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Mechanical Properties of Commercial Recycled Polypropylene from Plastic Waste

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Abstract – *In Indonesia increasing the use of plastic will increase plastic waste because waste management in Indonesia is still poor. Plastics can be recycled and used to make plastic bags, toys and various household utensils, but their use is still very limited. This limitation is because the strength of recycled plastic is not as good as virgin plastic pellets, so the resulting product tends to be brittle. This study aims to determine the mechanical properties of plastics made from recycled polypropylene plastic. Five pecimens are made according to the ASTM D 638 type II standard. The results show that yield strength is 16.357±2.65 MPa, elastic modulus 295,926 ± 41,97 MPa and ultimate tensile stress 19,701±1,261 MPa. Yield stress of recycled polypropyle has a lower value than the yield stress on recycled polypropylene studied by Abdelhaleem et.al or Barbosa et.al which is around 21 MPa[7][5] . This difference is possible due to the different quality of raw materials and processing.*

Keywords – *mechanical properties, tensile strength, polypropylene, plastic waste*

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1. Introduction

Plastics are widely used in everyday life because of their advantages, which is strong, lightweight, inexpensive, and resistant to chemicals and corrosion. In Indonesia, between 2012 and 2016, plastic consumption increased at a rate of 5% per year, roughly in line with Indonesia's GDP growth [1]. Increasing the use of plastic will increase plastic waste because waste management in Indonesia is still poor. Indonesia is the nation that dumps the second-largest volume of plastic waste into the world's oceans, with an estimated 3.22 million tonnes of plastic waste dumped annually[2]. This amount increases to 6.8 million tonnes in 2017[1].

Plastic is a polymer that has many types, like polyethylene terephthalate, high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), etc. Polypropylene is a low-density thermoplastic with excellent durability, fatigue resistance, and chemical resistance[3].

Polypropylene is a cost-effective material with unique physical, chemical, mechanical, thermal, and electrical properties not found in any other thermoplastic [4]. With these various advantages, polypropylene is widely used for automotive, household appliances, toys and industrial equipment.

Many parameters that are used to specify the mechanical properties of metals are used to specify the mechanical properties of polymers, such as modulus of elasticity, yield and tensile forces. The basic stress–strain test is used to describe some of these mechanical parameters in many polymeric materials. The mechanical properties of polymers are, for the most part, highly dependent on the rate of deflection.

There are three different types of stress-strain behaviour for polymeric material as shown in Figure 1. Curve A for a brittle polymer, which fractures while deforming elastically. Curve B for many metallic materials; the initial deformation is elastic, which is followed by yielding and a region of plastic deformation. Curve C for totally elastic material or rubber-like elasticity [5].

At room temperature, the tensile strength of polypropylene is 31-41,4 MPa, yield strength 31.0–37.2 MPa and elasticity modulus 1,14 – 1,55 GPa [5], but some researcher found lower value [6]. This discrepancy most probably because of the quality of the material being tested.

Plastics can be recycled and used to make plastic bags, toys and various household utensils, but their use is still very limited. This limitation is because the strength of recycled plastic is not as good as new plastic pellets, so the resulting product tends to be brittle.

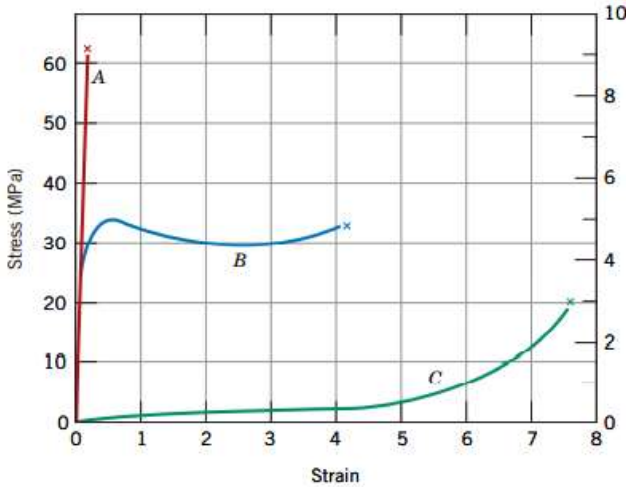

Figure 1. The stress–strain behavior for brittle (curve A), plastic (curve B), and highly elastic (elastomeric) (curve C) polymers.

This study aims to determine the mechanical properties of plastics made from recycled polypropylene plastic. This data will be useful for manufacturers of recycled plastics in product development as well as researchers who will improve the mechanical properties of recycled plastics.

2. Methodology

2.1. Materials

The material used in this research is commercially polypropylene recycled plastic.

2.2. Procedure

Specimens are made according to the ASTM D 638 type II standard with the dimension as shown in Fig. 1 and Table 1. Five specimens were tested using HP Series Digital Force Gauge with maximum load of 500 N at room temperature.

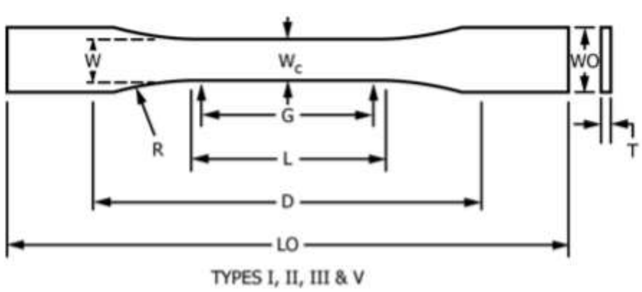

Figure 2. Test specimen[7]

Table 1. Test specimen dimension[7]

Dimension (see drawings)	7(0.28) or under	
	Type I	Type II
W-width of narrow section E,F	13(0.5)	6(0.25)
L-Length of narrow section	57(2.25)	57(2.25)
WO-Width of overall, min G	19(0.75)	19(0.75)
WO-Width of overall, min G	...	...
LO-Length overall, min H	165(6.5)	183(7.2)
G-Gage length I	50(2.00)	50(2.00)
G-Gage length I	...	...
D-Distance between grips	115(4.5)	135(5.3)
R-Radius of fillet	76(3.00)	76(3.00)
RO-Outer radius (Type IV)	...	...

3. Results & Discussions

Stress-strain curves are used to determine the maximum tensile stress and yield stress. The maximum tensile stress (UTS) is determined based on the value of the highest stress that occurs in the tensile test, while determining the yield stress (YS) using the offset method 0.002. For plastic polymer, strength is usually taken as tensile strength. The stress-strain curve for five specimens can be seen in Fig. 2 to Fig. 7. This curve is similar to curve B in Figure 1, the initial deformation is elastic, which is followed by yielding and a region of plastic deformation.

Five specimens tested showed similar curves, except for specimen 3 which experienced a strain that tended to be greater than the other 4 specimens. This is because the hole of specimen 3 was defective due to the tensile test, resulting in increased elongation and increased strain. To ensure data validity, specimen 3 was discarded and the mean values of the yield strength, the elastic modulus and the respective standard deviation were obtained. as shown in Table 2.

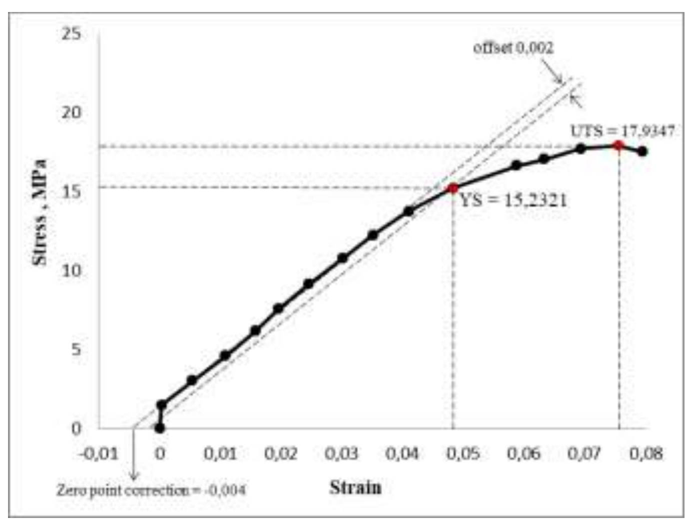

Figure 3. Stress-strain curve of specimen 1

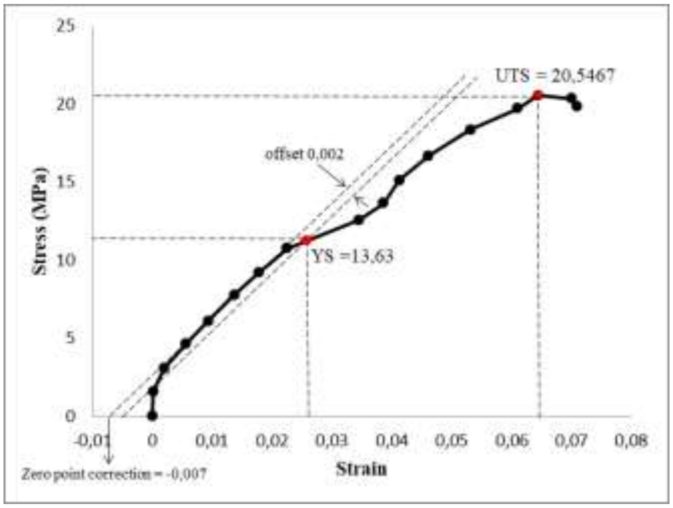

Figure 4. Stress-strain curve of specimen 2

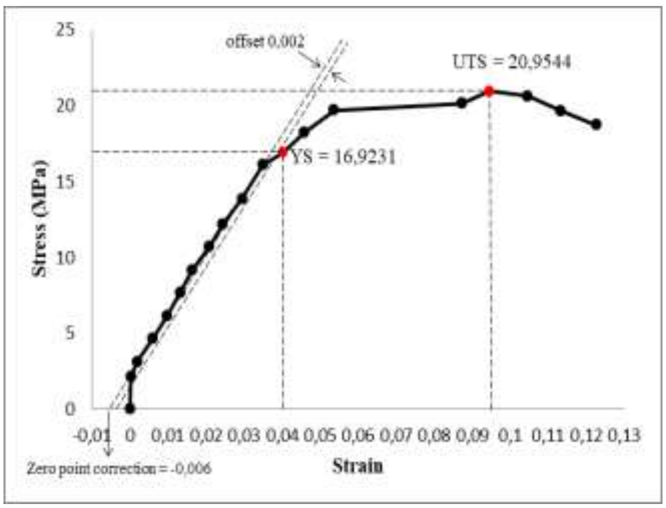

Figure 5. Stress-strain curve of specimen 3

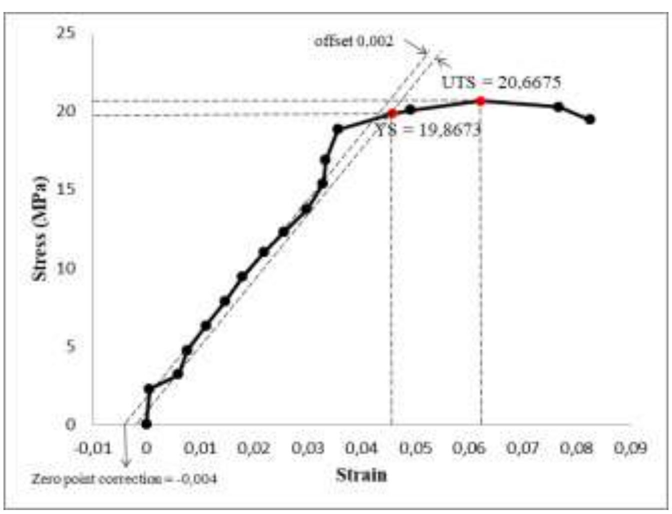

Figure 6. Stress-strain curve of specimen 4

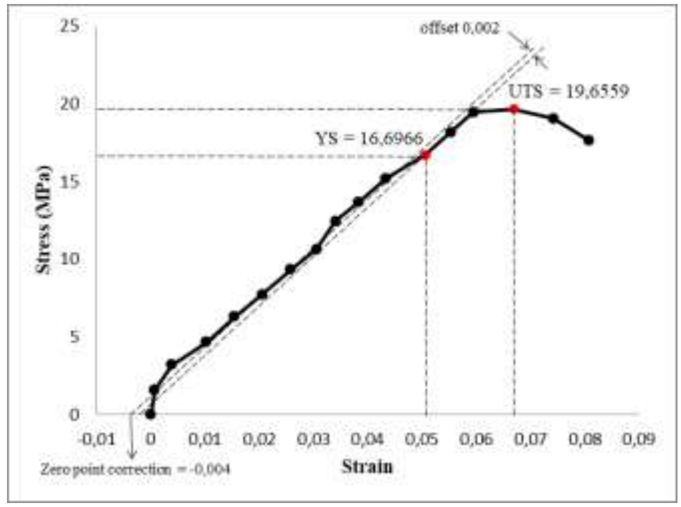

Figure 7. Stress-strain curve of specimen 5

Table 2. Mean and standar deviation of yield strength and elastic modulus for recycled polypropylene

Mechanical properties	**Mean Value**	**Standar deviation**
Yield strength (MPa)	16.357	2.65
Elastic Modulus (MPa)	295,926	41,97
Ultimate tensile stress (MPa)	19,701	1,261

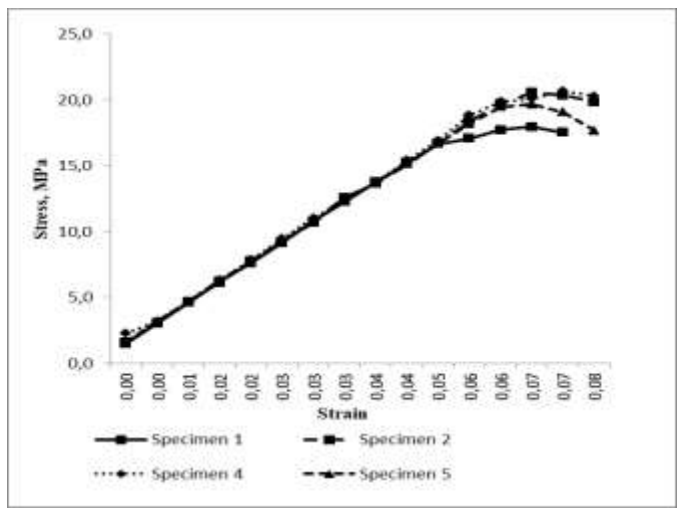

Figure 7. Stress-strain curve of specimen 1,2,4,5

Yield stress of recycled polypropyle has a lower value than the yield stress on recycled polypropylene studied by Abdelhaleem et.al or Barbosa et.al which is around 21 MPa[8][6] . This difference is possible due to the different quality of raw materials and processing. Several previous studies stated that up to a raw material ratio of 70% the mechanical properties of recycled polypropylene are not much different from the virgin ones[6][9][10].

4. Conclusion

The mechanical properties of polypropylene have been tested using a tensile testing machine. The results show that yield strength is 16.357±2.65 MPa, elastic modulus 295,926 ± 41,97 MPa and ultimate tensile stress 19,701±1,261 MPa. Yield stress of recycled polypropyle has a lower value than the yield stress on recycled polypropylene studied by Abdelhaleem et.al or Barbosa et.al which is around 21 MPa[7][5] . This difference is possible due to the different quality of raw materials and processing.

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