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Department of Polymer and
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Investigation of Polypropylene (PP): Properties and Industrial Applications

A Graduation Project

Submitted to the Council of the College Materials Engineering/ the University of Babylon in Partial Fulfillment of the Requirements for the Bachelor's Degree of Science in Materials Engineering/ Polymer

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بِسْمِ اللهِ الرَّحْمَنِ الرَّحِيمِ

((يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ

وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا

تَعْمَلُونَ خَبِيرٌ))

صَدَقَ اللهُ العَلِيُّ العَظيم

سورة المجادلة: الآية 11

Dedication

We started with more than one hand, and we suffered more than they are, and we suffered a lot of difficulties, and here we are today, thank God We wrap up the nights and The tiredness of the days and the summary of our journey between the covers of this humble work

To the fountain that never tires of giving To the one who woven my happiness with threads woven from her heart **to my dear mother**.

To those who strive and wretched to enjoy comfort and contentment, who did not skimp on anything in order to push me on the path of success, who taught me to ascend the ladder of life with wisdom and patience **to my dear father**.

To whom their love runs through my veins and meditates in their memory my heart **to my sister and my brothers.**

To those who taught us letters of gold, words of pearls, and phrases of the highest and most glorious expressions in science. To those who crafted for us their knowledge of letters, and their thought as a beacon illuminating the biography of science and success for us. **to our honorable professors.**

Acknowledgements

First of all I thank Allah who gave me the ability and desire to complete this.

I extend my highest thanks, gratitude, appreciation and love to those who carried the holiest message in life.. to those who paved the way for us with knowledge and knowledge.. our distinguished professors, especially the mention

(Dr. Ali Salah Hassan) who was the best teacher in his treatment of us and his guidance, support and continuous encouragement throughout this project.

Sincere thanks are also expressed to the staff of the material engineering college and Department of Polymer and Petrochemical Industries and laboratories for the encouragement during this work

Finally, I would like to thank my family, my friends and everyone help me to accomplish the present work.

Supervisor Certification

We certify that this project entitled **(Investigation of Polypropylene (PP) Properties and Industrial Applications).** was prepared

By: Montadher Khilel Hussein, Zahraa Muthanna Abd Al-Kathem and Zainab Kareem Daham

under our supervision at Babylon University / Collage of Material Engineering / Department of Polymers Engineering & Petrochemical Industries , in partial Fulfillment of requirements for the Award Bachelor Degree of Science in Material Engineering , Polymer& Petrochemical Industries..

We Recommend that this project be forwarded for examinations in accordance with the regulation of the University of Babylon.

Supervisor: Assist. Prof. Dr. Ali Salah Hassan

ABSTRACT

In this work, a polypropylene polymer was studied and prepared because of its properties suitable for industrial applications. It is used in car covers and bumpers, in the manufacture of door panels, and interior decorations. It is also used in the film industry and in food packaging.

Where the polymer was used and the sheets were prepared by means of a double screw extrusion machine with homogeneous fish at three temperatures (150,160,170) C, and the mechanical properties were studied from the tests (tensile, impact, and hardness) as well as (hardness, toughness, and elongation).

And then studying the same properties above for sheets filled with alumina Al2O3 at a single concentration ratio was 5% of the polymer, as we show through the results when the temperature increases, the toughness will increase and offset by a decrease in stress and increased strain, and accordingly, the elastic modulus will decrease as a result of the increase in shock resistance and also in the presence of a decrease in the hardness value.

This is in complete agreement with the addition of the plasticizer, as the addition of the plasticizer (alumina) has similar behavior to the increase in temperature, and therefore we can suggest that the samples were suitable for use in the bumpers of cars and traffic equipment.

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Chapter one

1.1. Introduction of polymer :

Polymer science was known in the thirties of the last century, but it is nowadays reached a high level of knowledge The development where the people along time ago used natural polymers in their daily need for thousands of years He needed to make his own clothes from cotton, wool and silk, and he also used polymers in his applications Many of them are: glues, bonding agents, dyes, and asphalt. It took place during the nineteenth century and the beginnings of twentieth century polymeric discoveries Before the term macromolecules took its current definition, it Charles Goodyear succeeded in 1839 in producing rubber like natural rubber and more The benefit of it through the so-called process of vulcanization (heating natural rubber with sulfur to 270 *C). And Leo bakeland made Bakelite, as it is used as a heat insulator. In 1920, El Staudinger published his article entitled “uber polymerisation”, in which he presented the development of modern theory, and we can say that these materials are used at the present time. Almost in all branches of economics, and because of this, the number of specialists who are qualified in the field is increasing their activity with the chemistry and technology of polymer art[1,5].

Polymers are industrial chemical compounds with large molecules, their preparation is one of the branches of chemical engineering, where complex organic materials are used in their manufacture such as (coal, oil, natural gas, cellulose) and carbon is mainly in its composition, and the word consists of two syllables (Poly) means multiple, (Mers) means massive particles, and the word polymers translates to (plastics) [1]. Polymer molecules are large compared to hydrocarbon molecules, and because of their size they are called macromolecules, as the atoms are linked to each other by a strong covalent bond. The backbone of most polymeric chains is a chain of carbon atoms, as individual carbon atoms are bonded to two nearby carbon atoms. Long molecules are made up of skeletons called repeat units that successfully repeat along the chain. The term monomer refers to the small atoms from which the polymer is formed, and the term (monomer unit) is usually used instead of the above two terms [2]. The degree of polymerization represents the number of repeating units in the chain of a polymer molecule, and is expressed by the number (n) placed under the arc containing the repeating unit. The higher the degree of polymerization of any polymer, the higher this indicates that it has a large molecular weight [3,4]. Polymers play an active role in our daily lives, and there are natural polymers that appear naturally, Natural inorganic polymers include diamond, graphite, sand, asbestos, agate, Wool, feldspar, and feldspar (aluminum silicate). Organic natural polymers include many compounds. Such as starch, simmons, amino acids, and proteins. The daily life of each individual cannot grow (evolve) without engineering materials, including polymers, and without these materials, it is not possible to reach space, as 70% of the parts of spaceships are made of these polymers, especially structural composite materials, and thanks to the widespread use of polymers in cars, The weight of these cars decreased, and through this reduced fuel consumption by 25%, and the polymers allowed doctors (heart surgeons) to work and research on the design of heart valves, as hundreds of these valves were replaced in the past year, thus escaping this large number of people from certain death.[6] Finally, in the field of sports, where the athletes were able to jump about 6.15 meters to the apex of trachea by virtue of polymers, as bronchus is made of polyester reinforced with carbon fibers, and these examples can be mentioned without limits, but besides these advantages, there are negatives of polymers that can be divided into:

- Direct, polymers have insufficient properties, including physical and mechanical properties, compared with metallic materials,

- The intermediate, where there are some difficulties in getting rid of the spent pieces as a result of the difficulty of decomposition and decomposition of these wastes, and the process of their decomposition is estimated at about 200 years,

- Another problem is the inaccuracy of some products manufactured from these materials according to accurate technical specifications,
- High costs when designing and producing machines that form polymers and auxiliary devices for forming, such as moulds [6].

1.1.2 Classification of Polymers:

Polymers are classified according to their physical properties into classes

1.1.2.1. Thermosets polymer:

These polymers undergo chemical changes when heated, and the polymeric chains intertwine in them, and these polymers, after heat treatment, become insoluble, non-fusible, and poor conductors of heat and electricity. The chains are linked to each other by strong chemical bonds that cannot be easily broken, so these materials cannot be reconstituted again when exposed to a certain temperature and by increasing the temperature, they will char and decompose, meaning that they are not quickly affected by the temperature that is below the temperature of decomposition. It has low density, high electrical insulating properties, high thermal insulation, high stiffness, and strong strength [4]. The degree of cross linking in thermoset polymers is shown in Fig 1.Examples of this type are: phenol formaldehyde, epoxy, and unsaturated polyester (PS) [7]. Most thermostats incorporate specific fibers or fillers to reduce cost and for Modify physical properties, reduce shrinkage during processing, and enhance flame retardancy. [7-9].

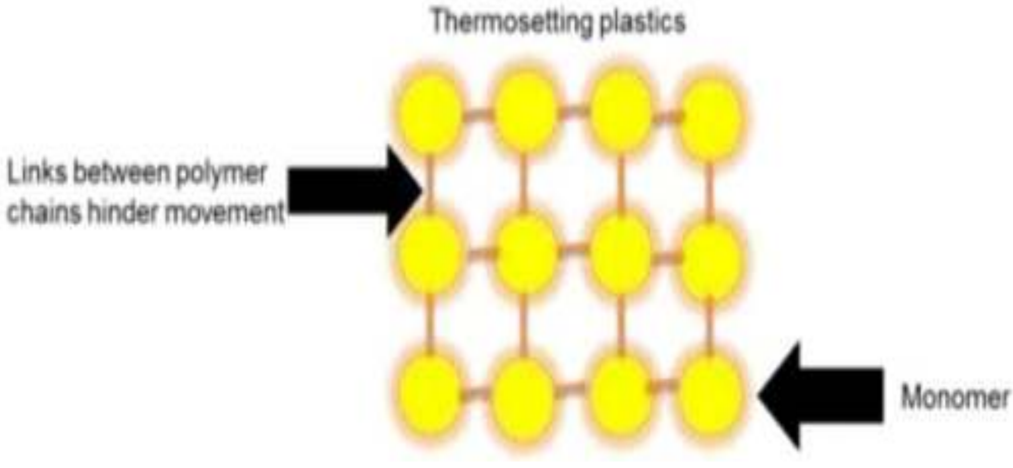

Figure (1.1: The degree of cross linking in thermoset polymers[7].

1.1.2.2. Thermoplastic polymer:

They are hard polymeric materials at normal temperatures, but they soften with heat (soften) and turn into a dough-like substance so that its shape can be changed by hand. Which are used in the polymer and synthetic fiber industries, and upon cooling the material passes through all the previous stages where it gradually hardens and returns again to take the solid state. Thermoplastics contain the simplest particles structure, with chemically independent macromolecules By heating, it is softened or Melting, then shaped, shaped, welded, and hardened when cool. Multiple heating and cooling cycles It can be repeated without severe damage, allowing Reprocessing and recycling [11]. There are many commercial polymers that fall into this category, including: polyethylene (PE), polystyrene (PS), polycarbonate (PC), polyvinyl chloride (PVC), polypropylene (PP) and others. This category includes polymers, whose properties change with the influence of temperature, by the influence of temperature they turn into molten, and when their temperature approaches the degree of glass transition (T_g), they become flexible and then increase the degree of flexibility by converting them to viscous molten, and when the temperature of the molten is reduced, it recovers its strong solid state, This class is considered one of the most important industrial polymers. And the fig2 are explain the structure of thermoplastic.[11]

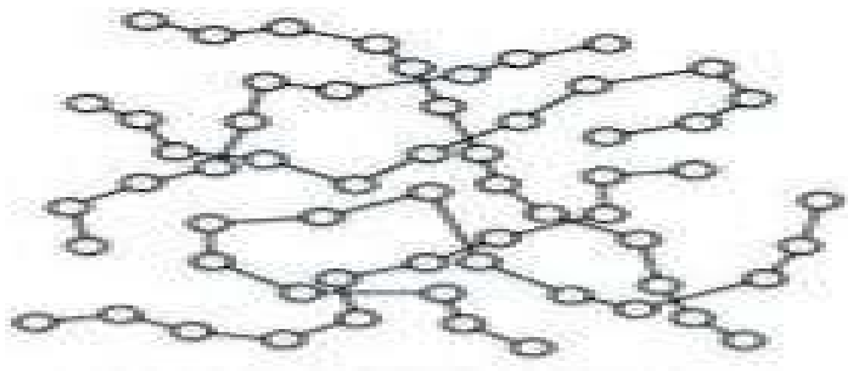

Figure (1.2): Structure of thermoplastic[11].

1.1.2.3. Elastomers polymer:

Flexible polymers represented by rubber (Rubber) have distinct properties such as elongation (Eongation or Extensibility). The ability of this class of polymers to show the properties of elasticity depends on the nature of polymeric molecules with long flexible chains located in randomly coiled positions, so that the average distance between the two ends of the polymer molecule Much less than the distance when the molecule is in the extended position, and in general, the glass transition temperature (Tg) of flexible polymers is lower than the temperature at which it is used where the polymeric chains are free in local movement, and flexible polymers are characterized by a low degree of glass transition (Tg) [11]. The property profiles of elastomers depend mainly on the choice of the particular rubber, the compound composition, the production process and the shape and design of the product. Moreover the type of loading, e.g. whether it is static or dynamic, strongly influences elastomer properties. Satisfactory properties can be obtained only by proper compounding of elastomers with chemicals and additives, and by subsequent vulcanization in appropriate conditions. Depending on the type and amount of rubber chemicals and additives in a compound, and depending on the degree of vulcanization, a given rubber can yield vulcanizates with considerably different properties with respect to hardness, elasticity or strength. Rubbers are also capable of adhering to most other materials, enabling different hybrid constructions. In combination with fibres, such as rayon, polyamide, polyester, glass or steel-cord, the tensile strength is increased considerably with a reduction in extendibility. By joining elastomers to metals, components which combine the elasticity of elastomers with the rigidity of metals can be achieved [12].

Figure (1.3): Structure of elastomers[12].

1.2. Literature Review:

in 2001,J.Aurrekoetxea and et.al, studied the effects of recycling on the microstructure and the mechanical properties of isotactic PP.Chemical structure ,melt viscosity ,crystallization behavior and tensile properties are measured .The result shows main effect of recycling is the lowering of the melt viscosity ,which is attributed to molecular weight decrease.FTIR result shows recycling effect was chain scission not of oxidation. Elastic modulus and yield stress increase with the number of recycling steps [50].

in 2003 J. Aurrekoetxeaa,et.al, reported the effect of injection molding induced morphology on the fracture behaviour of virgin and recycled polypropylene (PP). The microhardness and the degree of crystallinity are studied,Virgin PP has shown higher microhardness values and bigger plastically deformed zone at the crack tip than recycled one. These two differences are due to the higher crystallinity of the recycled PP[51].

in 2005,Rust. N studied a degradation of isotactic virgin and recycled polypropylene used in lead acid battery casings .various ratios of virgin and different grades of recycled PP use in the manufacturing of lead acid battery cases and their influence on its physical and chemical properties. The MFI and rheological studies of recycled polypropylene that contained a stabilizer showed a significant improvement in terms of maintaining long term polymer stability. Spectroscopic analysis showed that the chain scission, which occurs in polypropylene during recycling, is mainly as a result of heat and mechanical shearing and does not generally occur due to oxidation of the polymer. The study showed that a slight decrease in the tensile strength .However, it was found that small additions of recycled material with virgin PP initially increased the impact strength of the material. However, a small amount of recycled material seemed to improve the heating sealing ability by acting as a lubricant between the larger molecules[52].

In 2005 the establishment of Ota, Amiko, Satyanarayana conducted a study to study the relationship between the mechanical and physical properties of polypropylene and the material after molding PP / fiberglass and after molding by injection machine at several temperatures, as well as changing the proportion of glass up to 20% and 30%, so the density and temperature of the study were studied Fluidity, stability, crystallization, tensile and shock properties. The degree of fluidity of the composite material depends on the percentage of glass greens, the longitudinal distribution of glass fibers, cleaved polypropylene urine, cleaved polypropylene exchange, and the elasticity switch of the material increases linearly with the fiber content [53].

In 2005 Senol Sahin and Pasa Yayla The mechanical properties of polypropylene random copolymer (PP-R) with different processing parameters were studied and with special attention investigated the influence of master batch addition on the variation in the mechanical properties of injection moulded PP-R. Tensile, instrumented Charpy impact, Shore D hardness, differential scanning calorimeter (DSC) and Vicat softening temperature (VST) tests were conducted on the test samples containing different colour, The effect of processing parameters on material performance was studied on samples which were directly obtained from extruded pipes and on injection moulded samples and finally the effects of storage time on the polymer properties were investigated.[54]

In 2011, S. Ferrandiz and et.al, showed the rheological behavior of a material that recycled materials have been incorporated. The transformation process to be applied is the injection molding. This mixture provides virgin polypropylene and copolymer polypropylene waste materials. The result show that ,The characterization of the recycled polypropylene used in the blends shows us that no thermal degradation occurs during processing and whose behavior is very similar to that of virgin material used in the same application. And make a compared between experimental and simulation by using the equivalent box model (EBM).The rheological model proposed was shown to work accurately for the all materials studied, and a good correlation between experimental and simulation flows [55].

Also in 2011 Mirigul Altan, et al, investigated the tensile and thermal properties of the polypropylene (PP) reinforced with titan dioxide (TiO_2) and zinc oxide (ZnO) nanoparticles, nanoparticles are modified with maleic anhydride grafted styrene ethylene butylene styrene (SEBS-g-MA) and silane, respectively. Nanocomposites are prepared by using twin screw extruder at nanoparticles content of 1%, 3% and 5% of TiO_2 and ZnO. The result show that all tensile properties except elongation increases. On the other hand, although TiO_2 has higher hardness than ZnO, the elongation of the composites with TiO_2 is higher than that of ZnO [56].

In 2013, Mahendrasinh M. Raj and et.al, studied the mechanical properties of recycled polypropylene blended with virgin polypropylene. Tensile strength ,flexural strength and impact strength and melt flow index(MFI) are measured for mixture of recycle polypropylene .The result show MFI increase, tensile and flexural and impact decrease with recycle ratio. Also tensile strength and modulus of elasticity decrease with number of cycle[57].

In 2014 Achmad, et alprepared nanocomposite of Polypropylene (PP)/calcium carbonate ($CaCO_3$) was from master batch by twin-screw extruder. The effect of three different CaCO3 (5, 10, and 15 wt. %) nanoparticles on the rheological and the mechanical properties of the polypropylene nanocomposite was examined. The results show that the storage modulus (G′) and the loss modulus (G″) of the nanocomposite increases with CaCO3 nanoparticles percentage increasing. The tensile results show an increment in the tensile modulus (especially at 10 and 15 wt. %), while the tensile strength decreases with nanoparticles percentage increasing. The incorporation of CaCO3 nanoparticles in polypropylene matrix has improvement in the flexural and Izod impact properties of the nanocomposite.[58].

In 2017 Li, J Liu, L Qin, C Zhang, Y Sha, J Jiang, X Wang, Crystalline polymers can exhibit anomalous crystallization behaviors as restricted into nanodomains. Herein, syndiotactic polypropylene (sPP) was infiltrated into nanoporous alumina templates with different pore diameters, and their nonisothermal and isothermal crystallization kinetics were investigated. As located inside nanopores, the crystallization of sPP becomes sluggish. The crystallization temperatures reveal a pronounced cooling rate dependence for sPP in large nanopores. At fast cooling rates, the homogeneous nucleation is dominated.nucleation, respectively. For sPP in small nanopores, the homogeneous nucleation always predominates, which induces less cooling rate effect. In addition, based on the Avrami equation and Lauritzen-Hoffman growth theory [59].

In 2020 AS Sufian, N Samat, MYM Sulaiman… The investigation on the influences of alumina (Al2O3) particles in nano-sized retrieved from Aluminium (Al) dross was conducted on the tensile, thermal and wear properties of polypropylene (PP) composites. The thermal decomposition method was used to synthesise the micro α-Al2O3 particles from Al-dross, was followed by the wet-milling method to produce the nano α-

Al_2O_3. The PP composites (nano and micro α-Al_2O_3 particles) were prepared via melt compounding followed by compression molding. The coupling agent was also added to facilitate the particle dispersion. The tensile tests showed the maximum tensile strength and Young's modulus of both composites to be corresponding to the samples containing 5 wt% of α-Al_2O_3. The superiority of nano α-Al_2O_3 on improving the property of PP had also been evident in the abrasive wear performance. A small amount of α-Al_2O_3 had been adequate in enhancing the thermal stability of PP than that of neat PP [60].

1.3. The aim of the project :

Preparation and study the mechanical properties of Sheets from polypropylene-filled in alumina and its use in industrial applications.

Chapter Two

2.2. Polypropylene

Polypropylene is the third-largest volume polyolefin and one of the major plastics worldwide. The commercial plastic was first introduced in 1957 [13]. Melting point about 160-175°C glass transition temperature -15°C and Processing temperature 225-260°C[13]. Fig.4 Polypropylene structure.

Figure (2.1): Polypropylene polymer [14]

Polypropylene is a type of thermoplastic polymer; it is a part of both the average household and is in commercial and industrial applications. The chemical designation is C_3H_6, PP is widely used in variety of applications including packaging, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, and automotive components [15]. Polypropylene is a semi crystalline polymer containing both crystalline and amorphous phases. The relative amount of each phase depends on structural and stereo chemical characteristics of the polymer chains and the conditions under which the resin is converted to final products such as fibers, films, and various other geometric shapes during fabrication by extrusion, thermoforming, or molding [16].

2.1.2.Polypropylene production method :

Polypropylene (PP) is a thermoplastic material that is produced by polymerizing propylene molecules. There are a number of different ways to link the monomers together, but PP as a commercially used material in its most widely used form is made with catalysts that produce crystallizable polymer chains. These give rise to a product that is a semi crystalline solid with good physical, mechanical, and thermal properties[9]. Propylene is a cheap and abundant monomer . it is of interest only when polymerized in the isotactic form using ziegler- natta catalysis [17]. Fig.15: Explain Ziegler – natta catalyst of polypropylene . Polypropylene is made by polymerizing high-purity propylene gas recovered from cracked gas streams in olefin plants and oil refineries. The polymerization reaction is a low-pressure process that utilizes Ziegler–Natta catalysts (aluminum alkyls and titanium halides). The catalyst may be slurried in a hydrocarbon mixture to facilitate heat transfer. The reaction is carried out in batch or continuous reactors operating at temperatures between 50 and 80°C and pressure in the range of 5 to 25 atm [12].

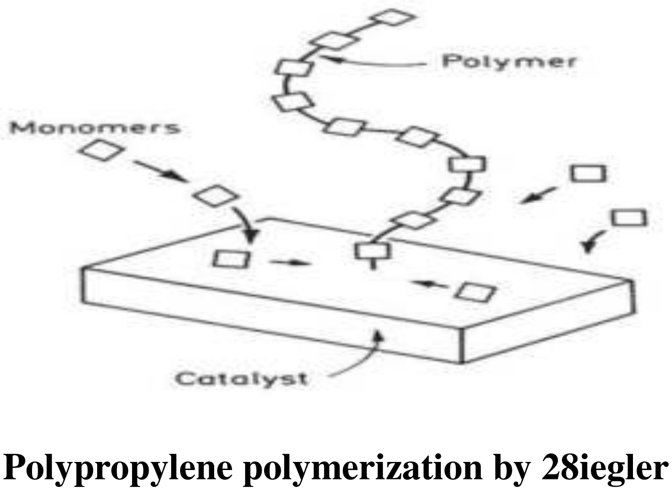

Figure (2.2) : Polypropylene polymerization by 28iegler – natta catalyst [17].

2.1.3. Classifications of polypropylene :

Polypropylene belongs to the group of vinyl polymers. Three stereo configurations of polypropylene can be distinguished, namely the isotactic, the syndiotactic and the atactic form [18,19,23].

2.1.3.1. Isotactic PP :

Isotactic (i-PP) is at each chiral center has the same configuration, i.e. all methyl groups are placed on the same side of the chain [19].That is with a regular stereochemistry at each alternating carbon atom, had greater rigidity and hardness than polyethylene[20].In the case of isotactic polypropylene, the methyl groups dictate a helical conformation to the backbone and this results in a regular structure which is able to crystallize readily[21]. While s-PP and a-PP are of minor commercial importance, i-PP contributes by far the most to the consumption of polypropylene. Because of its excellent cost/performance balance, versatile properties, good processability , isotactic polypropylene is found in a wide variety of products[19,1]. The greater the degree of isotacticity the greater the crystallinity and hence the greater the softening point, stiffness, tensile strength, modulus, and hardness[22].

2.1.3.2. Syndiotactic PP :

Alternate chiral centres are identical in the syndiotactic (s-PP) form[3,18]. Where there is a regular alternating arrangement of asymmetric carbon atoms [20].Which are soft disordered materials with low levels of crystallinity[21]. Syndiotactic PP has similar properties of isotactic PP, but is harder to synthesize[23].Fig.6: shows chain regularity(tactisity) of polypropylene.

2.1.3.3. Atactic PP :

in atactic polypropylene (a-PP), the arrangement of the methyl groups is completely randomly[18,19].That is with a random distribution of different stereochemical arrangements at each methyl-bearing carbon atom. It was found to be amorphous and of little strength[20]. Atactic polymers will generally be amorphous, soft, flexible materials. So, atactic PP is a low melting gooey material[23].

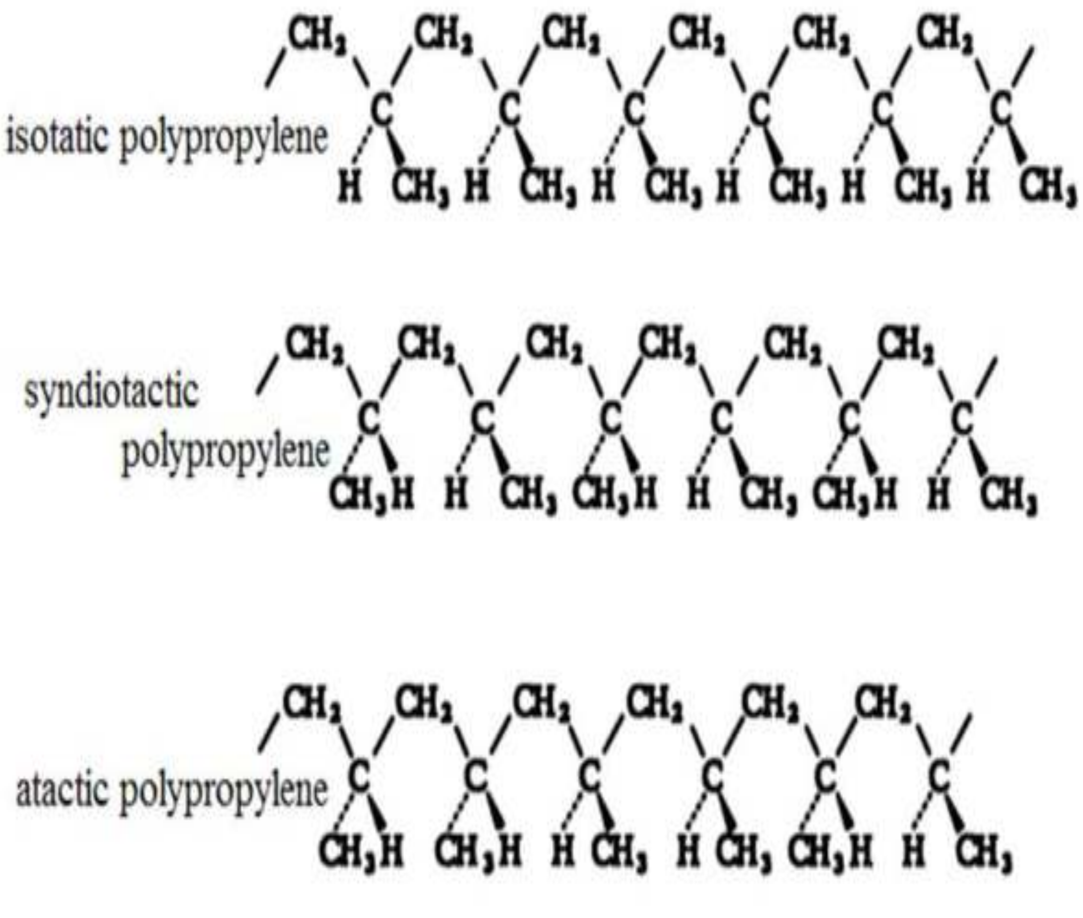

Figure (2.3) : Tactisity of polypropylene [21].

2.1.4. Polypropylene Properties :

Polypropylene has grown to a commodity polymer with numerous grades for specific end uses. At present, the physical properties of PP can be tailored to the requirements with respect to processing and structure[25].Because polypropylene (PP) is low in cost but has outstanding mechanical properties and moldability, it accounts for more than half of all the plastic materials used in automobiles[26]. Polypropylene has excellent and desirable physical, mechanical, and thermal properties when used in room-temperature applications. It is relatively stiff and has a low density, and relatively good resistance to impact[27].Polypropylene is one of the most important commercial plastic for its superior intrinsic properties such as high melting temperature and high chemical resistance. PP has a low density (0.90 g cm–3)and has a higher softening point and hence can be used at higher temperatures[28].

So, the properties of polypropylene are intimately related to both the fabrication history of the material and its intrinsic polymer structure .The intrinsic polymer structure is related to the catalyst ,polymerization and compounding technologies. PP is also a high versatile material because it can be compounded with high amounts of fillers, reinforcing agents and other polymeric material[18].

2.1.4.1. Mechanical properties:

Among the properties of polypropylene is that it has a high fatigue resistance, good electrical insulation properties [29] and a high resistance to environmental stress cracking..Polypropylene has a low density (0.905 g/cm3), is hard, brittle, wear-resistant, has low water absorption and is considered of low cost [30]. Also, it can bend (Warp) under the influence of molding stresses [31]. Polypropylene is stiffer than HDPE due to its higher melting point [32]. Polypropylene has a high degree of crystallinity, and therefore it is a polymer with high tensile strength [11], and it is shell-moldable and has a high yield stress. Polypropylene is more susceptible to breakage than PE, especially at low temperatures, due to the lower degree of glass transition of polypropylene. Spun polypropylene can be rolled into ropes or filaments and turned into weaves. Injection molding, extrusion and blow molding are among the most productive methods used in the polypropylene industries [29].

The following structural factors, in addition to the chemical composition, affect all of the major mechanical properties of polymers:

1 Molecular weight
2 .Cross-linking and branching
3 Copolymerization (random, block, and graft(
4 Molecular orientation
5 Fillers

In addition to the structural and molecular factors listed above, the following environmental or external variables are important in determining mechanical behavior:

1 Temperature.
2 Time, frequency, rate of stressing or straining.

3 Pressure.
4 Type of deformation (shear, tensile, biaxial) [38].

2.2. Thermal properties :

The melting point of polypropylene occurs in a range, so the melting point is determined by finding the highest temperature of a differential scanning calorimetry chart. Perfectly isotactic PP has a melting point of 171 °C (340 °F). Commercial isotactic PP has a melting point that ranges from 160 to 166 °C (320 to 331 °F), depending on atactic material and crystallinity. Syndiotactic PP with a crystallinity of 30% has a melting point of 130 °C (266 °F).[15] Below 0 °C, PP becomes brittle. The thermal expansion of PP is very large, but somewhat less than that of polyethylene [33].

2.1.4.2. Physical and Chemical Properties :

Polypropylene at room temperature is resistant to fats and almost all organic solvents, apart from strong oxidants. Non-oxidizing acids and bases can be stored in containers made of PP. At elevated temperature, PP can be dissolved in nonpolar solvents such as xylene, tetralin and decalin. Due to the tertiary carbon atom PP is chemically less resistant than PE .[34] There is White and translucent in appearance, polypropylene is an all-round thermoplastic with high durability and lightweight. It has a low density, a slippery surface and a low coefficient of friction. It is also an excellent resistant to heat, electricity, fatigue, chemicals and organic solvents. Stress-cracking is not an issue for PP as it also displays good levels of corrosion resistance.

Uses:	**Thermoplastics, fibers, thermoplastic elastomers**
Monomer:	Propylene
Polymerization:	,Zieglar-Natta polymerization metallocene catalysis polymerization
Morphology:	highly crystalline (isotactic), highly amorphous (atactic)
Melting temperature:	165°C
Glass transition temperature:	-17 ºC

Table (1.1): shows the properties of polypropylene [35]

2.2. Extrusion process :

Extrusion molding: It is a method that depends on continuous annealing of polymeric materials in the annealing system, pushing them forward and then extruding through a channel called Die. (The screw) and the thrusting system and the extrusion head (Istanba). The idea of extrusion started in 1879 by the inventor: M. Graye in England/UK. Extrusion is basically the transformation of the raw material into a specified shape product by forcing it through a die. Many different materials can be formed through an extrusion process, such as metals, ceramics, clays, foodstuffs, and plastics either in the molten or solid state. Extrusion is a high volume manufacturing process in which raw plastic material is melted and formed in to continuous profile [36].

Extrusion process for polymers Extrusion is a high-productivity manufacturing (forming) process, and this process is usually continuous to produce large lengths, the polymeric material is molten by the influence of temperatures applied to it through heaters and is extruded through a die to obtain the desired shape, and the method of work is summarized by the movement of the snail The screw is constantly inside the cylinder, as it derives its circular motion from an electric motor by means of a belt that is attached to the gearbox, to control the speed through several gears of various sizes sitting on the shaft and the bearing chair, and the "helix" is responsible for mixing, homogenizing and pushing the material The molten into the mold, for the annealing system, is the same as in the injection process except for the presence of additional fans to regulate the heating process. At the end of the cylinder there is a filter, and in the cylinder there is a relief valve to expel excess gases and vapors. The important parameters (variables) in the extrusion machine are temperatures and speed, when The exit of the product falls into a basin of water for cooling, and there are other ways to cool the product, for example: air fans, the extrusion process is easy, but difficult for thermally hard materials. The extruded material takes the shape of the mold according to the section to be produced. It is the ideal way to manufacture shapes of standard sizes such as bars, tubes, strips and plates, and it is also suitable for thermally hard polymeric materials (Thermosets), such as manufacturing (pipe,films) [37].

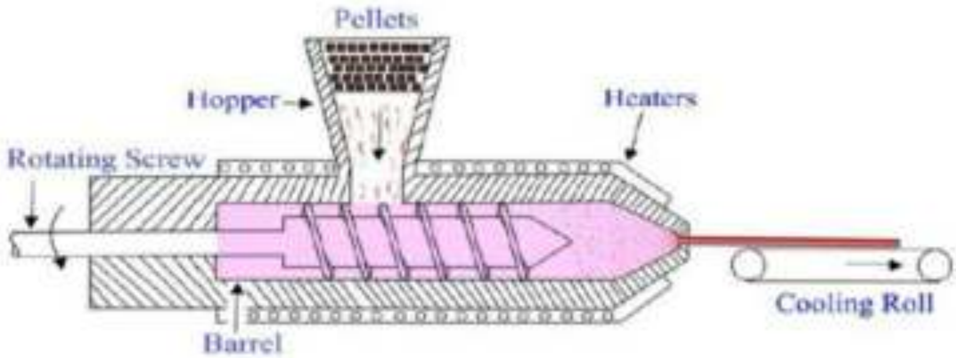

Figure (2.4) : showing a section of a single screw extruder for thermoplastic polymer materials.[37]

The drive system in extrusion machines must meet the following :

- wide limits of rotational speed change = 10: 1 with high efficiency

- good stability of the rotating speed of the screw when changing loads from (0-100),
- stability or little change of circular torque in Indication of circular speed
- ease of maintenance and repair and low costs.

2.2.1. Twin Screw Extruder :

A twin screw extruder is a machine with two screws which can be categorized by the intermeshing structure, the rotation direction in to (co-rotating and counter- rotating), by the functions of screws designed to perform, or by screw speed. Two main areas of application for twin screw extruders are profile extrusion of thermally sensitive materials (e.g. PVC), and specifically polymer processing operations, such as compounding, chemical reactions [36].

The most important process parameters are melt temperature and pressure. Other parameters related to the extruder are,-:

1 Screw Speed.
2 Motor Load.
3 Barrel Temperatures.
4 Die Temperatures.
5 Cooling Rate [36].

There are many parameters affecting the resulting structure, such as annealing temperature, polymer molecular weight, feed rate, screw configuration, and screw speed. All of them direct or indirectly affect the shearing intensity and the residence time during processing, and consequently the structure of the obtained product [36]. The advantage of twin screw extruder is low energy consumption, greater tolerance to difficult material to process and flexibility for producing small quantities of multiple items [18].

Chapter Three

3.1. The materials used in the preparation :

3.1.2. Polypropylene :

Polypropylene is the third-largest volume polyolefin and one of the major plastics worldwide. The commercial plastic was first introduced in 1957 [13]. Melting point about 160-175°C glass transition temperature -15°C and Processing temperature 225-260°C[13]. Fig.4 Polypropylene structure.

Figure (3.1) : Polypropylene polymer [14]

Polypropylene is a type of thermoplastic polymer; it is a part of both the average household and is in commercial and industrial applications. The chemical designation is C3H6, PP is widely used in variety of applications including packaging, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, and automotive components [15]. Polypropylene is a semi crystalline polymer containing both crystalline and amorphous phases. The relative amount of each phase depends on structural and stereo chemical characteristics of the polymer chains and the conditions under which the resin is converted to final products such as fibers, films, and various other geometric shapes during fabrication by extrusion, thermoforming, or molding [16].

As for the rest of the details related to polypropylene in terms of properties, preparation and types, it mentioned the first chapter.

Figure (3.2) : Indicates polypropylene in bulk form.

3.1.3. Aluminum oxide

Aluminum oxide or alumina has been used since 1970 as a material for manufacture of components of prostheses and surgical devices. It is very inert and resistant to corro sion in an in vivo environment . It elicits minimal response from the tissues and remains stable for many years of ser vice . It is found in nature as corundum in emery, topaz , and emerald , and as the precious gemstones ruby and sapphire. Commercially it is extracted from ores such as bauxite and cryolite using the Bayer process. Its most sig nificant use is in the production of aluminum metal. Other than applications in prostheses and surgical devices, it is commonly used as an abrasive due to its hardness, and as a refractory material due to its high melting point**.**

3.1.3.2. Properties of Alumina

a - alumina is dense (specific gravity of 3.97), nonporous, and nearly inert. It is extremely hard and scratch - resis tant (9 on the Mohs scale, next only to diamond). It has excellent corrosion resistance in in vivo environments . The physical properties of alumina such as strength, fatigue resistance, and fracture resistance depend on the grain size, porosity, and purity. Further , alumina exhib its high surface wettability , resulting in a low coefficient of friction . These excellent wetting characteristics are due to an outer surface of alumina that adsorbs a molec ular film of water and biological molecules. The low coefficient of friction and wear rates of alumina occur only when the surface roughness is less than 0.02 μm , i.e. , grain size is smaller than 4 um with a very narrow size distribution. If the surface roughness is higher than 0.02 μm , large grains can pull out and lead to very rapid wear of loadbearing surfaces . Table B.1 lists some of the mechanical properties of 99.5 % pure alumina**.**

3.1.3.3. Structure of Alumina

The Alumina Obtained By The Bayer Process is Recrystallized, Based on the Application for Which It Will Be Used. Alumina Exists in Many Crystal Phases: A, 8, 7, 1, 0, 0, 0, and x, Depending on the Heat-Treatment Conditions. However, A - Aluminum Or Corundum Is Most Thermodynamically Stable Form, and Hence is used as a biomaterial. IT HAS A RHOMBOHEDRAL STRUCTURE (A = 4.758) and C = 12.991 (Figure 6). The Structure of Can Be Viewed As A Hexagonal Close - Packed Array of O- Atoms with 2/3 of the Octahedral Sites

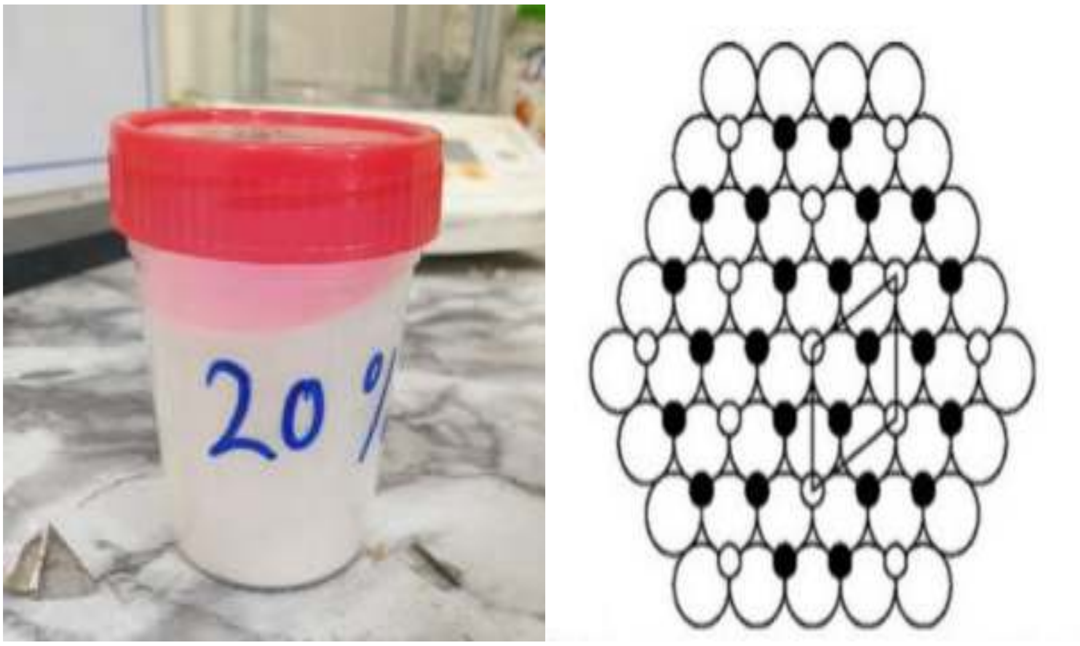

FIGURE (3.3) : Crystal structure of alumina

3.2. Sample preparation:

In this work, sheets were prepared from polypropylene polymer found in laboratories of the Department of Polymer and Petrochemical Industries, with a fixed weight of 50 g at different temperatures (150, 160, 170) respectively using a two-screw extruder with a homogeneous thickness in an acceptable proportion.And then prepare samples filled with alumina at the addition ratio was 100% to 5% where the weight of the polymer was 47.5 to 2.5 alumina at the same temperatures.

sample	ratio	Temperature	name
PP pure	**50**	**150**	**A1**
PP pure	**50**	**160**	**A2**
PP pure	**50**	**170**	**A3**
PP/Al2o3	**47.5/2.5**	**150**	**A4**
PP/Al2o3	**47.5/2.5**	**160**	**A5**
PP/Al2o3	**47.5/2.5**	**170**	**A6**

Table (3.1): Table showing details of samples.

3.3. Mechanical Properties of Polymer:

3.3.2. Tensile test :

Tensile test is a measurement of the ability of a material to applied forces tending to pull it apart and observe the extent of material stretches before breaking. Different types of plastic materials are often compared based on tensile property data (i.e. strength, modulus, and elongation data) [40]. The tensile test is one of the important mechanical tests through which it is possible to obtain many engineering information that determines the mechanical behavior of materials during use, including: - [40,41]

A. Yield Stress.
B. Ultimate Tensile Strength.
C. Modulus of Elongation.
D. Percentage Elongation.
E. Percentage Reduction Area.

Figure.(3.4): Indicates the tension device

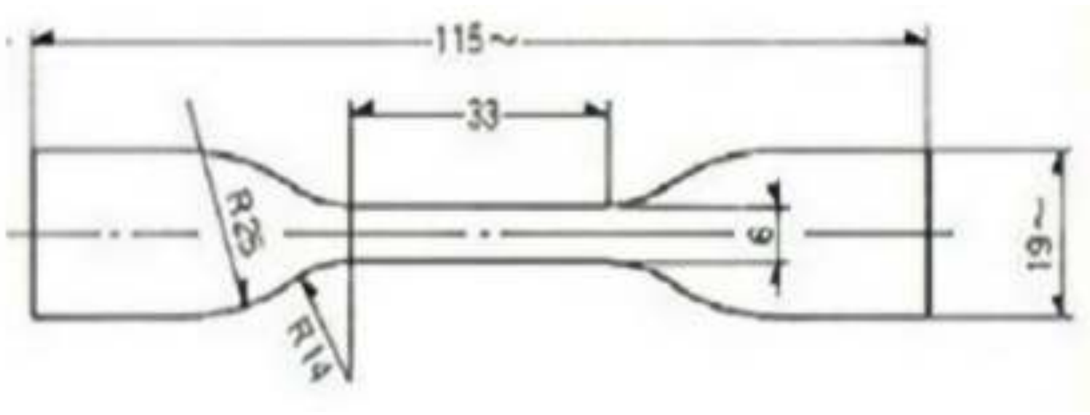

Figure (3.5) : Indicate the shape of the tensile sample with dimensions (ASTMD 638IV).

When a specific load is applied to a test sample so that it applies to its longitudinal axis, the sample will suffer from a certain elongation according to the amount of force applied to it, and thus we get a geometric curve called (stress-strain curve), (Stress-Strain Curve) [40, 42] , as shown in the figure (4).

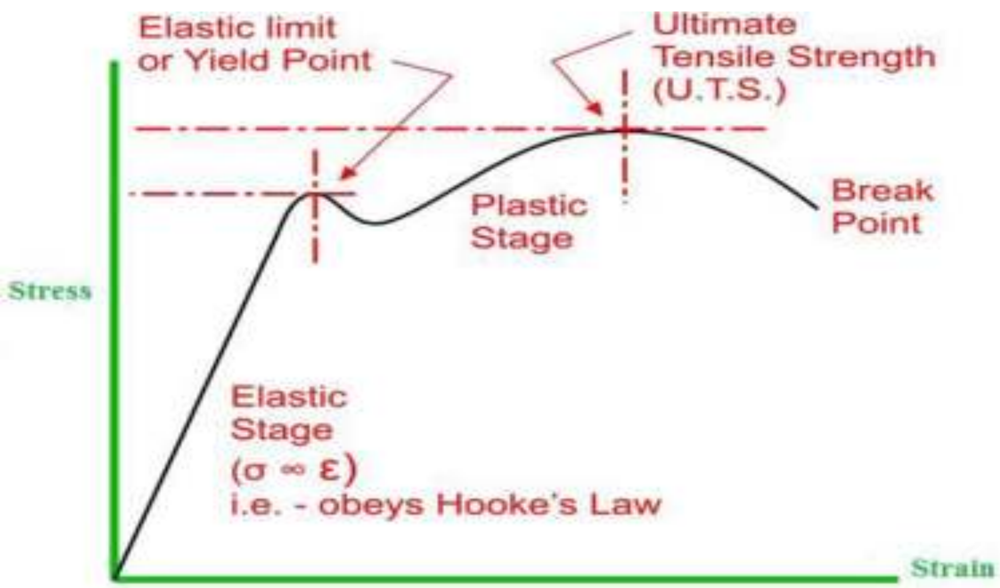

Figure.(3.6):Typical Stress Strain Curve for Polymer Testing [43]

Where stress can be expressed by the following relationship: - [40, 44].

$$\sigma = \frac{P}{A} \qquad \text{...} \textbf{(1)}$$

Stress is denoted by the symbol and its unit is N/m2, where:

- P: is the force applied to the sample to cause elongation and is along the sample axis and its unit (N)
- A: is the cross-sectional area of the sample and its unit (m2)

As for the strain, it is symbolized by the symbol (&) and it is expressed by the following relationship [45]:-

$$\epsilon = \frac{\Delta L}{L_o} = \frac{L - L_o}{L_o} \qquad \text{...} \textbf{(2)}$$

Whereas:

- L = Elongation (final length of the sample.
- Lo = the initial length of the sample (initial)
- LΔ = the amount of change in length.

The strain is of two types: Elastic Strain and Plastic Strain [44], and the ratio between the stress applied to the material and the resulting strain in the elastic zone of the stress-strain curve is a fixed ratio called the modulus. Elasticity (Modulus of Elasticity) or Young's Modulus, which is symbolized by the symbol (E) and measured in units (N/m2) and expressed by the following relationship:

$$E = \frac{\sigma}{\epsilon} = \frac{P/A}{\Delta L/L_o} = \frac{PL_o}{\Delta LA} \qquad \text{...} \textbf{(3)}$$

The importance of knowing Yunk's modulus lies in calculating the change in the dimensions of samples manufactured from homogeneous flexible materials under the influence of tensile or pressure loads, i.e. knowing the extent to which samples bear elongation or compression. Of great importance when choosing a material for a particular engineering application.

3.3.3. Hardness Test :

Hardness is one of the basic mechanical characterization engineering materials. It can be defined as the resistance of the solid material to cut, scratching, wear, indentation, penetration and workability. In other words, it is the resistance of the material to scratching by tools and machine harder than it. As compared with other characterizations hardness has the advantage of being easily to measure which can be determined from any piece of sufficient size [46].

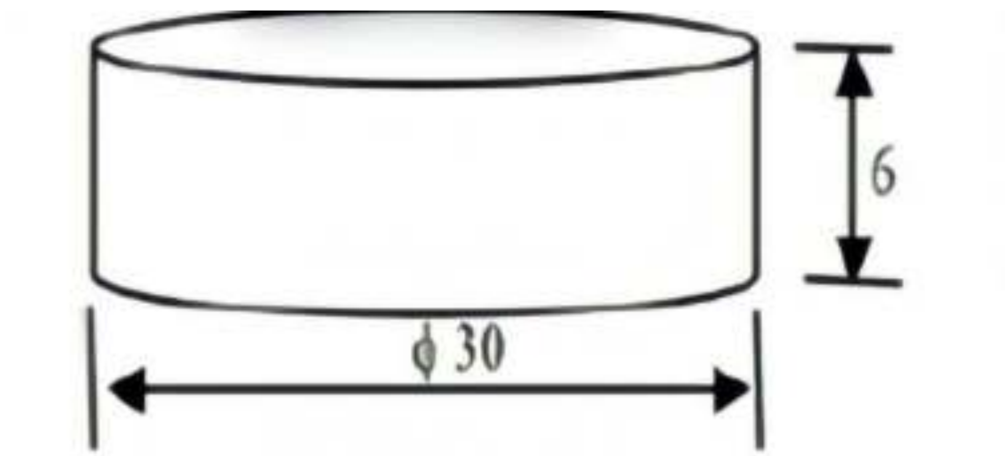

Figure (3.7): Indicate the shape of the hardness sample(shore D)with dimensions (ASTMD 2240).

Hardness has been well established in characterizing metallic material and ceramics for many years, but only recently it has been widely employed for characterizing polymers. In practice, hardness is measured in terms of the size of an impression made on a specimen by an indenter of a specified shape when a specified force is applied for a specified time; the indent being measured after the force has been removed. There are three principal standard testing methods for expressing the relationship between hardness and the size of the impression, these being Brinell, Vickers, and Rockwell. For practical and calibration reasons, each of these methods is divided into a range of scales, defined by a combination of applied load and indenter geometry. Shore (A and D) and Rockwell methods are applied for examining the hardness of polymers [47].

Figure (3.8): Indicates the hardness device (Shore D).

3.3.4. Impact test:-

The impact properties of the polymeric materials depend mainly on the toughness of the material. Toughness can be described as the ability of the polymer to absorb applied energy. The molecular flexibility has a great significance in determining the relative brittleness of the material. Impact energy is a measure of toughness, and the impact resistance is the ability of a material to resist breaking (fracture) under a shock-loading [48].

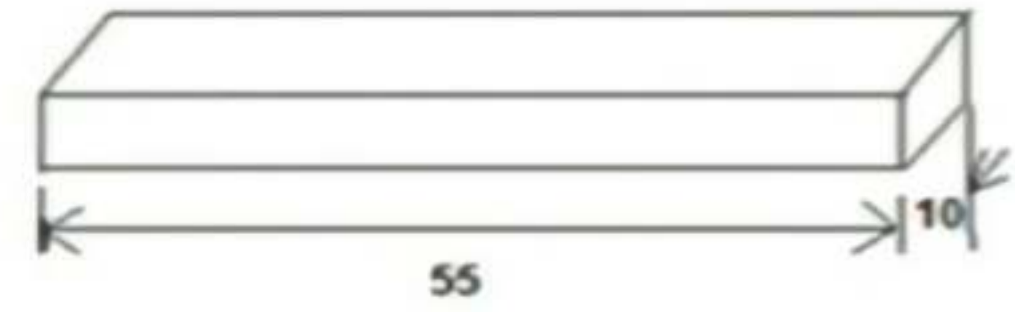

Figure (3.9): Indicate the shape of the impact sample with dimensions (ASTMD 256-87).

Two basically different test methods, namely Izod and Charpy type, are used generally. In Izod type testing, the specimen is clamped vertically. to a cantilever beam and broken by a single swing of the pendulum released from the fixed distance from the specimen clamp [.48] The impact strength is calculated by dividing the impact values obtained from the scale by the cross section area of the specimen. One point indicating the advantages of the Charpy test over an Izod test is that the specimen does not have to be clamped; therefore, it is free of variations in clamping pressures. Impact resistance can be obtained from the following relationship [49]:

$$I.S = UC/A \quad \text{...} \quad (4)$$

Where-:

- I.S: impact resistance of the material (J/m2).
- UC: impact energy (J).
- A: cross-sectional area of the sample (m2).

Chapter four

Tensile test results:

When installing the prepared samples in a tensile test device type (5E/wdw) with a load (5kN) and a velocity value (10 mm/min) and conducting the test on it, a graph was obtained between the applied force (p) and the elongation occurring in the sample through the graph in the test device (ΔL), and from this diagram were extracted the stress strain values. The stress-strain curves were drawn for all the prepared samples and the figures below show the results of the tests.

Where the results showed when adding the plasticizer, which is alumina, will lead to a gradual decrease in the value of the modulus of elasticity and consequently a decrease in its stiffness. The reason for this is due to the mechanical behavior of the plasticizers that do not arrange and line up the chains regularly.

sample name	Elastic modulas (Gpa)	Tensile strength(Mpa)
A1	**0.31**	**26**
A2	**0.28**	**19**
A3	**0.185**	**21**
A4	**0.18**	**20**
A5	**0.15**	**22**
A6	**0.09**	**16**

Table (4.1): It shows elastic modulas and tensile strength of samples.

Figure (4.1): It Shows a stress-strain diagram for a sample (A1).

Figure (4.2):): It Shows a stress-strain diagram for a sample (A2).

Figure (4.3): It Shows a stress-strain diagram for a sample (A3).

Figure (4.4): It Shows a stress-strain diagram for a sample (A4).

Figure (4.5): It Shows a stress-strain diagram for a sample (A5).

Figure (4.6): It Shows a stress-strain diagram for a sample (A6).

Figure (4.7): Tensile test sample befor and after mearsurd.

4.2. Impact test result:

When placing the prepared samples in the impact tester type German pendulum impact tester, gant company (HAMBURG), model WP 400 type charpy. And conducting the test on it, the impact energy was obtained, and through the presence of the measured sample area, the impact resistance was obtained through equation (4) for the six samples prepared according to the table (4.2).

Where the results showed, that the impact resistance has increased in the fiber-reinforced polymer (PP + Al_2O_3) than it is in the base polymer (pp). When a plasticizer is added, which is alumina, it will lead to an increase in its toughness due to the increase in elongation caused by the material Annealed, where there is a vacuum between the polymeric chains that allows shock absorption.

sample name	Impact Strength (KJ/m^2)
A1	**2.39**
A2	**2.7**
A3	**3.18**
A4	**7.25**
A5	**8.31**
A6	**8.88**

Table (4.2): It shows Impact Strength of samples.

Figure (4.8): Impact test sample befor and after mearsurd.

4.3. Hardness (Shore D) test result:

When the prepared samples were placed in the Shore De hardness tester and the test was conducted on them, five readings were measured for each of the six samples, and the final rate of hardness was taken to obtain the required accuracy according to the table (4.3).

Where the results showed that the hardness value is relatively less when adding a plasticizer, alumina, meaning that the hardness resistance is lower in the fiber-reinforced polymer (PP + Al_2O_3) than it is in the base polymer (PP). The reason for this is the movement of the chains and their lack of regular alignment The hardness of materials depends on the type of forces that bind atoms or molecules in a substance. The stronger the bond, the higher the hardness values. And vice versa.

sample name	Hardness
A1	**59.3**
A2	**59**
A3	**56.7**
A4	**56.2**
A5	**54.3**
A6	**53.1**

Table (4.3): It shows value of hardness of samples.

Figure (4.9): it Shaow the sheets of pure pp and PP/AL2O3 for hardness test.

Chapter five

5.1. Conclusions:

1. Through the results of the tensile test, we noticed a decrease in the stiffness (decreased the elastic modulas), while on the other hand, the toughness increased with increasing temperatures at the pure polymer and the same condition continued with the addition of the filler.
2. We conclude through the impact tests of the pure polymer by increasing the temperature higher than melting temperature , the impact resistance has increased, as well as by adding the filler as well.
3. The results of the hardness test for PP showed tha t there was a decrease when the temperature was increased, and the same behavior occurred when the plasticizer was added Al_2O_3.

5.2. Suggestion study and Recommendations:

1. We suggest using HDPE polymer in industrial applications, including car supports, due to its low cost.
2. Study of the optical and electrical properties of the prepared samples.
3. Using nanofilers such as Zno Tio2 and studying the mechanical properties of the resulting compound.

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الخلاصة

تم في هذا العمل دراسة وتحضير بوليمر البولي بروبلين لما له من خواص مناسبة للتطبيقات الصناعية ، حيث يستعمل في اغطيه ومصدات السيارات وتصنيع الواح الابواب والديكورات الداخلية وايضا تستخدم في صناعة الافلام وفي تغليف المواد الغذائية .

حيث تم استخدام البوليمر وتحضير شيتات عن طريق ماكنة البثق ثنائية اللولب بأسماك متجانسة عند ثلاث درجات حرارة كانت (150,160,170) درجة مئوية ودراسة الخصائص الميكانيكية من فحوصات (الشد والصدمة والصلادة) وكذلك (الجساءة والمتانة والاستطالة) .

ومن ثم دراسة نفس الخواص اعلاه لشيتات مملوءة بالالومينا Al_2O_3 عند نسبة تركيز واحدة كانت 5 % من البوليمر حيث لاحضنا من خلال النتائج عند زيادة درجة الحرارة فان المتانة سوف تزداد ويقابلها نقصان بالإجهاد وزيادة الانفعال وعليه فان معامل المرونة سوف يقل نتيجة زيادة مقاومة الصدمة وايضا بوجود نقصان في قيمة الصلادة.

وهذا يتفق تماما مع اضافة الملدن حيث ان اضافة الملدنات (الالومينا) لها سلوك مشابه لزيادة درجة الحرارة وعليه يمكن ان نقترح ان العينات كانت تصلح للاستخدام في مصدات السيارات والمعدات المرورية

جمهورية العراق
وزارة التعليم العالي
والبحث العلمي
جامعة بابل
كلية هندسة المواد
قسم البوليمرات والصناعات البتروكيمياوية

التحقيق في مادة البولي بروبيلين : الخصائص والتطبيقات الصناعية

مشروع تخرج
مقدم إلى كلية هندسة المواد/ جامعة بابل وهي جزء من متطلبات نيل درجة البكالوريوس في علوم هندسة المواد / البوليمر

من قبل

منتظر خليل حسين

زهراء مثنى عبد الكاظم

زينب كريم دحام

إشراف

أ.م.د. علي صلاح حسن

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