,655	-3,105	36,671	5,386
Mean	410,013	-22,037	410,137	3,207	20,849	3,284	38,248	-2,056	38,259	5,627
Max	419,550	-9,680	419,590	3,322	30,329	3,404	39,137	-0,903	39,141	5,828
S.D.	14,820	11,844	14,775	0,128	8,213	0,111	1,382	1,105	1,378	0,224
C. of V.	3,614	-53,745	3,603	3,976	39,391	3,366	3,614	-53,745	3,603	3,976
L.C.L.	373,199	-51,458	373,432	2,891	0,447	3,010	34,813	-4,800	34,835	5,071
U.C.L.	446,828	7,385	446,841	3,524	41,251	3,559	41,682	0,689	41,683	6,183

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	28,632	5,972	1098,211
2	53,209	5,725	1184,999
3	27,891	5,589	1215,102
Min	27,891	5,589	1098,211
Mean	36,577	5,762	1166,104
Max	53,209	5,972	1215,102
S.D.	14,408	0,194	60,693
C. of V.	39,391	3,366	5,205
L.C.L.	0,785	5,280	1015,333
U.C.L.	72,369	6,244	1316,875

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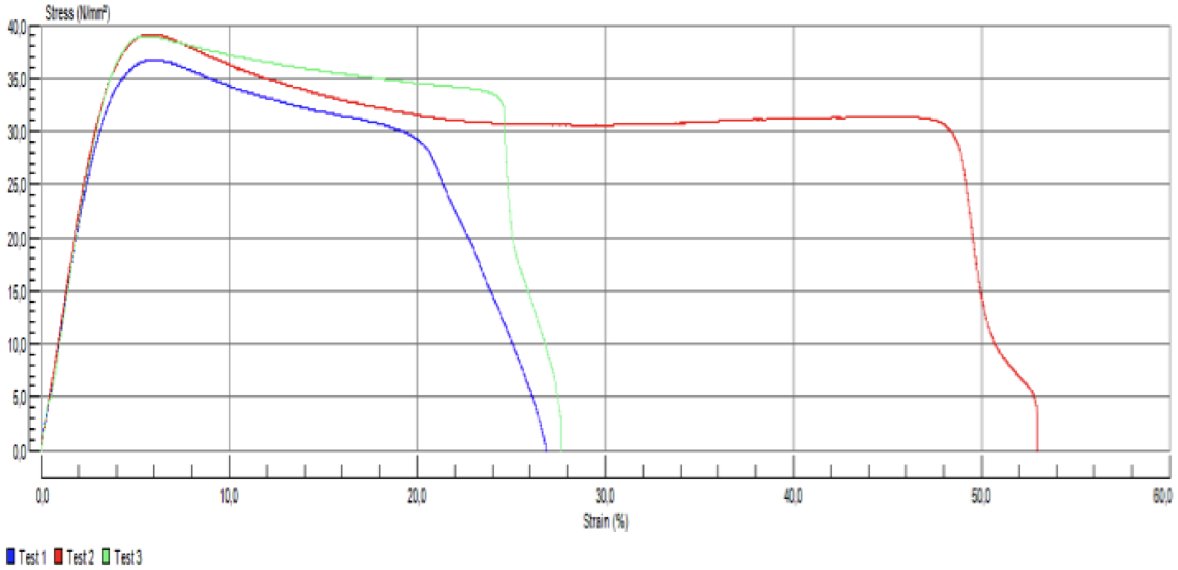

Testometric
materials testing machines

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Analysis

Course, year : Thesis project, 2015
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 16.1.2015 14:26
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	377,140	16,940	378,210	3,108	55,317	3,342	35,181	1,580	35,281	5,453
2	416,080	-28,290	416,330	3,506	25,022	3,588	38,813	-2,639	38,837	6,151
3	415,670	303,690	416,320	3,236	12,052	3,427	38,775	28,329	38,836	5,677
Min	377,140	-28,290	378,210	3,108	12,052	3,342	35,181	-2,639	35,281	5,453
Mean	402,963	97,447	403,620	3,283	30,797	3,452	37,590	9,090	37,651	5,760
Max	416,080	303,690	416,330	3,506	55,317	3,588	38,813	28,329	38,837	6,151
S.D.	22,365	180,038	22,006	0,203	22,203	0,125	2,086	16,795	2,053	0,356
C. of V.	5,550	184,755	5,452	6,188	72,095	3,619	5,550	184,755	5,452	6,188
L.C.L.	347,406	-349,797	348,954	2,779	-24,359	3,142	32,407	-32,630	32,552	4,875
U.C.L.	458,521	544,691	458,286	3,788	85,953	3,763	42,772	50,811	42,751	6,646

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	97,047	5,863	1163,594
2	43,898	6,295	1135,152
3	21,144	6,012	1145,856
Min	21,144	5,863	1135,152
Mean	54,030	6,057	1148,201
Max	97,047	6,295	1163,594
S.D.	38,953	0,219	14,365
C. of V.	72,095	3,619	1,251
L.C.L.	-42,735	5,512	1112,515
U.C.L.	150,795	6,601	1183,886

Testometric
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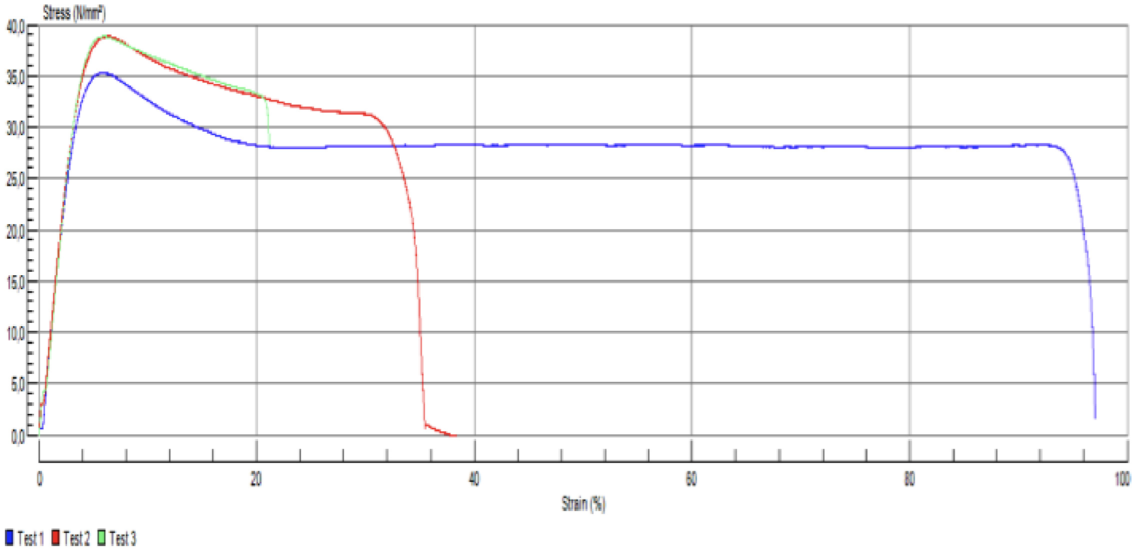

Testometric
materials testing machines

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Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 15:05
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	413,730	180,880	414,410	3,387	37,496	3,609	38,594	16,873	38,658	5,942
2	406,300	182,070	406,570	3,316	29,807	3,505	37,901	16,984	37,926	5,818
3	408,660	111,030	408,660	3,095	22,119	3,095	38,121	10,357	38,121	5,430
Min	406,300	111,030	406,570	3,095	22,119	3,095	37,901	10,357	37,926	5,430
Mean	409,563	157,993	409,880	3,266	29,807	3,403	38,206	14,738	38,235	5,730
Max	413,730	182,070	414,410	3,387	37,496	3,609	38,594	16,984	38,658	5,942
S.D.	3,796	40,676	4,060	0,152	7,688	0,272	0,354	3,794	0,379	0,267
C. of V.	0,927	25,745	0,991	4,663	25,794	7,986	0,927	25,745	0,991	4,663
L.C.L.	400,132	56,948	399,795	2,888	10,708	2,728	37,326	5,312	37,294	5,066
U.C.L.	418,994	259,039	419,965	3,644	48,907	4,078	39,085	24,164	39,176	6,394

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	65,782	6,332	1155,254
2	52,293	6,149	1176,676
3	38,805	5,430	1199,130
Min	38,805	5,430	1155,254
Mean	52,294	5,970	1177,020
Max	65,782	6,332	1199,130
S.D.	13,489	0,477	21,940
C. of V.	25,794	7,986	1,864
L.C.L.	18,786	4,786	1122,518
U.C.L.	85,801	7,155	1231,522

Testometric
materials testing machines

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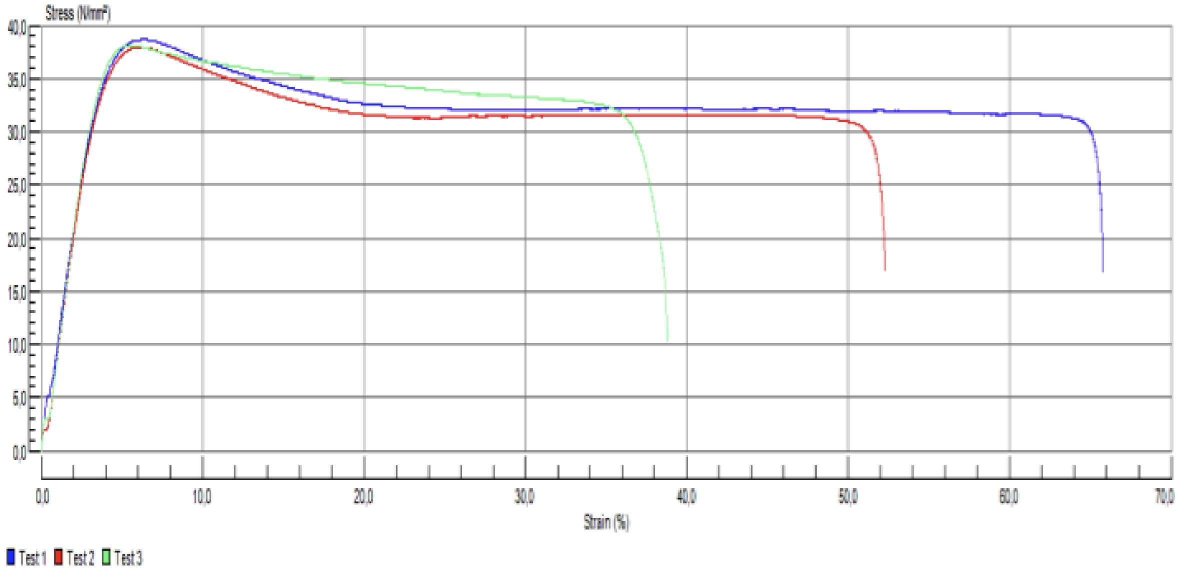

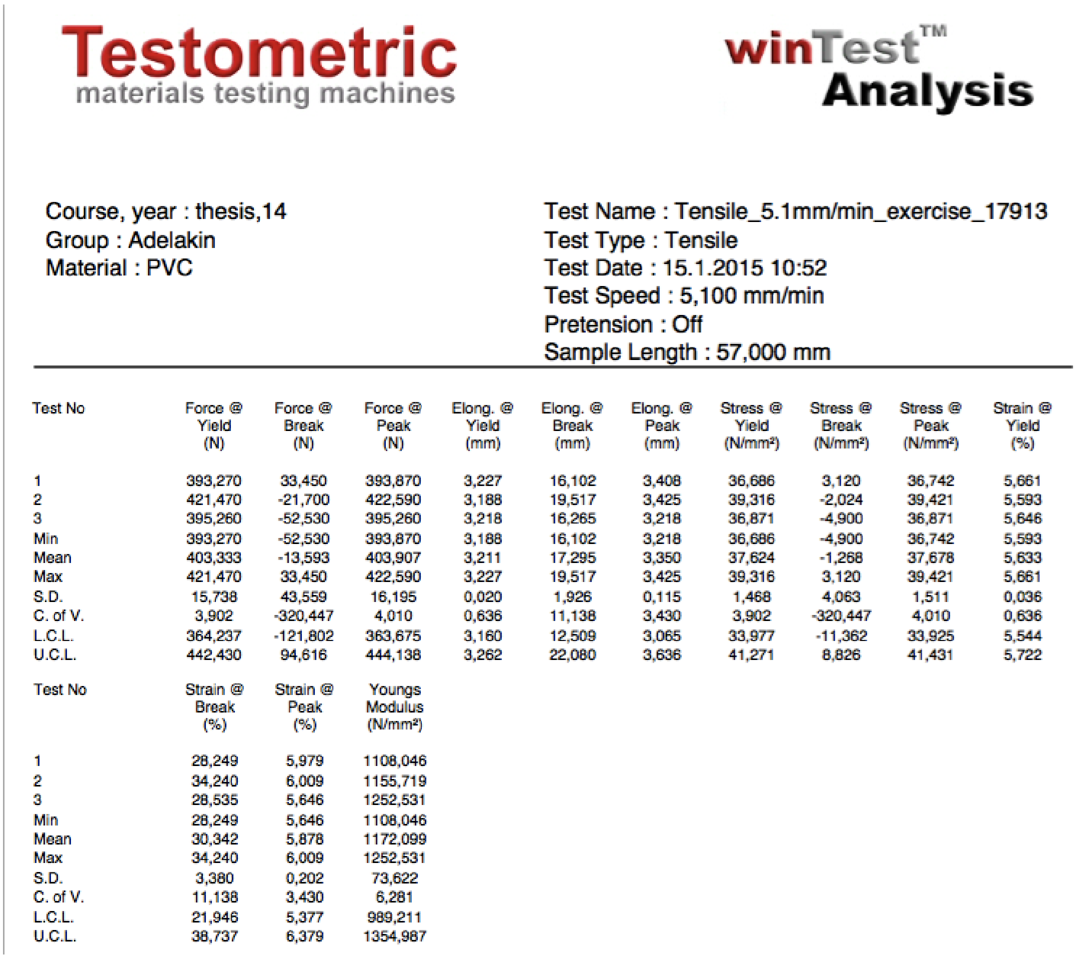

Testometric
materials testing machines

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Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 10:52
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	393,270	33,450	393,870	3,227	16,102	3,408	36,686	3,120	36,742	5,661
2	421,470	-21,700	422,590	3,188	19,517	3,425	39,316	-2,024	39,421	5,593
3	395,260	-52,530	395,260	3,218	16,265	3,218	36,871	-4,900	36,871	5,646
Min	393,270	-52,530	393,870	3,188	16,102	3,218	36,686	-4,900	36,742	5,593
Mean	403,333	-13,593	403,907	3,211	17,295	3,350	37,624	-1,268	37,678	5,633
Max	421,470	33,450	422,590	3,227	19,517	3,425	39,316	3,120	39,421	5,661
S.D.	15,738	43,559	16,195	0,020	1,926	0,115	1,468	4,063	1,511	0,036
C. of V.	3,902	-320,447	4,010	0,636	11,138	3,430	3,902	-320,447	4,010	0,636
L.C.L.	364,237	-121,802	363,675	3,160	12,509	3,065	33,977	-11,362	33,925	5,544
U.C.L.	442,430	94,616	444,138	3,262	22,080	3,636	41,271	8,826	41,431	5,722

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	28,249	5,979	1108,046
2	34,240	6,009	1155,719
3	28,535	5,646	1252,531
Min	28,249	5,646	1108,046
Mean	30,342	5,878	1172,099
Max	34,240	6,009	1252,531
S.D.	3,380	0,202	73,622
C. of V.	11,138	3,430	6,281
L.C.L.	21,946	5,377	989,211
U.C.L.	38,737	6,379	1354,987

Testometric
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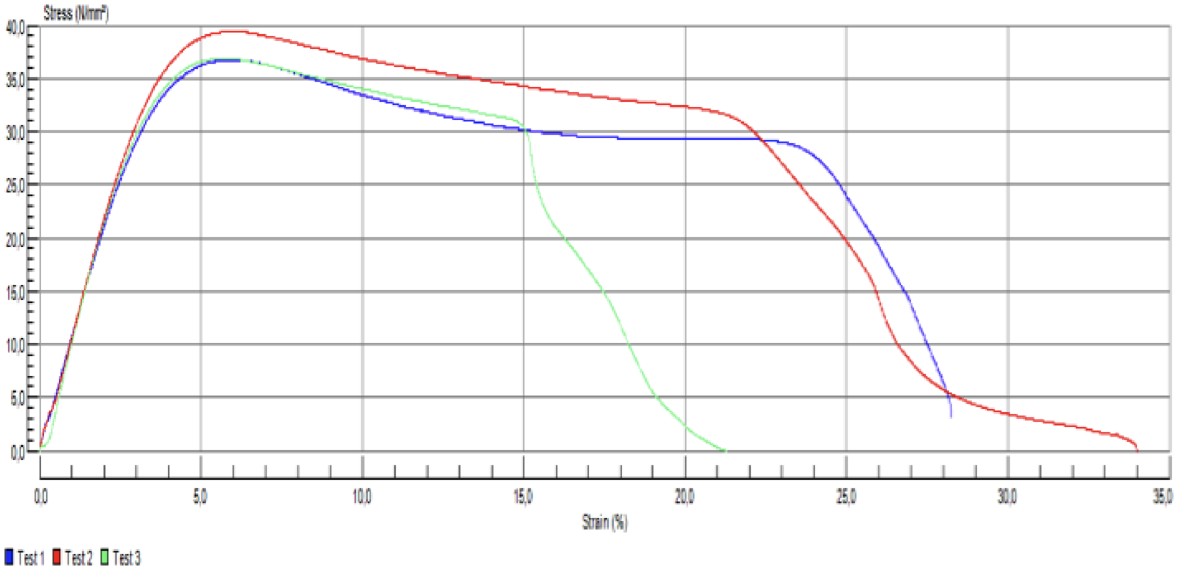
Analysis



Testometric
materials testing machines

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Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 16.1.2015 14:57
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	400,910	-40,060	401,610	3,298	15,826	3,498	37,398	-3,737	37,464	5,786
2	387,330	-48,370	387,470	3,302	23,589	3,345	36,132	-4,512	36,145	5,793
3	387,410	317,800	388,360	2,985	12,530	3,247	36,139	29,646	36,228	5,237
Min	387,330	-48,370	387,470	2,985	12,530	3,247	36,132	-4,512	36,145	5,237
Mean	391,883	76,457	392,480	3,195	17,315	3,363	36,556	7,132	36,612	5,605
Max	400,910	317,800	401,610	3,302	23,589	3,498	37,398	29,646	37,464	5,793
S.D.	7,817	209,051	7,919	0,182	5,678	0,127	0,729	19,501	0,739	0,319
C. of V.	1,995	273,424	2,018	5,693	32,792	3,761	1,995	273,424	2,018	5,693
L.C.L.	372,464	-442,860	372,807	2,743	3,210	3,049	34,745	-41,312	34,777	4,813
U.C.L.	411,303	595,773	412,153	3,647	31,420	3,678	38,368	55,576	38,447	6,398

Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	27,765	6,137	1175,549
2	41,384	5,868	1165,786
3	21,982	5,696	1072,703
Min	21,982	5,696	1072,703
Mean	30,377	5,901	1138,012
Max	41,384	6,137	1175,549
S.D.	9,961	0,222	56,770
C. of V.	32,792	3,761	4,989
L.C.L.	5,632	5,349	996,986
U.C.L.	55,122	6,452	1279,039

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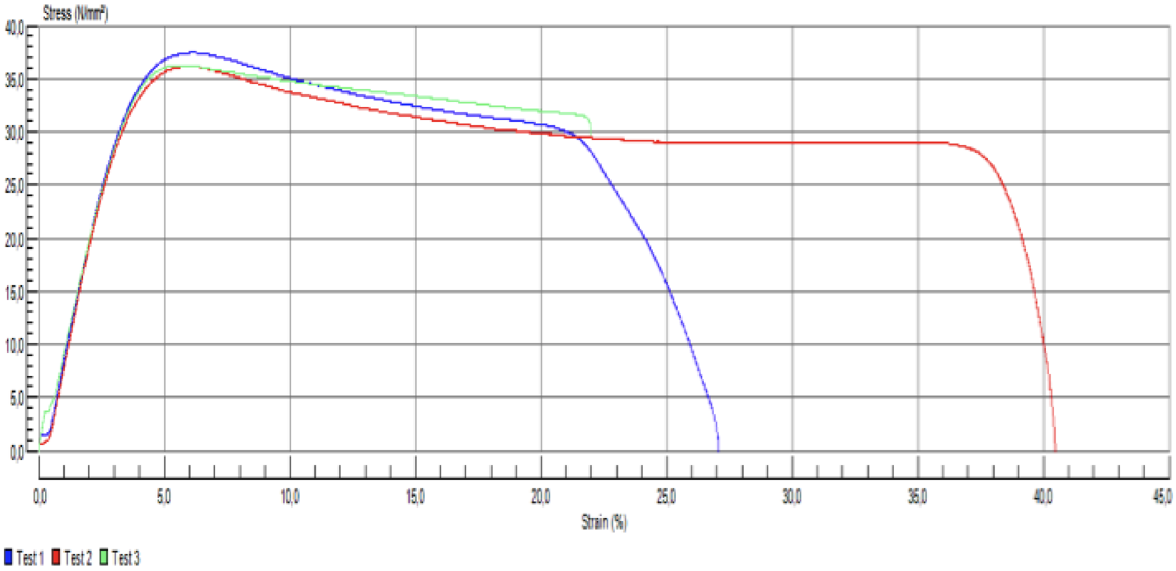
Analysis



Testometric
materials testing machines

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Analysis

Course, year : thesis,14
Group : Adelakin
Material : PVC

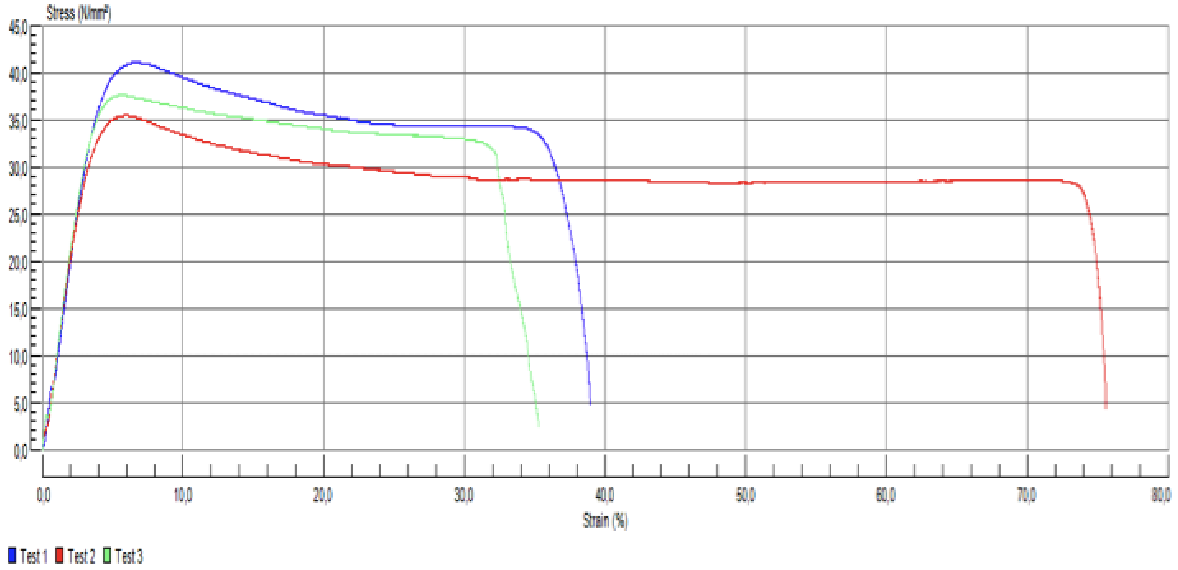
Test Name : Tensile_5.1mm/min_exercise_17913
Test Type : Tensile
Test Date : 15.1.2015 15:35
Test Speed : 5,100 mm/min
Pretension : Off
Sample Length : 57,000 mm

Test No	Force @ Yield (N)	Force @ Break (N)	Force @ Peak (N)	Elong. @ Yield (mm)	Elong. @ Break (mm)	Elong. @ Peak (mm)	Stress @ Yield (N/mm²)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Strain @ Yield (%)
1	439,490	49,600	439,600	3,718	22,204	3,754	40,997	4,627	41,007	6,523
2	379,250	47,260	379,530	3,276	43,102	3,360	35,378	4,409	35,404	5,747
3	400,080	26,620	402,490	2,858	20,115	3,212	37,321	2,483	37,546	5,014
Min	379,250	26,620	379,530	2,858	20,115	3,212	35,378	2,483	35,404	5,014
Mean	406,273	41,160	407,207	3,284	28,474	3,442	37,899	3,840	37,986	5,761
Max	439,490	49,600	439,600	3,718	43,102	3,754	40,997	4,627	41,007	6,523
S.D.	30,594	12,646	30,311	0,430	12,711	0,280	2,854	1,180	2,828	0,754
C. of V.	7,530	30,725	7,444	13,095	44,643	8,139	7,530	30,725	7,444	13,095
L.C.L.	330,273	9,745	331,908	2,216	-3,104	2,746	30,809	0,909	30,962	3,887
U.C.L.	482,273	72,575	482,505	4,352	60,051	4,138	44,988	6,770	45,010	7,636

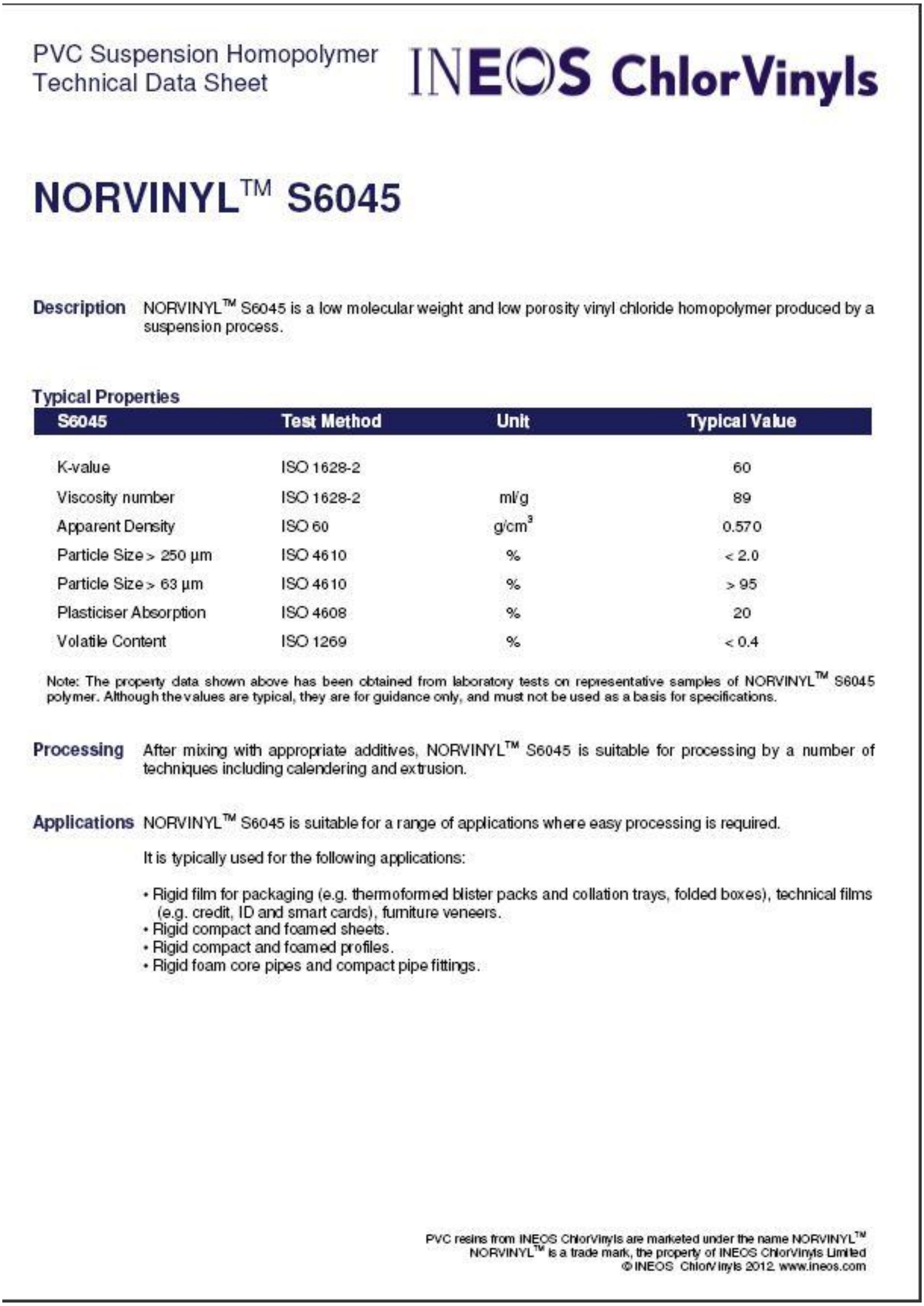
Test No	Strain @ Break (%)	Strain @ Peak (%)	Youngs Modulus (N/mm²)
1	38,954	6,586	1169,901
2	75,618	5,895	1147,762
3	35,289	5,635	1239,251
Min	35,289	5,635	1147,762
Mean	49,954	6,039	1185,638
Max	75,618	6,586	1239,251
S.D.	22,301	0,491	47,732
C. of V.	44,643	8,139	4,026
L.C.L.	-5,445	4,818	1067,065
U.C.L.	105,353	7,260	1304,211

Testometric
materials testing machines

winTest™
Analysis



APPENDIX 3



PVC Suspension Homopolymer
Technical Data Sheet

INEOS ChlorVinyls

NORVINYL™ S6045

Description NORVINYL™ S6045 is a low molecular weight and low porosity vinyl chloride homopolymer produced by a suspension process.

Typical Properties

S6045	Test Method	Unit	Typical Value
K-value	ISO 1628-2		60
Viscosity number	ISO 1628-2	ml/g	89
Apparent Density	ISO 60	g/cm^3	0.570
Particle Size > 250 µm	ISO 4610	%	< 2.0
Particle Size > 63 µm	ISO 4610	%	> 95
Plasticiser Absorption	ISO 4608	%	20
Volatile Content	ISO 1269	%	< 0.4

Note: The property data shown above has been obtained from laboratory tests on representative samples of NORVINYL™ S6045 polymer. Although the values are typical, they are for guidance only, and must not be used as a basis for specifications.

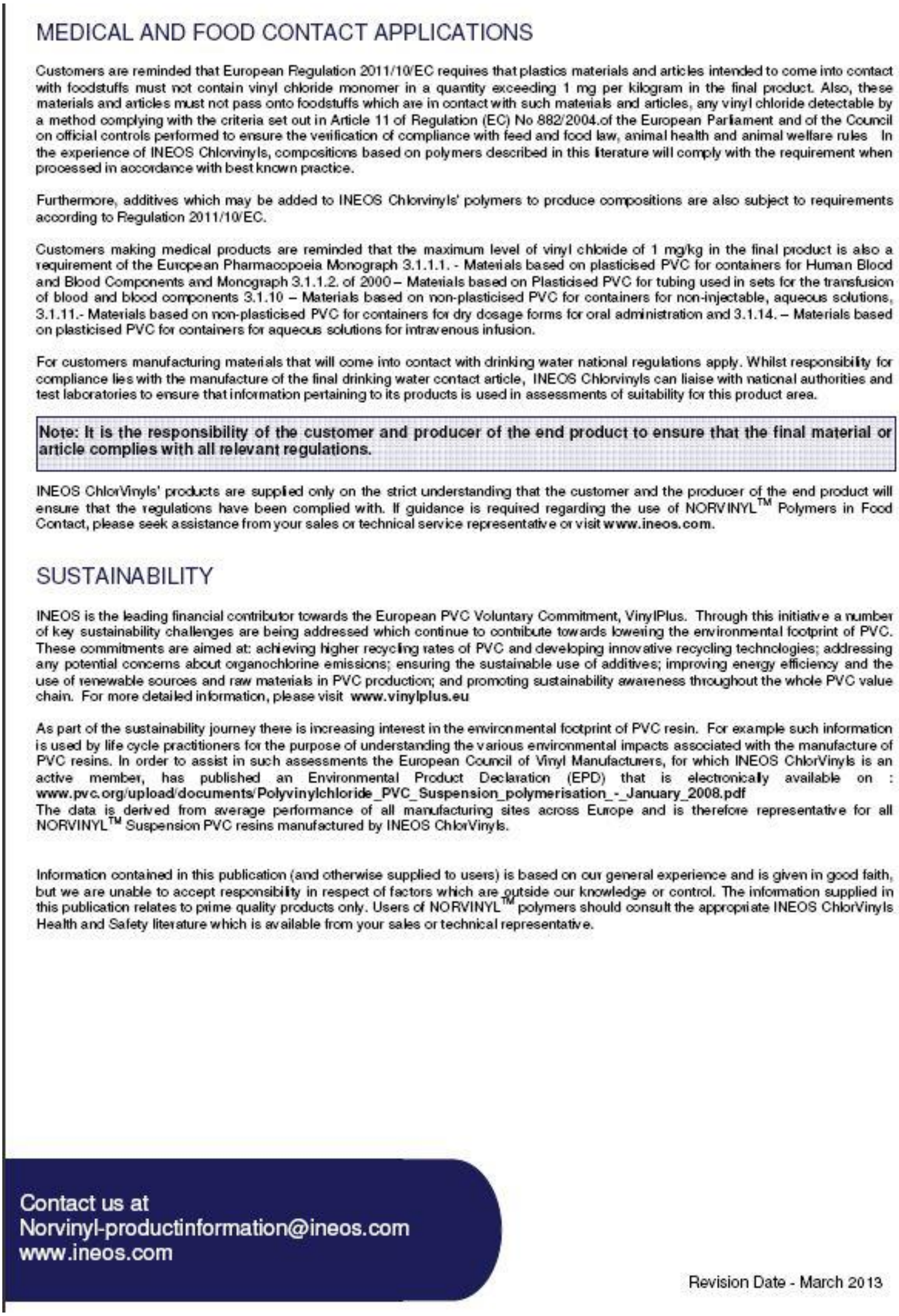
Processing After mixing with appropriate additives, NORVINYL™ S6045 is suitable for processing by a number of techniques including calendering and extrusion.

Applications NORVINYL™ S6045 is suitable for a range of applications where easy processing is required.

It is typically used for the following applications:

- Rigid film for packaging (e.g. thermoformed blister packs and collation trays, folded boxes), technical films (e.g. credit, ID and smart cards), furniture veneers.
- Rigid compact and foamed sheets.
- Rigid compact and foamed profiles.
- Rigid foam core pipes and compact pipe fittings.

PVC resins from INEOS ChlorVinyls are marketed under the name NORVINYL™
NORVINYL™ is a trade mark, the property of INEOS ChlorVinyls Limited



MEDICAL AND FOOD CONTACT APPLICATIONS

Customers are reminded that European Regulation 2011/10/EC requires that plastics materials and articles intended to come into contact with foodstuffs must not contain vinyl chloride monomer in a quantity exceeding 1 mg per kilogram in the final product. Also, these materials and articles must not pass onto foodstuffs which are in contact with such materials and articles, any vinyl chloride detectable by a method complying with the criteria set out in Article 11 of Regulation (EC) No 882/2004.of the European Parliament and of the Council on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules In the experience of INEOS Chlorvinyls, compositions based on polymers described in this literature will comply with the requirement when processed in accordance with best known practice.

Furthermore, additives which may be added to INEOS Chlorvinyls' polymers to produce compositions are also subject to requirements according to Regulation 2011/10/EC.

Customers making medical products are reminded that the maximum level of vinyl chloride of 1 mg/kg in the final product is also a requirement of the European Pharmacopoeia Monograph 3.1.1.1. - Materials based on plasticised PVC for containers for Human Blood and Blood Components and Monograph 3.1.1.2. of 2000 – Materials based on Plasticised PVC for tubing used in sets for the transfusion of blood and blood components 3.1.10 – Materials based on non-plasticised PVC for containers for non-injectable, aqueous solutions, 3.1.11.- Materials based on non-plasticised PVC for containers for dry dosage forms for oral administration and 3.1.14. – Materials based on plasticised PVC for containers for aqueous solutions for intravenous infusion.

For customers manufacturing materials that will come into contact with drinking water national regulations apply. Whilst responsibility for compliance lies with the manufacture of the final drinking water contact article, INEOS Chlorvinyls can liaise with national authorities and test laboratories to ensure that information pertaining to its products is used in assessments of suitability for this product area.

Note: It is the responsibility of the customer and producer of the end product to ensure that the final material or article complies with all relevant regulations.

INEOS ChlorVinyls' products are supplied only on the strict understanding that the customer and the producer of the end product will ensure that the regulations have been complied with. If guidance is required regarding the use of NORVINYL^{TM} Polymers in Food Contact, please seek assistance from your sales or technical service representative or visit **www.ineos.com**.

SUSTAINABILITY

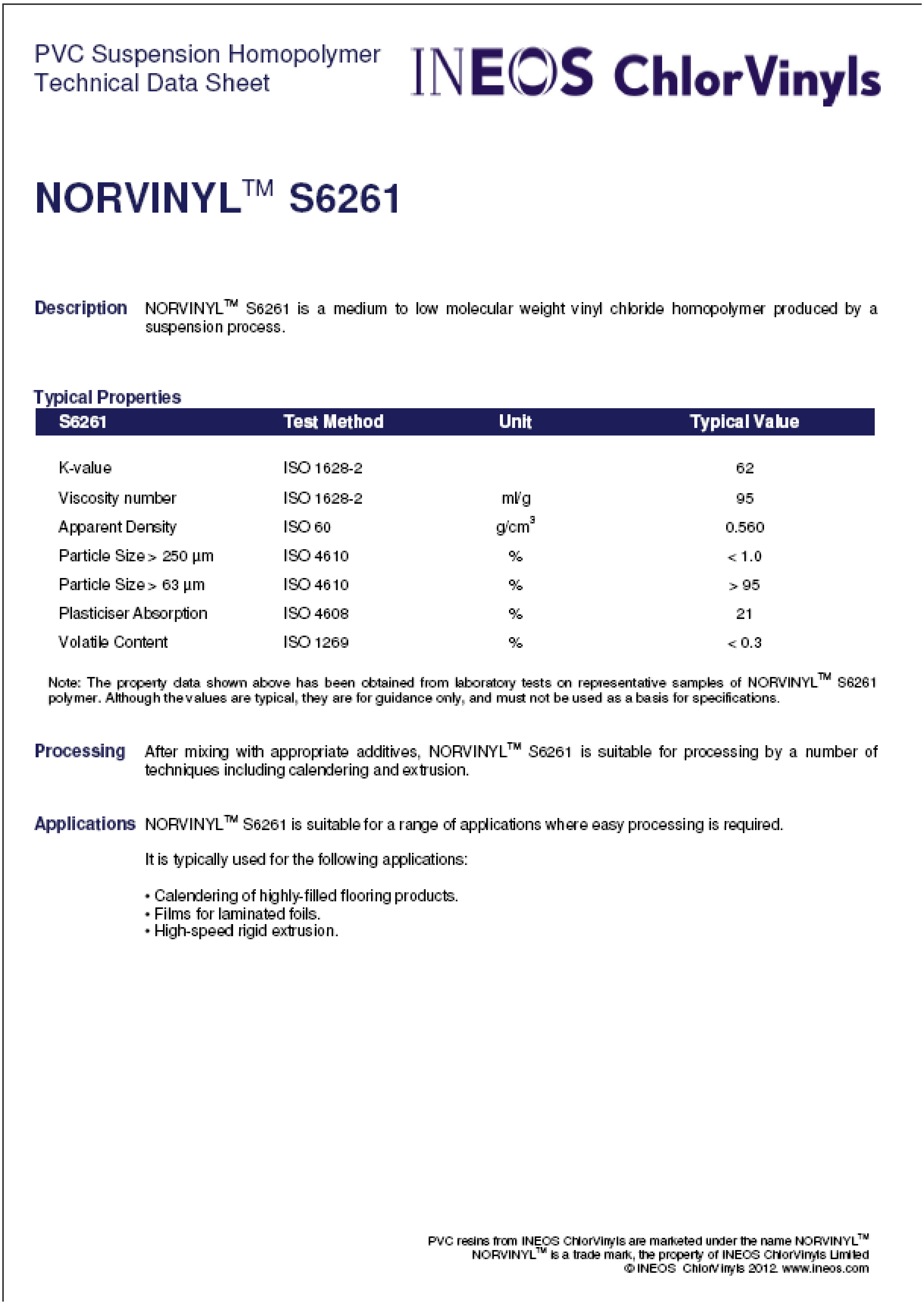
INEOS is the leading financial contributor towards the European PVC Voluntary Commitment, VinylPlus. Through this initiative a number of key sustainability challenges are being addressed which continue to contribute towards lowering the environmental footprint of PVC. These commitments are aimed at: achieving higher recycling rates of PVC and developing innovative recycling technologies; addressing any potential concerns about organochlorine emissions; ensuring the sustainable use of additives; improving energy efficiency and the use of renewable sources and raw materials in PVC production; and promoting sustainability awareness throughout the whole PVC value chain. For more detailed information, please visit **www.vinylplus.eu**

As part of the sustainability journey there is increasing interest in the environmental footprint of PVC resin. For example such information is used by life cycle practitioners for the purpose of understanding the various environmental impacts associated with the manufacture of PVC resins. In order to assist in such assessments the European Council of Vinyl Manufacturers, for which INEOS ChlorVinyls is an active member, has published an Environmental Product Declaration (EPD) that is electronically available on : **www.pvc.org/upload/documents/Polyvinylchloride_PVC_Suspension_polymerisation_-_January_2008.pdf**
The data is derived from average performance of all manufacturing sites across Europe and is therefore representative for all NORVINYL^{TM} Suspension PVC resins manufactured by INEOS ChlorVinyls.

Information contained in this publication (and otherwise supplied to users) is based on our general experience and is given in good faith, but we are unable to accept responsibility in respect of factors which are outside our knowledge or control. The information supplied in this publication relates to prime quality products only. Users of NORVINYL^{TM} polymers should consult the appropriate INEOS ChlorVinyls Health and Safety literature which is available from your sales or technical representative.

Contact us at
Norvinyl-productinformation@ineos.com
www.ineos.com

Revision Date - March 2013



PVC Suspension Homopolymer
Technical Data Sheet

INEOS ChlorVinyls

NORVINYL™ S6261

Description NORVINYL™ S6261 is a medium to low molecular weight vinyl chloride homopolymer produced by a suspension process.

Typical Properties

S6261	Test Method	Unit	Typical Value
K-value	ISO 1628-2		62
Viscosity number	ISO 1628-2	ml/g	95
Apparent Density	ISO 60	g/cm^3	0.560
Particle Size > 250 µm	ISO 4610	%	< 1.0
Particle Size > 63 µm	ISO 4610	%	> 95
Plasticiser Absorption	ISO 4608	%	21
Volatile Content	ISO 1269	%	< 0.3

Note: The property data shown above has been obtained from laboratory tests on representative samples of NORVINYL™ S6261 polymer. Although the values are typical, they are for guidance only, and must not be used as a basis for specifications.

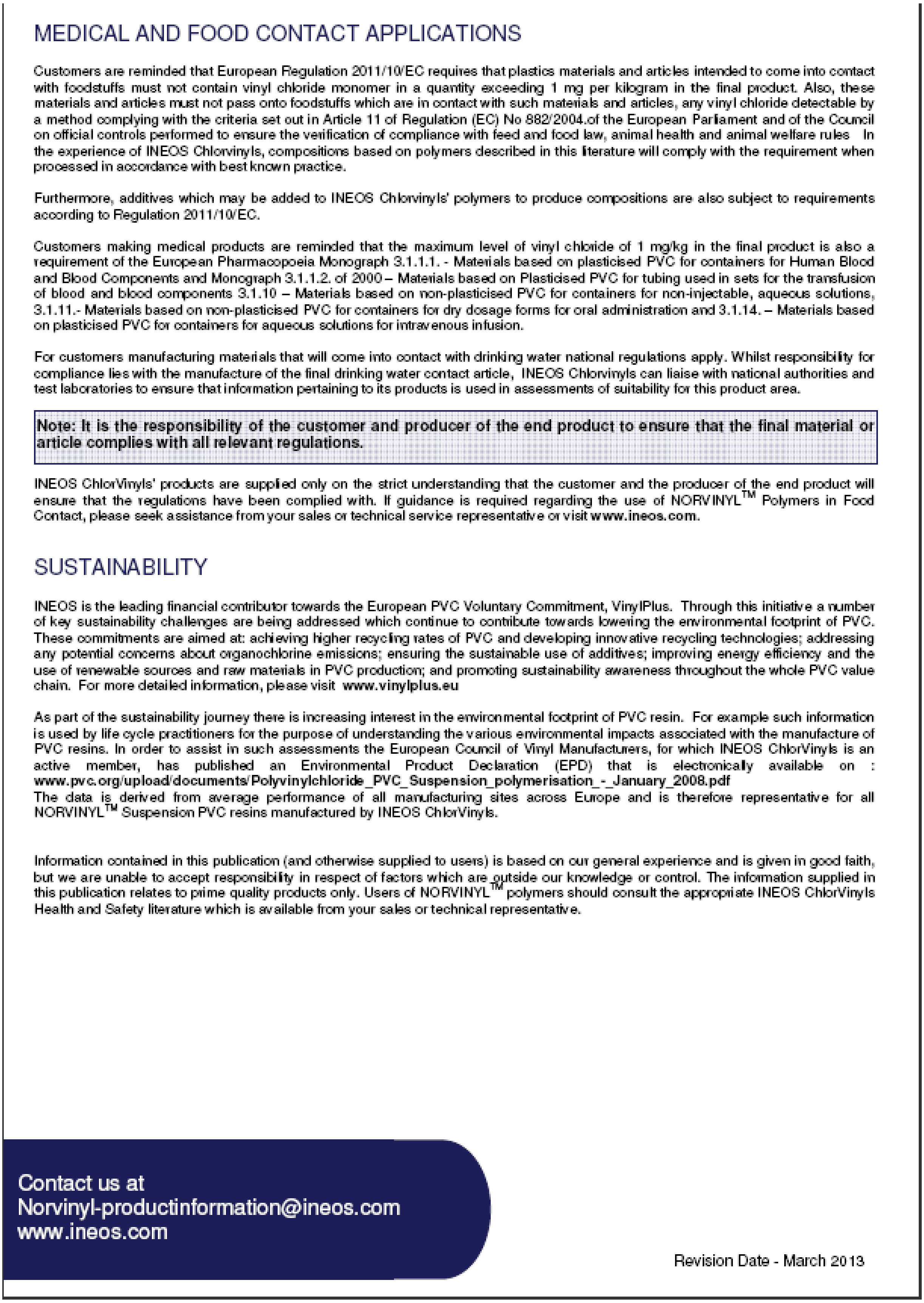
Processing After mixing with appropriate additives, NORVINYL™ S6261 is suitable for processing by a number of techniques including calendering and extrusion.

Applications NORVINYL™ S6261 is suitable for a range of applications where easy processing is required.

It is typically used for the following applications:

- Calendering of highly-filled flooring products.
- Films for laminated foils.
- High-speed rigid extrusion.

PVC resins from INEOS ChlorVinyls are marketed under the name NORVINYL™
NORVINYL™ is a trade mark, the property of INEOS ChlorVinyls Limited



MEDICAL AND FOOD CONTACT APPLICATIONS

Customers are reminded that European Regulation 2011/10/EC requires that plastics materials and articles intended to come into contact with foodstuffs must not contain vinyl chloride monomer in a quantity exceeding 1 mg per kilogram in the final product. Also, these materials and articles must not pass onto foodstuffs which are in contact with such materials and articles, any vinyl chloride detectable by a method complying with the criteria set out in Article 11 of Regulation (EC) No 882/2004.of the European Parliament and of the Council on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules In the experience of INEOS Chlorvinyls, compositions based on polymers described in this literature will comply with the requirement when processed in accordance with best known practice.

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SUSTAINABILITY

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As part of the sustainability journey there is increasing interest in the environmental footprint of PVC resin. For example such information is used by life cycle practitioners for the purpose of understanding the various environmental impacts associated with the manufacture of PVC resins. In order to assist in such assessments the European Council of Vinyl Manufacturers, for which INEOS ChlorVinyls is an active member, has published an Environmental Product Declaration (EPD) that is electronically available on : **www.pvc.org/upload/documents/Polyvinylchloride_PVC_Suspension_polymerisation_-_January_2008.pdf**
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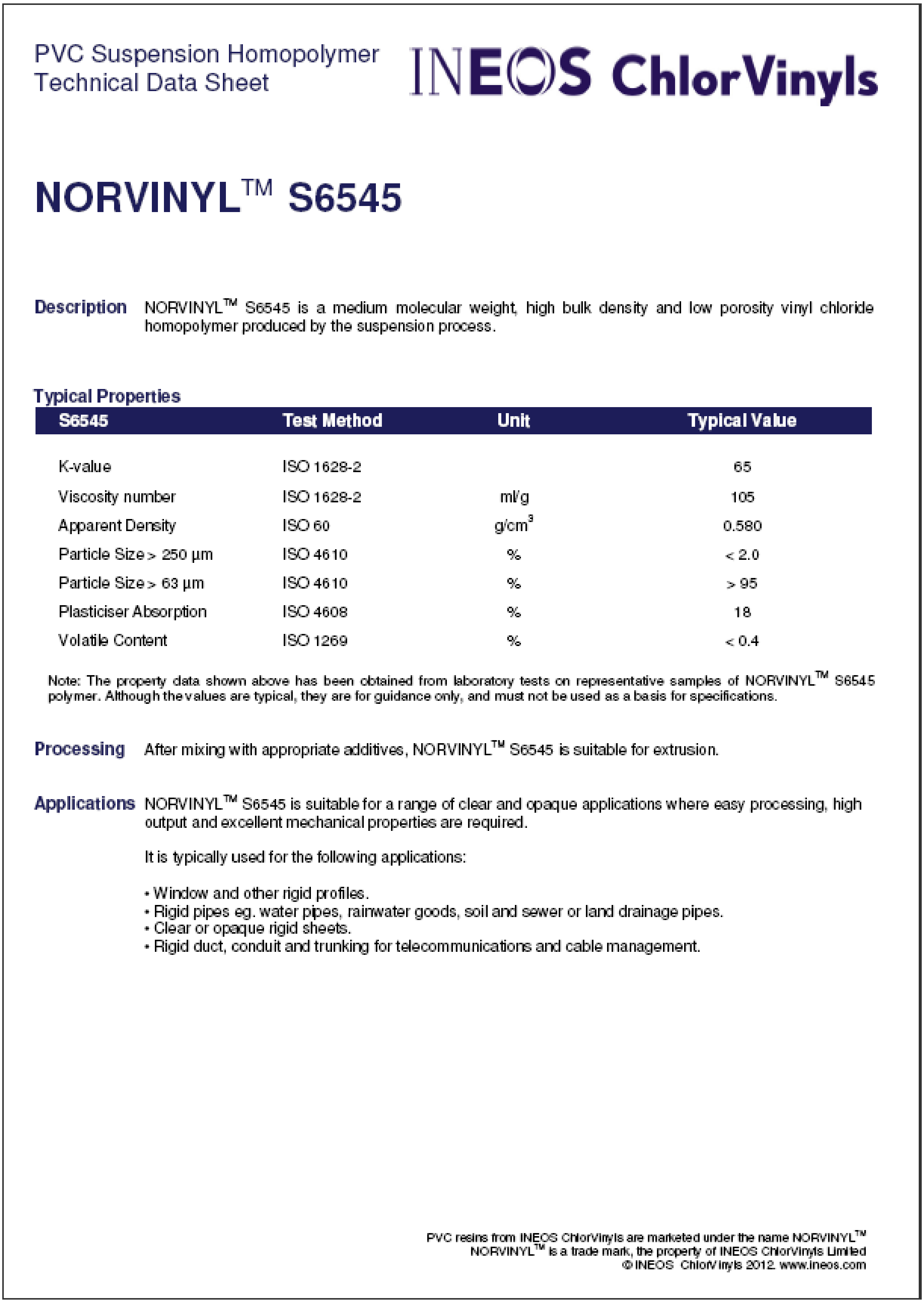
Revision Date - March 2013



PVC Suspension Homopolymer
Technical Data Sheet

INEOS ChlorVinyls

NORVINYL™ S6545

Description NORVINYL™ S6545 is a medium molecular weight, high bulk density and low porosity vinyl chloride homopolymer produced by the suspension process.

Typical Properties

S6545	Test Method	Unit	Typical Value
K-value	ISO 1628-2		65
Viscosity number	ISO 1628-2	ml/g	105
Apparent Density	ISO 60	g/cm^3	0.580
Particle Size > 250 µm	ISO 4610	%	< 2.0
Particle Size > 63 µm	ISO 4610	%	> 95
Plasticiser Absorption	ISO 4608	%	18
Volatile Content	ISO 1269	%	< 0.4

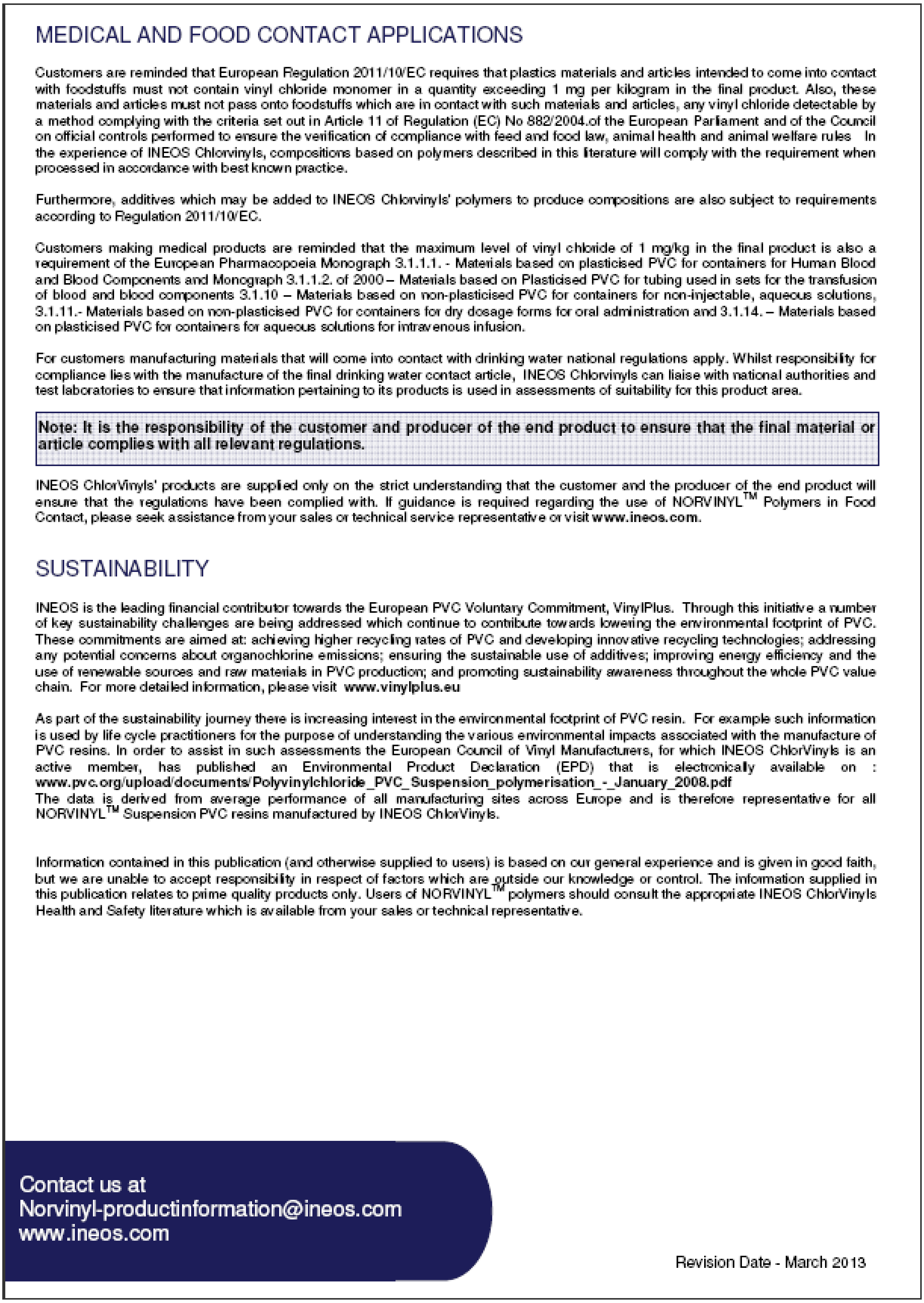
Note: The property data shown above has been obtained from laboratory tests on representative samples of NORVINYL™ S6545 polymer. Although the values are typical, they are for guidance only, and must not be used as a basis for specifications.

Processing After mixing with appropriate additives, NORVINYL™ S6545 is suitable for extrusion.

Applications NORVINYL™ S6545 is suitable for a range of clear and opaque applications where easy processing, high output and excellent mechanical properties are required.

It is typically used for the following applications:

- Window and other rigid profiles.
- Rigid pipes eg. water pipes, rainwater goods, soil and sewer or land drainage pipes.
- Clear or opaque rigid sheets.
- Rigid duct, conduit and trunking for telecommunications and cable management.



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SUSTAINABILITY

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The data is derived from average performance of all manufacturing sites across Europe and is therefore representative for all NORVINYL™ Suspension PVC resins manufactured by INEOS ChlorVinyls.

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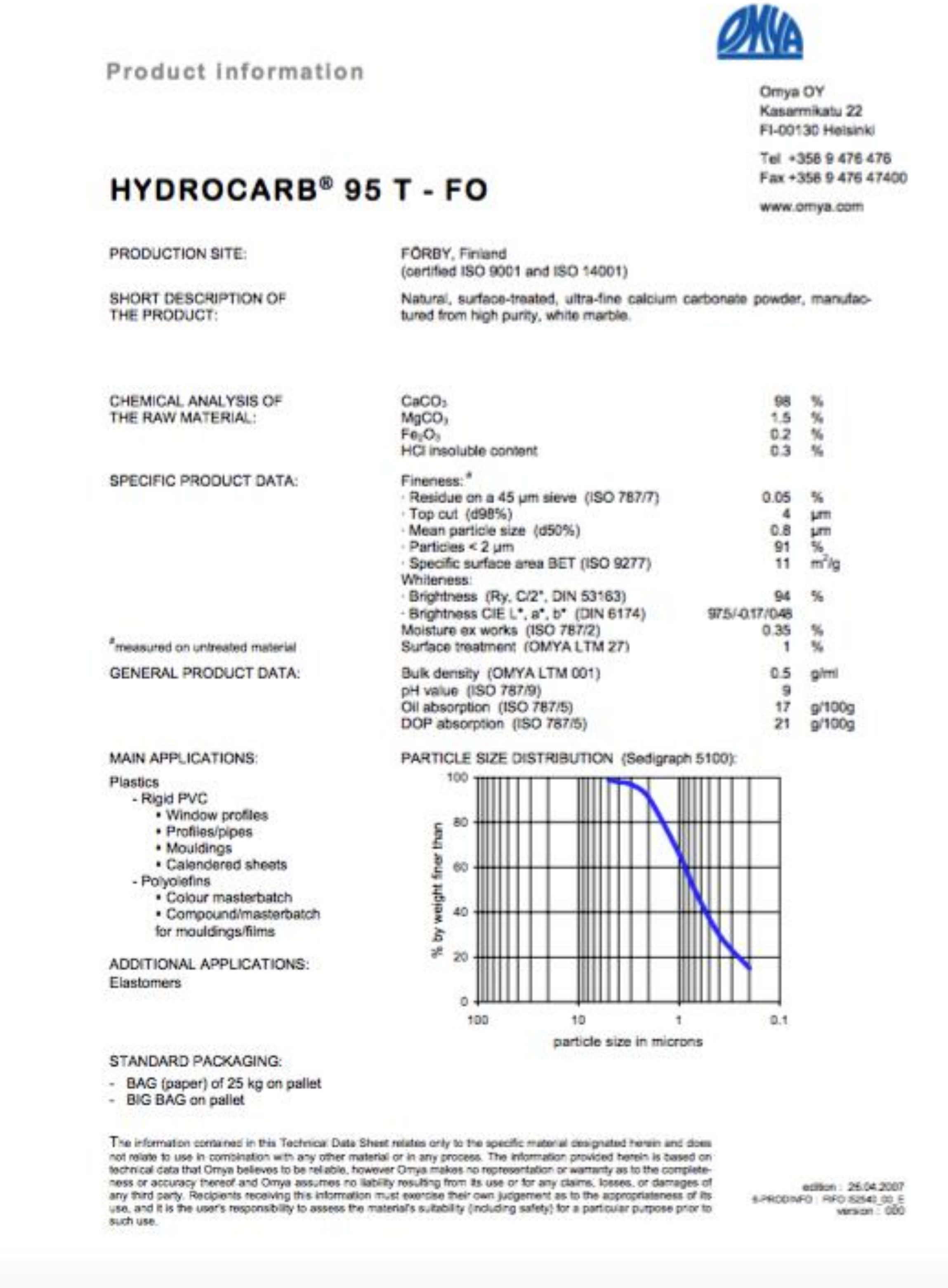
Revision Date - March 2013



Product information

Omya OY
Kasarmikatu 22
FI-00130 Helsinki

Tel +358 9 476 476
Fax +358 9 476 47400

www.omya.com

HYDROCARB® 95 T - FO

PRODUCTION SITE:	FÖRBY, Finland (certified ISO 9001 and ISO 14001)		
SHORT DESCRIPTION OF THE PRODUCT:	Natural, surface-treated, ultra-fine calcium carbonate powder, manufactured from high purity, white marble.		
CHEMICAL ANALYSIS OF THE RAW MATERIAL:	$CaCO_3$	98	%
	$MgCO_3$	1.5	%
	Fe_2O_3	0.2	%
	HCl insoluble content	0.3	%
SPECIFIC PRODUCT DATA:	Fineness: *		
	· Residue on a 45 µm sieve (ISO 787/7)	0.05	%
	· Top cut (d98%)	4	µm
	· Mean particle size (d50%)	0.8	µm
	· Particles < 2 µm	91	%
	· Specific surface area BET (ISO 9277)	11	m^2/g
	Whiteness:		
	· Brightness (Ry, C/2°, DIN 53163)	94	%
	· Brightness CIE L*, a*, b* (DIN 6174)	97.5/-0.17/0.48	
	Moisture ex works (ISO 787/2)	0.35	%
*measured on untreated material	Surface treatment (OMYA LTM 27)	1	%
GENERAL PRODUCT DATA:	Bulk density (OMYA LTM 001)	0.5	g/ml
	pH value (ISO 787/9)	9	
	Oil absorption (ISO 787/5)	17	g/100g
	DOP absorption (ISO 787/5)	21	g/100g

MAIN APPLICATIONS:

Plastics
- Rigid PVC
    - Window profiles
    - Profiles/pipes
    - Mouldings
    - Calendered sheets
- Polyolefins
    - Colour masterbatch
    - Compound/masterbatch for mouldings/films

ADDITIONAL APPLICATIONS:
Elastomers

PARTICLE SIZE DISTRIBUTION (Sedigraph 5100):

STANDARD PACKAGING:
- BAG (paper) of 25 kg on pallet
- BIG BAG on pallet

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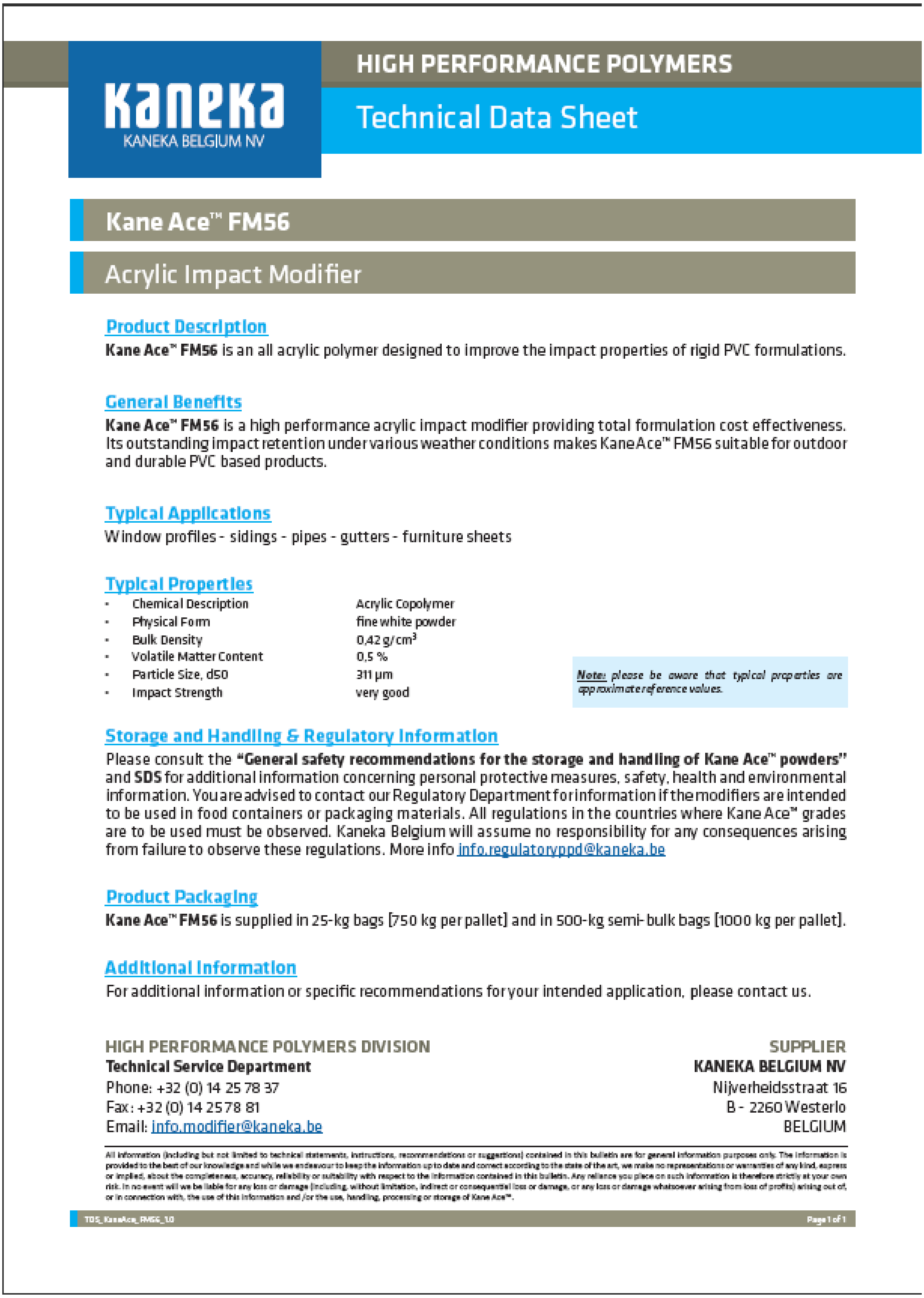

KANEKA BELGIUM NV

HIGH PERFORMANCE POLYMERS

Technical Data Sheet

Kane Ace™ FM56

Acrylic Impact Modifier

Product Description

Kane Ace™ FM56 is an all acrylic polymer designed to improve the impact properties of rigid PVC formulations.

General Benefits

Kane Ace™ FM56 is a high performance acrylic impact modifier providing total formulation cost effectiveness. Its outstanding impact retention under various weather conditions makes Kane Ace™ FM56 suitable for outdoor and durable PVC based products.

Typical Applications

Window profiles - sidings - pipes - gutters - furniture sheets

Typical Properties

Chemical Description	Acrylic Copolymer
Physical Form	fine white powder
Bulk Density	0,42 g/cm^3
Volatile Matter Content	0,5 %
Particle Size, d50	311 µm
Impact Strength	very good

__Note:__ please be aware that typical properties are approximate reference values.

Storage and Handling & Regulatory Information

Please consult the **"General safety recommendations for the storage and handling of Kane Ace™ powders"** and **SDS** for additional information concerning personal protective measures, safety, health and environmental information. You are advised to contact our Regulatory Department for information if the modifiers are intended to be used in food containers or packaging materials. All regulations in the countries where Kane Ace™ grades are to be used must be observed. Kaneka Belgium will assume no responsibility for any consequences arising from failure to observe these regulations. More info info.regulatoryppd@kaneka.be

Product Packaging

Kane Ace™ FM56 is supplied in 25-kg bags [750 kg per pallet] and in 500-kg semi-bulk bags [1000 kg per pallet].

Additional Information

For additional information or specific recommendations for your intended application, please contact us.

HIGH PERFORMANCE POLYMERS DIVISION
Technical Service Department
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Fax: +32 (0) 14 25 78 81
Email: info.modifier@kaneka.be

SUPPLIER
KANEKA BELGIUM NV
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B - 2260 Westerlo
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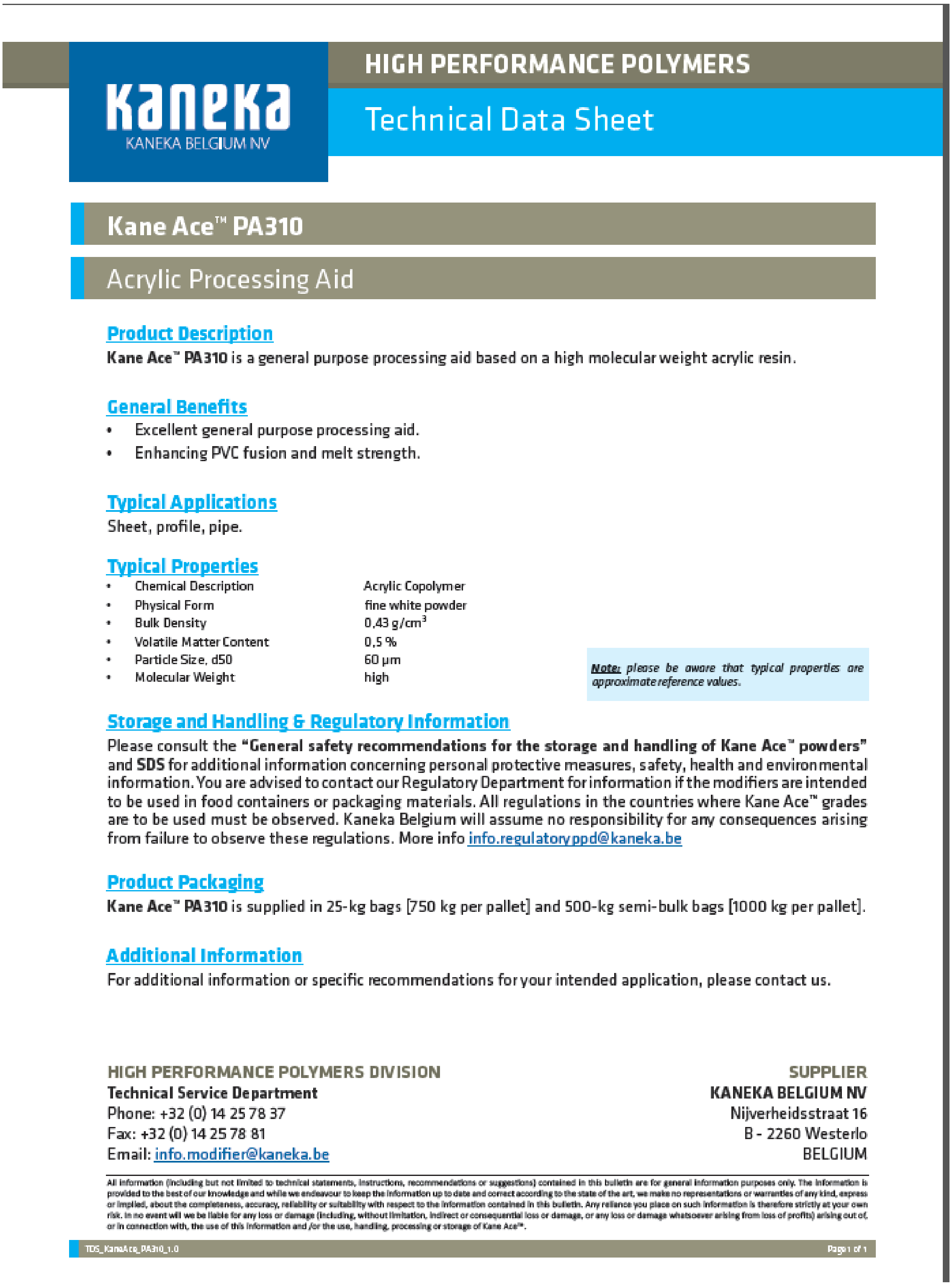

KANEKA
KANEKA BELGIUM NV

HIGH PERFORMANCE POLYMERS

Technical Data Sheet

Kane Ace™ PA310

Acrylic Processing Aid

Product Description

Kane Ace™ PA310 is a general purpose processing aid based on a high molecular weight acrylic resin.

General Benefits

- Excellent general purpose processing aid.
- Enhancing PVC fusion and melt strength.

Typical Applications

Sheet, profile, pipe.

Typical Properties

Chemical Description	Acrylic Copolymer
Physical Form	fine white powder
Bulk Density	0,43 g/cm^3
Volatile Matter Content	0,5 %
Particle Size, d50	60 µm
Molecular Weight	high

Note: *please be aware that typical properties are approximate reference values.*

Storage and Handling & Regulatory Information

Please consult the **"General safety recommendations for the storage and handling of Kane Ace™ powders"** and **SDS** for additional information concerning personal protective measures, safety, health and environmental information. You are advised to contact our Regulatory Department for information if the modifiers are intended to be used in food containers or packaging materials. All regulations in the countries where Kane Ace™ grades are to be used must be observed. Kaneka Belgium will assume no responsibility for any consequences arising from failure to observe these regulations. More info info.regulatoryppd@kaneka.be

Product Packaging

Kane Ace™ PA310 is supplied in 25-kg bags [750 kg per pallet] and 500-kg semi-bulk bags [1000 kg per pallet].

Additional Information

For additional information or specific recommendations for your intended application, please contact us.

HIGH PERFORMANCE POLYMERS DIVISION
Technical Service Department
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