POLYPROPYLENE (PP) REINFORCED WITH RECYCLE POLYETHYLENE TEREPHTHALATE (PET) AS AN ALTERNATIVE MATERIAL FOR NEW PLASTIC PRODUCT

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ABSTRACT

Polypropylene is one of the composite materials that have been developed to improve of its properties by reinforced with reinforcing material. This project will study on the best ratio that give high strength of Polypropylene reinforced with recycle Polyethylene Terephthalate fiber. Polypropylene will be mixed with recycle Polyethylene Terephthalate fiber through mixer and injected using injection mold machine. Then the product will then cut according to ASTM standard and tested using tensile test equipment. Result of the study shows that 7% volume compositions of recycle Polyethylene Terephthalate fiber give the maximum value of Ultimate Tensile Strength with value of 30.04 MPa. The study also shows that presence of recycle Polyethylene Terephthalate fiber in Polypropylene will improved 10% strength of Polypropylene. Variety of application can be used by this composite material because of the improvement in tensile properties. Also, using recycle Polyethylene Terephthalate fiber can reduce the cost of the product by industries. Besides that, using recycle Polyethylene Terephthalate as an fiber also can decrease pollution.

ABSTRAK

Polypropylene adalah salah satu bahan yang telah dimajukan untuk meningkatkat sifat kekuatannya dengan menggunakan bahan penguat tambahan. Kajian ini adalah untuk mengkaji nisbah terbaik yang menghasilkan sifat tegangan tertinggi oleh Polypropylene dikuatkan dengan fiber Polyethylene Terephthalate guna semula. Polypropylene akan dicampur dengan fiber Polyethylene Terephthalate guna semula mengunakan mesin campuran dan akan disuntik melalui mesin acuan suntikan. Kemudian kesemua produk akan dipotong mengikut spesifikasi ASTM dan diuji melalui mesin tegangan. Keputusan telah menunjukkan kekuatan yang paling tinggi terletak pada campuran yang mempunyai fiber Polyethylene Terephthalate guna semula sebanyak 7 peratus dengan nilai 30.04 Mpa. Kajian juga telah mendapati kehadiran fiber Polyethylene Terephthalate guna semula dapat meningkatkan sifat tegangan Polypropylene sebanyak 10 peratus. Kepelbagaian aplikasi boleh diaplikasikan melalui Polypropylene yang dikuatkan dengan fiber Polyethylene Terephthalate guna semula. kerana adanya peningkatan dalam sifat tegangan bahan ini. Malah dengan menggunakan fiber Polyethylene Terephthalate guna semula, industri dapat mengurangkan kos untuk produk yang dihasilkan. Selain itu, ia juga dapat membantu mengurangkan pencemaran dengan menggunakan bahan kitar semula.

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LIST OF SYMBOLS

PP	-	Polypropylene
PET	-	Polyethylene Terephthalate
UTS	-	Ultimate tensile strength, MPa
P_{max}	-	Maximum load before failure, N
A	-	Average cross sectional area
σ^i	-	Tensile strength at *i*-th data time, MPa
P^i	-	load at *i*-th data point, N
A	-	Average cross sectional area
ε_i	-	tensile strain at *i*-th data point
δ_i	-	extensometer displacement at *i*-th data point, mm
L_g	-	extensometer gage length, mm
NAPCOR	-	National Association for PET Container Resources

CHAPTER 1

INTRODUCTION

1.1 Project Background

Over a decade, plastic has been widely used in daily life. Whether where we go, where we sleep, when we eat and even when we walk, we will use plastic to complete our daily life. Plastic is a great development found by the researcher and also the manufacturer, engineer or others in terms of plastic value in the industry because of very high demands in markets. There are many types of plastic. In order to consider the cost to produce one product and the quality of the product by the manufacturer, choosing what type of plastic is very important.

Plastic have a good quality in the properties especially in their mechanical properties. Although plastic have a great variety of properties, the development of plastic can be expanded in order to have a better properties. One of the ways to expand the properties of the plastic is by mixing it with other material to produce new material which has better properties than before. These techniques that are also known as reinforcement technique were used to strengthen the structure of the plastic. This new material also knows as a reinforced plastic. This alternative way has been widely developed just to make sure it meets the demands of industry. This is because of the escalation of market and the demand by the user.

This project will covered only about reinforcements of Polypropylene (PP). The main focused of the studies is the tensile strength in PP that been reinforced with the recycle materials which is recycle Polyethylene Terephthalate (PET) fiber.

The main objective of this project is to experimentally find the best ratio of volume fraction PP with recycle PET fiber that contributes higher tensile properties. In this project, recycle PET fiber with different volume fraction will be mixed together with PP through mixing machine. The sample will be categorized depends on its volume composition. Then injection molding machine will be used in the fabrication process to produce the sample of the test. After the samples have been injected, it is then will be prepared according to ASTM standard and will be tested through tensile test machine to study its tensile properties.

1.2 Problem Statement

PET is a plastic material which has found increasing application within the packaging field. PET is not only used broadly in products in the packaging field such as bottles, it also used in electrical and electronic instruments, automobiles products, house-wares, lighting products, power tools, material handling equipment, and sport products. However, the largest uses of PET are for containers, where on-half containers go to landfills and incinerators. PET container recycling rates have been declining over the last few years and states, municipalities, trades associations and non-profits are recommending different solutions.

Table 1.1: PET bottle recycling rate in US by NAPCOR

Year	Total U.S. Bottles Collected *(mmlbs.)*	Bottles on U.S Shelves *(mmlbs.)*	Gross Recycling Rate
1995	775	1950	39.7%
1996	697	2198	31.7%
1997	691	2551	27.1%
1998	745	3006	24.8%
1999	771	3250	23.7%
2000	769	3445	22.3%
2001	834	3768	22.1%
2002	797	4007	19.9%
2003	841	4292	19.6%
2004	1003	4637	21.6%
2005	1170	5075	23.1%

From Table 1.1, we can see that the rate of recycling is return to increase starting 2004 but the rate is still low compare to the last 12 years which is year 1995-1999. This show that the investigation about the usage of recycle material is needed to help increasing the recycling rate increased.

PET is one of the most important fibers for industrial production. Due to its high performance, low cost, and recyclables, it is one of the most attractive candidates for high strength fibers. Thus, this study is using recycle PET to use as fibers in PP to create a Polypropylene reinforced plastic. The processed will be done using mixer and injection molding machine. The tensile strength then will be investigated by using tensile test machine.

1.3 Objective of Project

The objective of this project is to find the suitable ratio between PP and recycle PET fibers and to measure the strength of that mixing material. This project also will study the economy value based on the mixing product and PP.

1.4 Scopes of Project

1. Preparing the material which is Polypropylene (pallet) and recycle Polyethylene Terephthalate (fiber)
2. Mixed PP with recycle PET fiber using mixer machine with volume composition of :
    i. 0% recycle PET fiber , 100 % PP
    ii. 3% recycle PET fiber , 97 % PP
    iii. 5% recycle PET fiber , 95 % PP
    iv. 7% recycle PET fiber , 93 % PP
    v. 10% recycle PET fiber , 90 % PP
3. Each of composition then are injected through injection mold
4. Cutting process of injected product to standard size according to ASTM standard.
5. Preparation samples for tensile test.
6. Test the specimen with tensile test equipment to find the tensile properties.
7. Compile the tensile properties data from tensile test.
8. Result evaluation and discussion.
9. Conclusion of the project from the result.

CHAPTER 2

LITERATURE REVIEW

2.1 Plastics

The growth of the plastic industry for over a century has been spectacular evolving into today's routine to sophisticated high performance products. Examples of these products include packaging, building and construction, electrical and electronic, appliance, automotive, and practically all market worldwide [1]. Plastic can be classified in many ways, but most commonly by their polymer backbone. Other classifications include thermoplastic, thermosets, elastomer or addition. Plastics are polymers which is long chains of atoms bonded to one another. A molecule has a group of atoms which have strong bonds among themselves but relatively weak bonds to adjacent molecules. Polymers contain thousand to millions of atoms in a molecule which is large. Polymers are prepared by joining a large number of small molecules called monomers [2]. Plastics are materials composed principally of large molecules (polymers) that are synthetically made, or, if naturally occurring, are highly modified [3]. There are 4 types of polymer structure. It's shown in Figure 2.1.

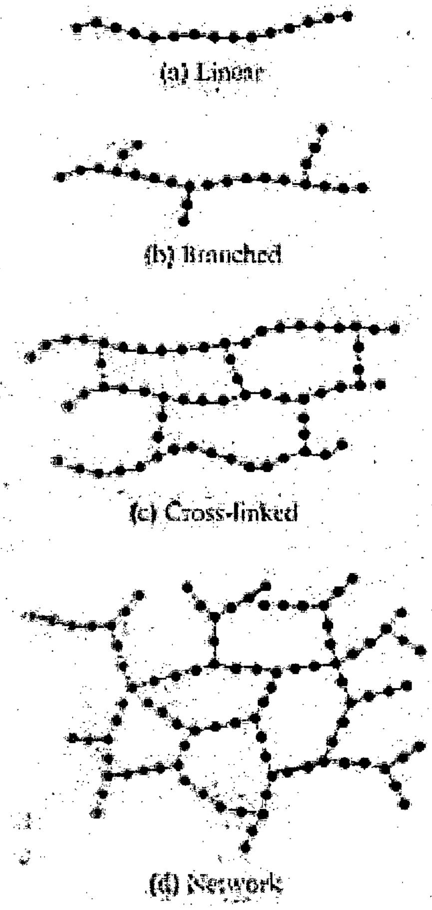

Figure 2.1: Plastic structure

The word 'plastic' is from the Greek word *plastikos,* meaning "able to be molded and shaped" [4]. Plastic is used broadly in our daily life. Plastic is divided into two major classifications. The two basic groups of plastic materials are the thermoplastics and the thermosets. Over 90% of plastics used are thermoplastic [5].

There are many types of plastic. It's difficult to know the types of plastic until the Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988. The coding identification code is shown in Table 2.1:

Table 2.1: Resin Identification Coding System by SPI [6]

Codes	Descriptions	Properties	Packaging Applications
1 PETE	Polyethylene Terephthalate (PET or PETE)	Clarity, strength / toughness, barrier to gas and moisture, resistance to heat.	Plastic soft drink and water bottles, beer bottles, mouthwash bottles, peanut butter and salad dressing containers, ovenable film, ovenable pre-prepared food trays.
2 HDPE	High Density Polyethylene (HDPE)	Stiffness, strength / toughness, resistance to chemicals and moisture, permeability to gas, ease of processing, ease of forming	Milk, water and juice containers, trash and retail bags, liquid detergent bottles, yogurt and margarine tubs, cereal box liners.
3 V	Vinyl (V)	Versatility, ease of blending, strength / toughness, resistance to grease/oil, resistance to chemicals, clarity.	Clear food packaging, shampoo bottles.
4 LDPE	Low Density Polyethylene (LDPE)	Ease of processing, barrier to moisture, strength / toughness, flexibility, ease of sealing.	Breadbags, frozen food bags, squeezable bottles (i.e. honey, mustard).
5 PP	Polypropylene (PP)	Strength / toughness, resistance to chemicals, resistance to heat, barrier to moisture, versatility, resistance to grease/oil.	Ketchup bottles, yogurt containers and margarine tubs, medicine bottles.
6 PS	Polystyrene (PS)	Versatility, insulation, clarity, easily foamed.	Compact disc cases, food-service applications, grocery-store meat trays, egg cartons, aspirin bottles, cups, plates.
7 OTHER	Other	Dependent on resin or combination of resins.	Three and five-gallon reusable water bottles and ketchup bottles.

2.1.1 Thermoplastics

Thermoplastic is defined as the plastics that can be reformed repeatedly by application of heat and pressure. Thermoplastic are solids at room temperature that can be melted or softened again by heating, place into a mold or other shaping device, and then cooled to give desire shaped. The thermoplastic can be reshaped at any time by reheating the part [3]. Thermoplastic resins consist of long molecules, each of which may have side chains or groups that are not attached to other molecules. Thus, they can be repeatedly melted and solidified by heating and cooling so that any scrap generated in processing can be reused. There are crystalline and amorphous thermoplastics. During processing they soften and upon cooling harden into products that are capable of being repeatedly softened by reheating with their morphology (molecular structure) being crystalline or amorphous [1].

No chemical change generally takes place during forming. The temperature service range of thermoplastics is limited by their loss of physical strength and eventual melting at elevated temperatures.

2.1.2 Thermosets

Thermosets plastic is defined as the plastics that may not be reheated and softened again. Thermoset plastics, on the other hand, react during processing to form crosslinked structures that cannot be remelted and reprocessed. Thermoset scrap must be either discarded or used as low-cost filler in other products. Thermosets may be supplied in liquid form or as a partially polymerized solid molding powder. In their uncured condition, they can be formed to the finished product shape with or without pressure and polymerized by using chemicals or heat.

2.2 Polypropylene (PP)

Polypropylene is a thermoplastic polymer which is can be recycled. It was used in a wide variety of applications, including food packaging, textiles, plastic parts, reusable containers, and automotive components.

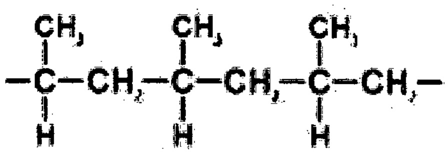

Figure 2.2: Polypropylene Chain Structure

Figure 2.2 shows the chain structure of polypropylene. The relative orientation of CH3 on the figure with its neighborhood on the monomers gave a strong effect on the finished polymer ability to form crystals. Which is the connection between chains of polypropylene make the structure became strong. Polypropylene is in the polyolefin family of plastics representing major plastic used worldwide providing different performances. They have low specific gravity and good resistance to chemical and fatigue [1]. The non-polar nature of the polymer gives Polypropylene low water absorption. Polypropylene has good chemical resistance and a good insulator but low dielectric constant [7].

Polypropylenes offer a good balance of properties and cost unachieved by most other thermoplastics polymer. Polypropylene has good mechanical, electrical and chemical properties and good resistance to tearing [4]. Long fiber and continuous fiber reinforcement technology with Polypropylene produce molding material with higher tensile strength and semi finished materials such as sheet and tape which are beginning to find applications, mainly in structural parts [5]. This shows that the properties of Polypropylene can be improved by adding a fibers or other reinforcement material. If additional stiffness or strength is needed, reinforcement can be added to Polypropylene [3]. A very important property difference that has led to many applications for Polypropylene is its superior resistance to cracking from mechanical stress [3].

2.3 Polyethylene Terephthalate (PET)

PET stands for polyethylene terephthalate, a plastic resin and a form of polyester. PET has been known for many years since the first laboratory samples of this fiber were developed by a small English company in 1941. Then, this research was enlarged by the findings of Dupont on textiles in the 1950s, and the work of Goodyear introducing the first polyester tire fabric in 1962s. In the late 1960s and early 1970s, polyesters were developed specifically in the area of packaging-film, sheet, coatings and bottles [8].

Polyethylene terephthalate is a polymer that is formed by combining two monomers called modified ethylene glycol and purified terephthalic acid [9].

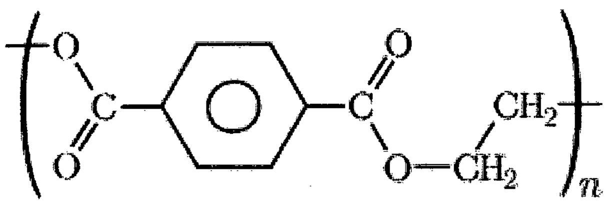

Figure 2.3: Polyethylene Terephthalate Chain Structure

Depending on its processing and thermal history, it may exist both as an amorphous (transparent) and as a semi-crystalline (opaque and white) material. PET is the family of polyester plastics, are available in engineering grades providing high performance mechanical and electrical properties [1]. For packaging applications, PET is used because it combines optimum processing, mechanical and barrier properties.

PET is a popular package for food and non-food products. Manufacturers use PET plastic to package products because of its strength, thermo-stability and transparency. Customers choose PET because it is inexpensive, lightweight, shatter-resistant and recyclable. PET from soda bottles typically is not reused in bottles but is made into non-food-contacting applications such as carpets, textile fibers and fiberfill for sleeping bags and winter coats [3].

PET finds application in such diverse end uses as fibers for clothing, films, bottles, food containers, and engineering plastic for precision molded parts [1]. PET is useful polymer used for fiber, film and plastic containers such as carbonated beverage bottles. Recently, the recycling of polymers such as PET after use is attracting the attention of many researches aware of environmental problems and wishing to find ways to save earth resources [10].

Recycled Polyethylene Terephthalate can be used to make many new products, including fiber for polyester carpet; fabric for T-shirts, athletic shoes, luggage, upholstery and sweaters; fiberfill for sleeping bags and winter coats; industrial strapping, sheet and film; automotive parts, headliners, fuse boxes, bumpers, grilles and door panels; and new PET containers for both food and non-food products.

The largest used of recycle PET is in the fiber sector. A large percentage of the total PET output compromising films, plastics and fibers is recycled by various methods and for several applications, which makes PET one of the largest in volume of recycled polymers in the world [2].

2.4 Reinforcement

Reinforced plastic consists of a polymeric resin strengthened by the properties of a reinforcing material. Reinforced plastics are composites in which a resin is combined with a reinforcing agent to improve one or more properties of the resin matrix. The modulus and strength of plastics can be increased significantly by means of reinforcement [2]. The strength and modulus of many plastic materials can be substantially increased by the addition of strong, high modulus materials, called reinforcements.

2.5 Recycling

Recycling refers to the responding and refabrication of a material that has been used and discarded by a consumer and that otherwise would be destined for disposal as solid waste. When plastics are collected for recycling, they are not pure. They contain product residues, dirt, labels and other materials and often contain more than one type of plastic resin, resins with different colors, additive packages and so on [7]. Recycling of waste will help to conserve natural resources, save energy in production and transport of goods and materials, reduce the risk of pollution, and reduce the demand for landfill.

An obvious benefit of recycling and use of biodegradable plastics is that both reduce the requirement for landfill or incineration of waste materials. Biodegradable plastics can be managed by composting, generally perceived as more environmentally beneficial than landfill or incinerators [7].Another benefits of recycling are cost reduction. a DOE report concluded that recycling PET products such as soft drink and ketchup bottles requires only about a third of the energy needed to produce the PET from virgin materials.

Mechanically recycled PET usually retains very favorable properties. Some reduction in intrinsic viscosity is common, but it can be reserved by solid-stating. Residual adhesives from attachments of labels are contaminant concern. Some of the adhesives residue can become trapped in the PET granules and is not removed by washing. Since this adhesives often contains rosin acids and ethylene vinyl acetate, the rosin acids plus acetic acid from ethylene vinyl acetate hydrolysis an catalyze hydrolysis of the PET during processing [7].

2.6 Injection Molding Machine

Injection molding is the most important molding method for thermoplastic. It is based on the ability of thermoplastic materials to be softened by heat and to harden when cooled. Injection molding is a widely used process to produce parts with variable dimensions. An injection molding machine consists of the following four components:

1. injection unit
2. control systems
3. drive systems
4. clamping unit

The wide variety in the types of parts that can be made by injection molding is the key reason that more injection molding machines are used for plastics processing than any other type or molding equipment.

The injection molding process is conceptually simple. A plastic is melted and then forced into the cavity of a closed mold, which gives shape to the plastic. After sufficient time for the plastic part to solidify (usually by cooling), the mold is opened and the part is removed. The major factors that determine costs are material type, mold cost, parts per cycle and mold cycle time [3].

2.7 Tensile Test

Tensile elongation and tensile modulus measurements are among the most important indicates of strength in a material and are the most widely specified properties of plastic materials. Tensile test, in a broad sense, is a measurement of the ability of a material stretches stand forces that tend to pull it apart and to determine to what extent the material stretches before breaking [11].

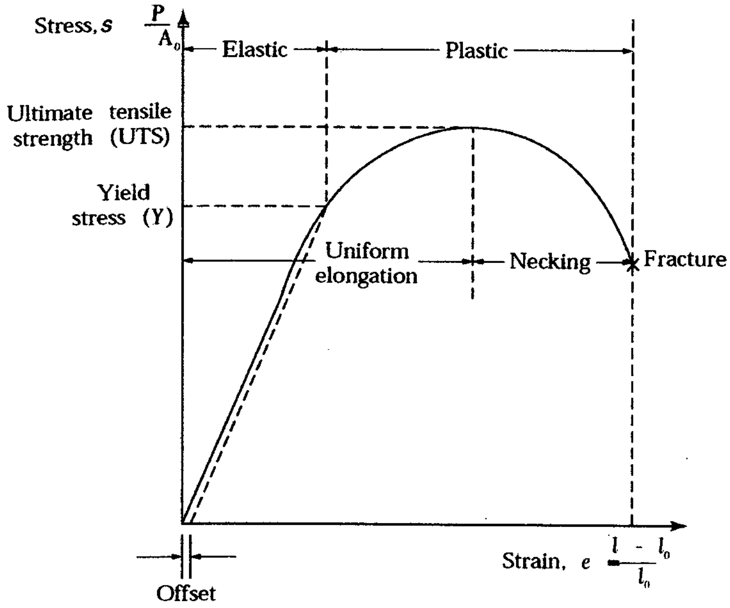

Figure 2.4: Optimal Stress – Strain Curve

When the recycle PET fiber has been reinforced to the Polypropylene structure it will then improve the modulus of polymer. Tensile strength can be examined by applying force to the material until it break. It can be calculated by the following formula:

Ultimate Tensile Strength will be calculated at each specimen using the equation:

$$UTS = P_{max} / A \quad (2.1)$$

Where:

UTS = Ultimate tensile strength, MPa

P_{max} = Maximum load before failure, N

A = Average cross sectional area

Strength at each time is calculated by:

$$\sigma^i = P^i / A \quad (2.2)$$

Where:

σ^i = Tensile strength at *i*-th data time, MPa

P^i = load at *i*-th data point, N

A = average cross sectional area