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A REVIEW ON APPLICATION OF POLYMERS IN MECHANICAL ENGINEERING

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ABSTRACT

The polymer industry ranks as the third largest manufacturing industry in the Universe with plastics production on the rise. This, combined with increasing consumer and industry demands as well as competitive pressures, highlights the need for continued education and advancement in the area of polymer engineering. Polymer Science program has to face the many challenges that plastics companies and industry encounter every day, and will introduce to traditional plastics as well as the latest innovations in specialty polymers with growing applications in the biomedical and pharmaceutical fields, and in electronics and nanotechnology.

Many materials found in nature are polymers. In fact, the basic molecular structure of all plant and animal life is similar to that of a synthetic polymer. Natural polymers include such materials as silk, shellac, bitumen, rubber, and cellulose. However, the majority of polymers or plastics used for engineering design are synthetic and often they are specifically formulated or "designed" by chemists or chemical engineers to serve a specific purpose. Other engineers (mechanical, civil, electrical, etc.) typically design engineering components from the available materials or, sometimes, work directly with chemists or chemical engineers to synthesize a polymer with particular characteristics. Some of the useful properties of various engineering polymers are high strength or modulus to weight ratios (light weight but comparatively stiff and strong), toughness, resilience, resistance to corrosion, lack of conductivity (heat and electrical), color, transparency, processing, and low cost. Many of the useful properties of polymers are in fact unique to polymers and are due to their long chain molecular structure. In this paper, focus will be on general characteristics, applications and an introduction to the mechanical behavior including elementary concepts of their inherent time dependent or visco elastic nature.

Keywords: Polymers, Plastics, Machines, Mechanical Engineering

I.INTRODUCTION TO POLYMERS

Polymers play a very important role in human life. In fact, our body is made of lot of polymers, e.g. Proteins, enzymes, etc. Other naturally occurring polymers like wood, rubber, leather and silk are serving the humankind for many centuries now. Modern scientific tools revolutionized the processing of polymers thus available synthetic polymers like useful plastics, rubbers and fiber materials. As with other engineering materials (metals and ceramics), the properties of polymers are related their constituent structural elements and their arrangement. The suffix in polymer 'mer' is originated from Greek word meros – which means part. The word polymer is thus coined to mean material consisting of many parts/mers. Most of the polymers are basically organic compounds, however they can be inorganic (e.g. silicones based on Si-O network). This chapter introduces classification of polymers, processing and synthesis of polymers, followed by mechanism of deformation and mechanical behavior of polymers.

Polymer types and Polymer synthesis & processing Polymers are classified in several ways – by how the molecules are synthesized, by their molecular structure, or by their chemical family. For example, linear polymers consist of long molecular chains, while the branched polymers consist of primary long chains and secondary chains that stem from these main chains. However, linear does not mean straight lines. The better way to classify polymers is according to their mechanical and thermal behavior. Industrially polymers are classified into two main classes – plastics and elastomers. Plastics are moldable organic resins. These are either natural or synthetic, and are processed by forming or molding into shapes. Plastics are important engineering materials for many reasons. They have a wide range of properties, some of which are unattainable from any other materials, and in most cases they are relatively low in cost. Following is the brief list of properties of plastics: light weight, wide range of colors, low thermal and electrical conductivity, less brittle, good toughness, good resistance to acids, bases and moisture, high dielectric strength (use in electrical insulation), etc. Plastics are again classified in two groups depending on their mechanical and thermal behavior as thermoplasts (thermoplastic polymers) and thermosets (thermosetting polymers).

II. THERMOPLASTS

These plastics soften when heated and harden when cooled – processes that are totally reversible and may be repeated. These materials are normally fabricated by the simultaneous application of heat and pressure. They are linear polymers without any cross-linking in structure where long molecular chains are bonded to each other by secondary bonds and/or inter-wined. They have the property of increasing plasticity with increasing temperature which breaks the secondary bonds between individual chains. Common thermoplasts are: acrylics, PVC, nylons, polypropylene, polystyrene, polymethyl methacrylate (plastic lenses or perspex), etc.

III. THERMOSETS

These plastics require heat and pressure to mold them into shape. They are formed into a permanent shape and cured or 'set' by chemical reactions such as extensive cross-linking. They cannot be re-melted or reformed into another shape but decompose upon being heated to too high a temperature. Thus thermosets cannot be recycled, whereas thermoplasts can be recycled. The term thermoset implies that heat is required to permanently set the plastic. Most thermosets composed of long chains that are strongly cross-linked (and/or covalently bonded) to one another to form 3-D network structures to form a rigid solid. Thermosets are generally stronger, but more brittle than thermoplasts. Advantages of thermosets for engineering design applications include one or more of the following: high thermal stability, high dimensional stability, high rigidity, light weight, high electrical and thermal insulating properties and resistance to creep and deformation under load. There are two methods whereby cross-linking reaction can be initiated – cross-linking can be accomplished by heating the resin in a suitable mold (e.g. bakelite), or resins such as epoxies (araldite) are cured at low temperature by the addition of a suitable cross-linking agent, an amine. Epoxies, vulcanized rubbers, phenolics, unsaturated polyester resins, and amino resins (ureas and melamines) are examples of thermosets.

IV. ELASTOMERS

Also known as rubbers, these are polymers which can undergo large elongations under load, at room temperature, and return to their original shape when the load is released. There are number of man-made elastomers in addition to natural rubber. These consist of coil-like polymer chains those can reversibly stretch by applying a force. Processing of polymers mainly involves preparing a particular polymer by synthesis of available raw materials, followed by forming into various shapes. Raw materials for polymerization are usually derived from coal and petroleum products. The large molecules of many commercially useful polymers must be synthesized from substances having smaller molecules. The synthesis of the large molecule polymers is known as polymerization in which monomer units are joined over and over to become a large molecule. More upon, properties of a polymer can be enhanced or modified with the addition of special materials. This is followed by forming operation. Addition polymerization and condensation polymerization are the two main ways of polymerization. Addition polymerization, also known as chain reaction polymerization, is a process in which multi-functional monomer units are attached one at a time in chainlike fashion to form linear/3-D macro-molecules. The composition of the macro-molecule is an exact multiple of for that of the original reactant monomer. This kind of polymerization involves three distinct stages – initiation, propagation and termination. To initiate the process, an initiator is added to the monomer. This forms free radicals with a reactive site that attracts one of the carbon atoms of the monomer. When this occurs, the reactive site is transferred to the other carbon atom in the monomer and a chain begins to form in propagation stage. A common initiator is benzoyl peroxide. When polymerization is nearly complete, remaining monomers must diffuse a long distance to reach reactive site, thus the growth rate decreases.

Polyurethane

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Polyurethane is a typical elastomeric material and among the most versatile materials today. It is a linear block copolymer consisting of alternating soft and hard segments with phase separation due to thermodynamic segmental incompatibility. Inspired by the hierarchical structure of spider silk, this kind of block copolymer can be synthesized with two distinct blocks that can differ in their propensity to crystallize. Either the soft or hard segments can be amorphous or semicrystalline.

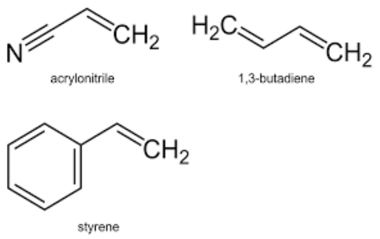
Recent experiments indicate that crystallizable segments lead to higher tensile strength and that systems with crystalline hard segment exhibit better stiffness, strength and mechanical toughness. We are using molecular dynamics simulations to investigate the influence of block architectures on mechanical properties and molecular chain movement.

V. CHARACTERISTICS AND TYPICAL APPLICATIONS OF FEW PLASTIC MATERIALS

a) Thermo plastics :

1. Acrylonitrile-butadiene-styrene (ABS):

Structure:

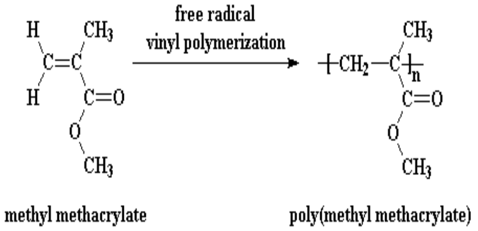


Characteristics:Outstanding strength and toughness, resistance to heat distortion; good electrical properties; flammable and soluble in some organic solvents.

Application: Refrigerator lining, lawn and garden equipment, toys, highway safety devices.

2. Acrylics (poly-methyl-methacrylate):

Structure:

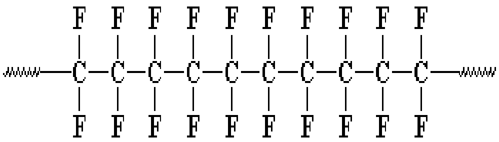


Characteristics: Outstanding light transmission and resistance to weathering; only fair mechanical properties.

Application: Lenses, transparent avircraft enclosures, drafting equipment, outdoor signs

3. Fluorocarbons (PTFE or TFE):

Structure:

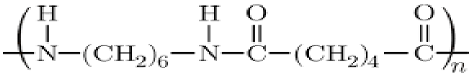


Characteristics: Chemically inert in almost all environments, excellent electrical properties; low coefficient of friction; may be used to 260o C; relatively weak and poor cold-flow properties.

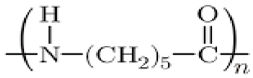
Application: Anticorrosive seals, chemical pipes and valves, bearings, anti adhesive coatings, high temperature electronic parts.

4. Polyamides (nylons):

Structure:



Nylon 66



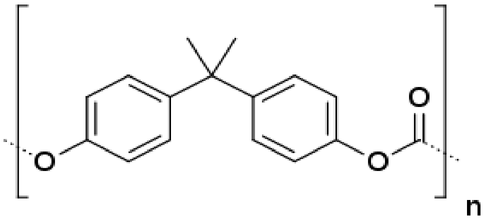
Nylon 6

Characteristics: Good mechanical strength, abrasion resistance, and toughness; low coefficient of friction; absorbs water and some other liquids.

Application: Bearings, gears, cams, bushings, handles, and jacketing for wires and cables

5. Polycarbonates:

Structure:

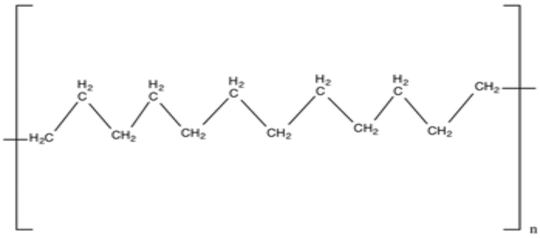


Characteristics: Dimensionally stable: low water absorption; transparent; very good impact resistance and ductility.

Application: Safety helmets, lenses light globes, base for photographic film

6. Polyethylene:

Structure:

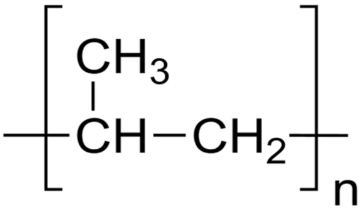


Characteristics: Chemically resistant and electrically insulating; tough and relatively low coefficient of friction; low strength and poor resistance to weathering.

Application: Flexible bottles, toys, tumblers, battery parts, ice trays, film wrapping materials.

7. Polypropylene:

Structure:

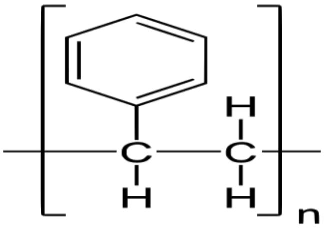


Characteristics: Resistant to heat distortion; excellent electrical properties and fatigue strength; chemically inert; relatively inexpensive; poor resistance to UV light.

Application: Sterilizable bottles, packaging film, TV cabinets, luggage

8. Polystyrene:

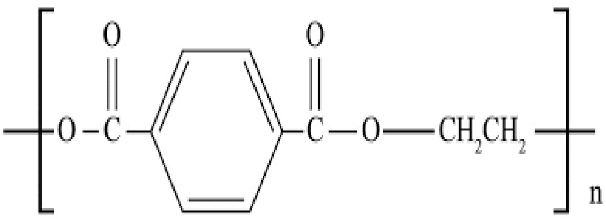
Structure:



Characteristics: Excellent electrical properties and optical clarity; good thermal and dimensional stability; relatively inexpensive Application: Wall tile, battery cases, toys, indoor lighting panels, appliance housings.

9. Polyester (PET or PETE):

Structure:



PET

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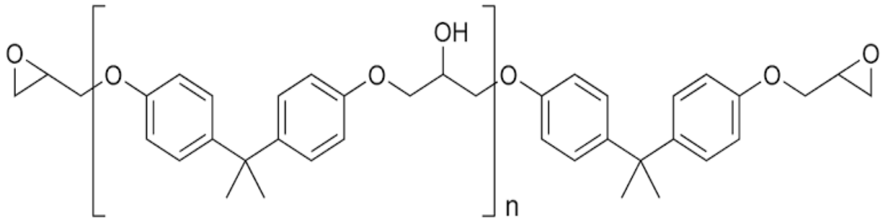
Characteristics: One of the toughest of plastic films; excellent fatigue and tear strength, and resistance to humidity acids, greases, oils and solvents.

Application: Magnetic recording tapes, clothing, automotive tire cords, beverage containers.

b) Thermo setting polymers

1. Epoxies:

Structure:

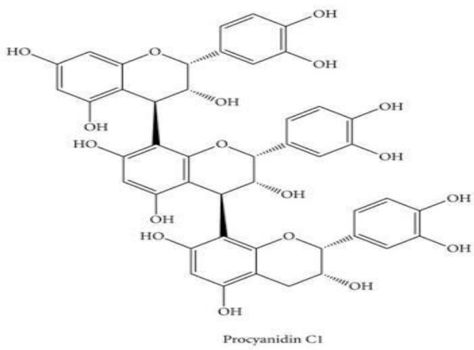


Characteristics: Excellent combination of mechanical properties and corrosion resistance; dimensionally stable; good adhesion; relatively inexpensive; good electrical properties.

Application: Electrical moldings, sinks, adhesives, protective coatings, used with fiberglass laminates.

2. Phenolics:

Structure:



Characteristics: Excellent thermal stability to over 150o C; may be compounded with a large number of resins, fillers, etc.; inexpensive. Application: Motor housing, telephones, auto distributors, electrical fixtures.

VI. ADVANCED TECHNOLOGY APPLICATIONS

New classes of polymeric materials with unique applications are being introduced. In many cases, properties and their usage were discovered only recently.

This paper covers two areas:

(1) Health, medicines and biotechnology, a rapidly developing domain based largerly on known materials but moving designed and engineered polymers

(2) Information and communications, an emerging field for polymers significantly based on their electronic properties. These two areas are attracting a great deal of attention, particularly among researchers who are not

traditional specialists in polymers science. The growing importance of these fields makes the interdisciplinary aspect of polymer research abundantly clear.

Structural Composites:

Polymer composites can provide the greatest strength to weight and stiffness to weight ratios available in any material, even the lightest, strongest metals. Hence, high performance and fuel economy driven application are prime uses of such composites. One of the most important attributes is the opportunity to design various critical properties to suit the intended application. Indeed, performance may be controlled by altering the constituents, their geometries and arrangement, and the interfaces between them in the composite systems. This makes it possible to create materials tailored to applications, the single greatest advantage and future promise of these material systems. Structural composites are of interest in aerospace applications and in numerous industrial and consumer uses in which light weight, high strength, long fatigue life,

and enhanced corrosion resistance are critical. Much needs to be done to advance processibility and durability, to provide a more comprehensive database, and to improve the economics of these systems. A wide range of future needs encompasses synthesis, characterization, processing, testing, and modeling of important polymer matrix composite systems.

In general, the future of polymer matrix composites is bright. The engineering community is now in the second generation of applications of composites, and primary structures are now being designed with these materials. There is a growing confidence in the reliability and durability of polymer composites and a growing realization that they hold the promise of economic as well as engineering gain. Commercial programs such as high speed civil transport will not succeed without the use of polymer composites. Integrated synthesis, processing, characterization, and modeling will allow the use of molecular concepts for the design of the material system and to estimate the effect of how the materials are put together on the performance, economy, and reliability of the resulting component. A more precise understanding of the manufacturing, processing, and component design steps will greatly accelerate the acceptance of these advanced materials. New horizons for properties and performance, for example, in smart and intelligent materials, actuators, sensors, high temperature organic materials and multi component hybrid systems, will involve the potential of introducing a new age of economic success and technical excellence. It has been estimated that finished product businesses already exist for the aggregate of polymers, reinforcements, prepregs, tooling machinery and other ancillary products.

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