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# The product strength analysis of woven bag made from recycled mineral water plastic cups based on the polypropylene content

**Key words:** woven bag, green manufacturing, tenacity, plastic wastes

## Introduction

Since the first time it was discovered, the use of plastic wastes has been having a gradual increase. It is influenced by technological development, industrial development as well as the rising number of population. The global use of plastic in 2007 had reached 260 million t (Asmita, Shubbamsingh, Tejashree & Road, 2015). Other than as the biggest contributor of solid wastes in the terrestrial environment, it is also noted that from the 260 million t of plastic produced, around 8 t of plastic wastes were carried by the stream and ended up in the high seas (Eriksen et al., 2014). The source of plastic wastes is dominated by packaging (38%), followed by buildings and constructions (21%), automotive (7%), electricity and electronics (6%) and other sectors (28%) the likes of medical and recreations (European Commission, 2009; Plastics Europe, 2009). The plastic wastes that can be managed by the Indonesian government are only around 20–30%. The rest of it will be dumped into the wastes disposal areas. The solid wastes removal and extermination by burying them under the ground are also typically done. Some researchers in their researches argue that the residual monomer consisted of the plastic polymer can be dangerous (Lithner, Larsson & Dave, 2011; Galloway, 2015; Comăniță, Hlihor, Ghinea & Gavrilescu, 2016). Besides, the chemical compounds used in the production of plastic as an additive, especially plasticizer, are dangerous to the human and environment's health, along with the degradation products which might be emitted during the life cycle of plastic.

Furthermore, Verma, Vinoda, Papireddy and Gowda (2016) added that the burning of poly vinyl chloride (PVC) will release the halogen which is dangerous and pollutes the air, leading to climate change. The toxic substances released that way are a thorough threat to the vegetation, health, and environment of human and animals. The polystyrene is destructive to the central nerves system. The dangerous brominated compounds act as a carcinogen and mutagen. The dioxin sediments in the plants and waterways, therefore it is dangerous to the human when consuming that food and water.

Based on that condition, the 3R (reuse, reduce, recycle) methods of plastic wastes management, as Visvanathan, Adhikari and Ananth (2007) explained in their research, are developed. Reuse is the repeated use of plastic products. Reduce is lowering the purchase or usage of plastic stuff, especially the disposable ones. Recycle is reprocessing the plastic products. By implementing this management system, the wastes will be transformed back to the initial cycle as raw materials for the other more useful products. The heightened global attention and awareness toward the environmental aspects enhance the industry to implement green manufacturing (GM) concept in their business practices (NPCS Board of Consultants & Engineers, 2014). The idea of green manufacturing (GM) is basically a process/system which has a minimum impact or negative influence on the environment. Some countries in the world have committed to pay more attention to the environmental aspects of their agendas. The implementation of GM can lower the material cost since it uses wastes as the raw materials, avoids aggravating the environmental damage, and positively influences the institutions' reputation (Webb, Arnott, Crawford & Ivanova, 2013).

The implementation of GM in manufacturing companies consider the thoroughness and links of their current business practices in woven bag production. The core phase in the process of using the raw materials made from recycled wastes is implementing the planning of GM principles by producing woven bag in accordance with the specifications determined by the companies and the consumers' demands, referring to Standard National Indonesia (SNI) and the positive impacts to the environment. The primary quality parameter of the woven bag is the tenacity of plastic threads. This tenacity is the main factor of strength quality of woven bag in carrying weights. To achieve the quality of thread tenacity qualified to the specifications, the experiments in the factors of machines setup and plastic raw materials' components are influential. This research will examine the influence of operational temperature in the extraction machines and the adding of plastic wastes as the raw materials of the woven bag. The temperature factor becomes an essential component in structuring microplastics. Ariff, Ariffin, Rahim and Jikan (2012) in their research explains that the viscosity of ore plastic liquids is strongly influenced by the operational temperature.

## Research materials

To be able to explain the role of plastic cup wastes in becoming the raw materials of the woven bag within the concept of green manufacturing, there will be discussions on some theoretical framework, such as plastic wastes, green manufacturing concept, and the production process of the woven bag.

**Plastic wastes**

Plastic is an artificial material which molecular structure has a complicated composition, which also purposely set to fulfill the specific applications demanded by plastic constructed by many monomers, which eventually constructs a polymer. The characteristic of plastic depends on the constructive monomer. In general, plastics have a low density, are electrically insulating, have varying mechanical strength, limited temperature resistance, and vary chemical resistance. In addition, plastic is also lightweight, easy to design, and low-cost manufacturing. Unfortunately, behind all these advantages, plastic waste creates problems for the environment. The plastic polymer is composed upon elements of carbon, oxygen, and hydrogen. The plastic molecules can be formed through the organic condensation or polymer addition and can also consist of other substances to improve the performance or economic values. Plastic classification based on its chemical structure is divided into two types, i.e. linear and three-dimensional network. When the monomer forms a polymer chain straight (linear), thermoplastic plastic will be formed which has properties melts at a certain temperature, attached to changes in temperature and can reversible to its nature, i.e. re-harden when cooled. When three-dimensional monomers due to chain polymerization will form thermosetting plastics with properties cannot keep up with changes in temperature. When once hardening has occurred, the material cannot be softened again. Plastic has various boiling and melting points, this is based on the formation monomers. Monomers are often used in plastic manufacturing is propene ($C_3H_6$), ethane ($C_2H_4$), vinyl chloride ($CH_2$), nylon, carbonate ($CO_3$), and styrene ($C_8H_8$). Generally, there are seven types of plastics which we often used in our daily lives, as seen in the table.

The mixed raw materials used in the woven bag production is polypropylene (PP) and the transparent plastic cup wastes (Fig. 1a), which is also come from PP. The raw materials are the type of plastic often used to wrap food or beverage type 5 (see the table). This type is also used as a food container and baby drink bottle. This product is considered as a disposable product which can only be used once and then becomes a solid wastes or recycled. The PP plastics consist of the crystalline polymer formed through the process of propylene gas polymerization. Propylene has a lower specific gravity compared to other types of plastics (Maddah, 2016). Polypropylene is a thermoplastic polymer. Polyolefin is ready to be formed by the process of propylene polymerizing with a suitable catalyst, such as aluminum alkyl and titanium tetrachloride. Therefore, it is light and suitable as a wrapper material. A polypropylene has a pretty high melting point (190–200°C), while its crystallization point is around 130–135°C. Polypropylene has a high chemical resistance, yet low impact strength.

A plastic can be degraded by the environment through four mechanisms, which are photodegradation, thermal oxidation degradation, hydrolytic degra-

TABLE. Seven types of plastics based on the danger levels toward the environment and human (Ryedale District Council, n.d.)

| Symbol | Acronym | Information |
|---|---|---|
|  | PET | For mineral water and ready to drink bottles. Not to be refilled, especially with hot water. |
|  | HDPE | Milky white bottles. Usually for mineral water galoon, plastic chairs, or milk packaging for food. This bottle is also disposable. |
|  | PVC | Hardly recyclable plastics, such as plastic wrap or bottles. The components of this plastic can melt and diffuse to the food in the temperature of < 15° |
|  | LDPE | Usually for food, plastic packaging have soft or flexible texture. Food plastic wraps or bottles with this symbols is quite safe to be used. |
|  | PP | Safe to be used as food or beverage wraps. Usually this plastic is used as food container and baby drink bottles. The plastic is transparent. |
|  | PS | Disposable sterofoam packaging for food/beverage. This material can mix with the food under high temperature. Dangerous to the brain and nerves. |
|  | other | SAN (styrine acrylonitrile), ABS (acrynitrile butadiene styrene), PC (polycarbonate), nylon. Usually for food/beverage, household appliances, computer, etc. Plastic with code 7 SAN and ABS is good and safe to be used for food/beverage. Meanwhile, PC is dangerous for the body. |

a

b

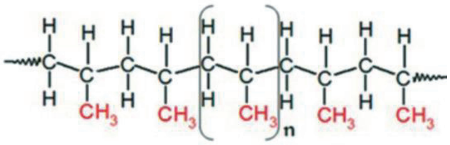

FIGURE 1. a – woven bag mixed raw materials of plastic cup wastes, b – polypropylene chemical structure

dation, and biodegradation by the microorganisms. Through these mechanisms, the plastic can be degraded perfectly within at least 50 years (Webb, Arnott, Crawford & Ivanova, 2013). Because of such a long time, there is a technology developed which can recycle plastic materials so that the environmental impacts can be reduced. Recycling processes of plastics can be divided into four ways category for primary, secondary, tertiary, and sometimes quaternary recycling. The primary category plastic processing is defined as a process without changing the type of product. This process category is characterized by simple, low-cost stages (Grigore, 2017). In addition, this process does not change the chemical structure of plastic (Singh, Hui, Singh, Ahuja, Feo & Fraternali, 2017). The secondary category of plastic processing is to change the shape of the product for use in other functions, for example beverage bottles are cut to be used as plant pots. Both of primary and secondary category processes are identical to mechanical changes (Stewart, 2009). Processing of tertiary recycling plastic waste is to break down plastic products into molecules chemically and then as the basis for making new products. Quaternary recycling is turning plastic waste into an energy source. The recycling process which is conducted when the product has been used by the consumers and re-processed into its polymer form is called mechanical, yet the transformation to the monomer form is called chemical. The method of energy recovery refers to the restoration of plastic energy composition, yet it has a negative impact on the health risks upon toxic substances in the air. Among those recycling methods, the chemical is the best because it leads to its construction of monomer, where the polymer is generated.

Some general steps in the process of chemical recycling of PP plastic are (Harron & Gilbert, 2014):

1. Collection: plastic wastes are collected from different locations.
2. Cleaning: The cleaning step consists of wastes washing and drying.
3. Sorting: In this step, not only separating the polymer from foreign substances, but also from other polymers.
4. Size reduction: This step is aimed to reduce the size of the wastes as well as separating the different polymer. The final product of shredding can be in a form of ragged plastic pieces.

## Green manufacturing

Green manufacturing includes a number of activities aimed to prevent pollution, to reduce the use of toxic substances, and to implement Reduce, Reuse, and Recycle (3R). The pollution prevention focuses on how to avoid and minimalize the wastes by reducing the wastes resources or doing on the spot recycling. Reducing the resources of wastes can be achieved through ways related to the process or the products (Dornfield, Yuan, Diaz, Zhang & Vijayaraghavan, 2013; Seth, Rehman & Shrivastava, 2018), such as the modification of product by changing the shape and the composition of the product's raw materials; substituting the input so that the use of raw materials and additive substances, which cause pollution and require process aids (such as lubricant and cooler), can be reduced; modifying the technology by involving an improvement in the automation process, optimation process, redesign of the tools and process substitution; as well as changing the operational procedure and management to decrease or removing the wastes and emission. The green concept includes the manufacturing process by using minimal materials and a process which minimalizes the negative impacts toward the environment, low energy and natural resources, safe for the employees, people, and consumers, but also protecting the economic values (Al Shayeb, 2013; Duić, Urbaniec & Huisingh, 2015).

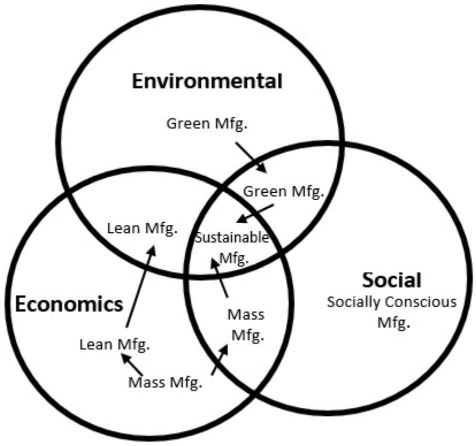


FIGURE 2. The linkages of green manufacturing with the economy, social, and environment

Green manufacturing (GM) has a significant role in enhancing sustainability in plastic use through plastic wastes recycle. The need for the green environment has reinforced the emergence of GM so that plastic sustainability can be achieved. The existence of sustainable manufacturing will be influential to the social, economy, and environment (Fig. 2). A sustainable manufacture refers to a manufacturing system or process that fulfills these three important factors – which are discussing its impacts toward the environment, economy, and society (Teodorescu, 2012; Astuti, Prawoto, Irawan & Sugiono, 2018). Considering the definition of the US Trade Department upon the sustainable manufacture that includes "minimalizing the negative impacts toward the environment, save energy and natural resources, safe for the employee, society, and consumers as well as being economically healthy" – the three underlined! A company cannot sustain if those three, at least, is not balanced with the financial.

Generally, the management of plastic wastes includes collecting, sorting, crushing, washing, and manufacturing into the product. The production process of PP woven bag involves the mixing of raw materials started from the pellet of PP or HDPE and other additives, extrusion of raw materials into the PP resin thread heated with $CaCO_3$ and pigment, melted and extruded as a flat film (Ain & Panchal, 2017). Meanwhile, the production process of the woven bag with the mixture of plastic bottle wastes includes several activities, such as:

– Recycle. The plastic as a wastes of packaged mineral water is recycled into the form of beans to be able to be used as a raw material by using a shredder machine to crush the plastics and shaped it into plastics beans.
– Mixing the raw materials in the mixer. The raw materials, which have been mixed using mixer machine with a certain composition to generate a finished material, are sheets of plastics with a quality-adjusted with SNI's requirements (4–6 g per 1 denier).
– Plastic extrusion process. The raw materials mixed with other materials using mixer are then inserted into a plastic extrusion machine to generate the plastic sheets.
– The cooling of the finished materials (plastic sheets). The cooling treatment to the plastic sheets is done by dipping it into cold water, where the temperature should not exceed

30°C. The objective is so that the PP plastics generated can have a strong crystal structure of PP plastics.

- The plastic sheets cutting process. The stretching process of plastic ribbons is done on a plate with certain temperatures so that the plastic ribbons have a strong tenacity due to the stretching. In this step, the ribbons will have a weaker tenacity.
- Annealing (heating without stretching). In this step, the plastic sheets are heated through a hot plate without any stretching so that the plastic sheets can recover its tenacity.
- Rolling. In this step, the plastic ribbons which have been cut are then rolled in a rolling machine consisted of many rolls moving back and forth in accordance with the arrangement set automatically so that the movement of the rolls would not overlap each other. The changing of the full rolls is done gradually in accordance with the rolls' position order and it can be done manually. The rolls changing should be done wearing gloves so that the plastic ribbons would not tear apart and harm the hands.
- Weaving the plastic rolls. This process is the knitting or spinning of the plastic ribbons/threads. It requires many rolls and it should be monitored by a supervisor because it is often that during the process, there are plastic rolls that break.
- Cutting. After the bag is cut, the lower part of the bag is sewn up and ready to be a woven bag.
- Final products. The final products of woven bags are ready to be delivered to the customers.

## Research methodology

This section discusses the theoretical framework and research design. This research is conducted in order to implement the green manufacturing concept within the manufacturing process of the woven bag by utilizing the raw materials made of mineral bottle plastic wastes. The recycling of plastic wastes has to be qualified according to the product quality standard. Accordingly, the research method is action research. It is emphasized on the actions by conducting a test of ideas into the practical or real situation within a micro scale, which is expected to be able to repair, improve the quality, and promote social recovery.

The research design is used as the foundation of this research so that the implementation could be conducted right, well, and smooth. In this section, there will be a discussion on the research object, research design up to the result, and the analysis. The research object is to design a process of PP plastic recycling management in the manufacturing system through a feasibility test of business practices. The concept of making woven bags is to make basic raw materials by mixing recycled plastic waste with pure plastic bijing or categorized as tertiary recycling in plastic waste. The alternative raw materials need to be developed due to the limit of primary raw materials which come from oil. The research is conducted in PT. Absolutech Distrindo, a manufacturing factory producing woven bags which is located in Pakis subdistrict, district of Malang, East Java. It has complete machines and tools so that it is possible to do the research in the factory.

The research design is used to determine the test parameter in order to acknowledge the woven bags' feasibility by using the alternative raw materials of PP mineral water bottle plastic wastes. The main parameter used to assess the woven bags' feasibility is the thread tenacity test, which also happens to be the woven bags' material. The test is conducted using a thread tensile strength test tool with a measurement unit of g per 1 denier. The product is confirmed to fulfill the Standard National Indonesia (SNI) if the power is around 4–6 g per 1 denier. Figure 3 shows one example of tensile strength test for experiment 1 (10% plastic wastes) with extruction temperature 175°C. According to the graph, it can be explained that the specimen will break after 14 s with maximum force at 24 N (1 N = 79.98 denier). The different experiment parameters gave different tensile strength.

The steps in the woven bag production experiment are from the raw materials of original plastic beans and plastic beans mixed with plastic bottle wastes. There are three experiments that will be conducted, which are experiment I: raw materials of 100% original plastic beans, extrusion temperature 1 = 175°C, extrusion 2 = 187°C, extrusion 3 = 200°C, extrusion 4 = 212°C, extrusion 5 = 225°C, lime percentage = 10% and cooling temperature = 20°C. Experiment II: raw materials of 90% original plastic beans, 10% plastic bottle wastes, extrusion temperature 1 = 175°C, extrusion 2 = = 187°C, extrusion 3 = 200°C, extrusion 4 = 212°C, extrusion 5 = 225°C, lime percentage = 10% and cooling temperature = 20°C. Experiment III: raw materials of 90% original plastic beans, 10% plastic bottle wastes, extrusion temperature 1 = 185°C, extrusion 2 = 197°C, extrusion 3 = 210°C, extrusion 4 = 222°C, extrusion 5 = 235°C, lime percentage = = 10% and cooling temperature = 20°C. The flowchart (Fig. 4) is presenting the general steps in the experiment process of woven bags production based on different conditions.

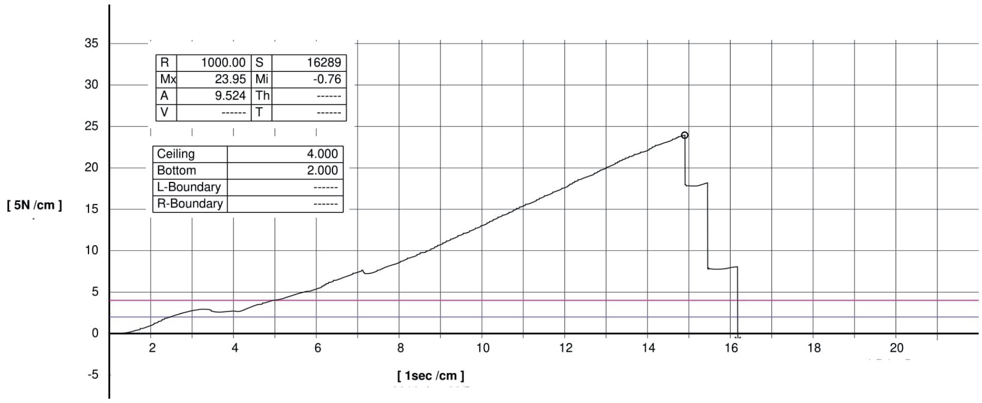


FIGURE 3. The tenacity test measurement for the woven bags' raw materials for experiment II, temperature 175°C

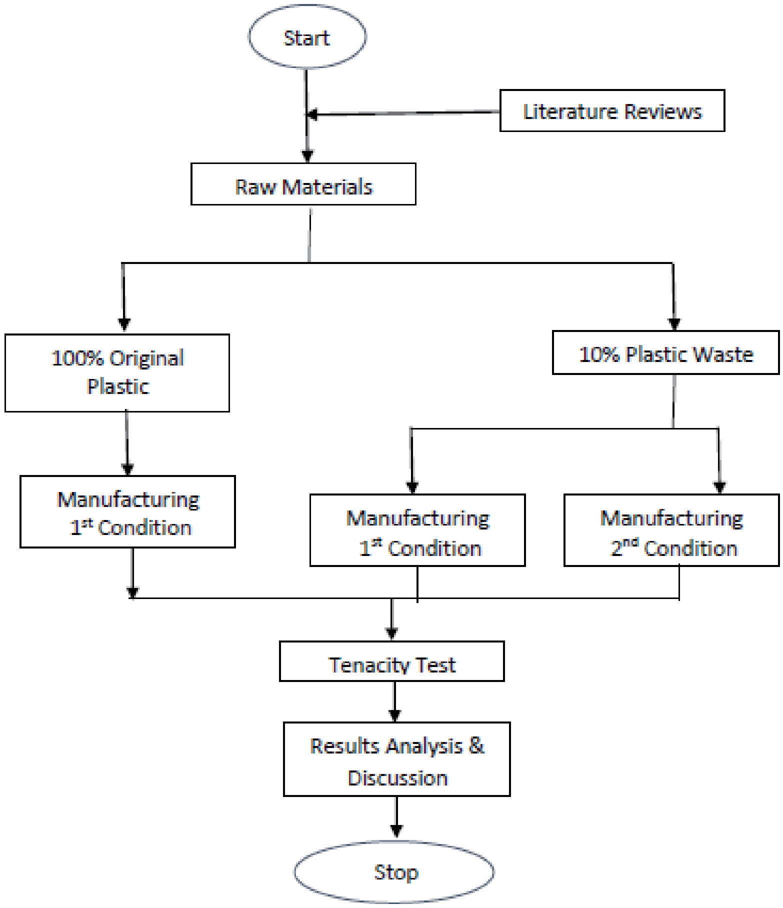


FIGURE 4. Flowchart of the woven bag manufacturing process based on differences in raw material and extrution temperature

## Results and discussion

As the beginning of improvement toward the woven bag production system with the mixed raw materials between plastic beans and plastic cup wastes, created two different manufacturing process conditions. The second condition of manufacturing process works with the extrusion temperature 1 = 175°C, extrusion 2 = 187°C, extrusion 3 = 200°C, extrusion 4 = 212°C, extrusion 5 = 225°C, lime percentage = 10% and cooling temperature = 20°C. To investigate the changes in the woven bags' tenacity, the raw materials, which used 100% original plastic beans and 90% original plastic beans (with 10% plastic wastes), are compared. According to the measurement results of each material with 8 replications of each (Fig. 5), there is an average tenacity of 5.15 g per 1 denier for the raw materials of 100% original plastic beans, while the mixed one has an average tenacity = 3.38 g

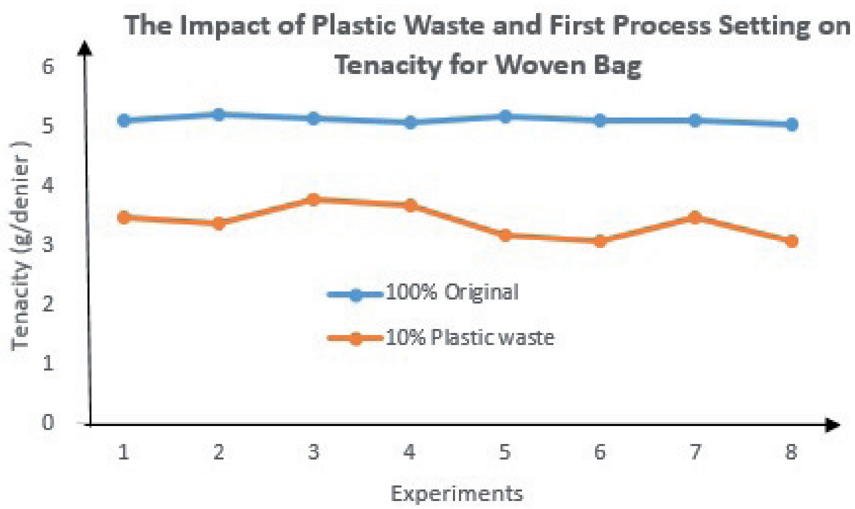


FIGURE 5. The result of tenacity measurement in setup machine condition 2 for wastes materials 0% and 10%

per 1 denier. T test has been used to decide whether the two groups of experimental data have significant differences or not. On the other hand, F test has been used to find out how much influence a parameter in the experiment determines the results. Based on the hypothesis test using the F test, concluded that $F_{\text{calcul.}} = 20$ and $F_{\text{table}} = 4.9$. With the value of $F_{\text{calcul.}} > F_{\text{table}}$, it can be considered that the original variance of tenacity is not homogenous with the recycled's tenacity. Besides, according to the result of t test, the $t_{\text{calcul.}} = 19.25$ and $t_{\text{table}} = 2.13$, which means the gap in the tenacity between the two materials is really significant.

The condition of manufacturing process 3 works on extrusion temperature 1 = 185°C, extrusion 2 = 197°C, extrusion 3 = 210°C, extrusion 4 = 222°C, extrusion 5 = 235°C, line percentage = 10% and cooling temperature = 20°C. To investigate the changes in the woven bags' tenacity, the raw materials, which used 100% original plastic beans and 90% original plastic beans (with 10% plastic wastes), are compared. According to the measurement results of each material with eight replications of each (Fig. 6), there is an average tenacity of 5.07 g per 1 denier for the raw materials of 100% original plastic beans, while the mixed one has an average tenacity = 4.76 g per 1 denier. Based on the hypothesis test using the F test, concluded that $F_{\text{calcul.}} = 97$ and $F_{\text{table}} = 4.9$. With the value of $F_{\text{calcul.}} > F_{\text{table}}$, it can be considered that the original variance of tenacity is not homogenous with the recycled's tenacity. Besides, according to the result of t test, the $t_{\text{calcul.}} = 2.17$ and $t_{\text{table}} = 2.13$, which means the gap in the tenacity between the two materials is not significant.

According to Figures 5 and 6, it can be concluded that statistically, there are changes in the woven bags' tenacity with the original raw materials and the one mixed with plastic cup wastes. There are two machine setting conditions com-

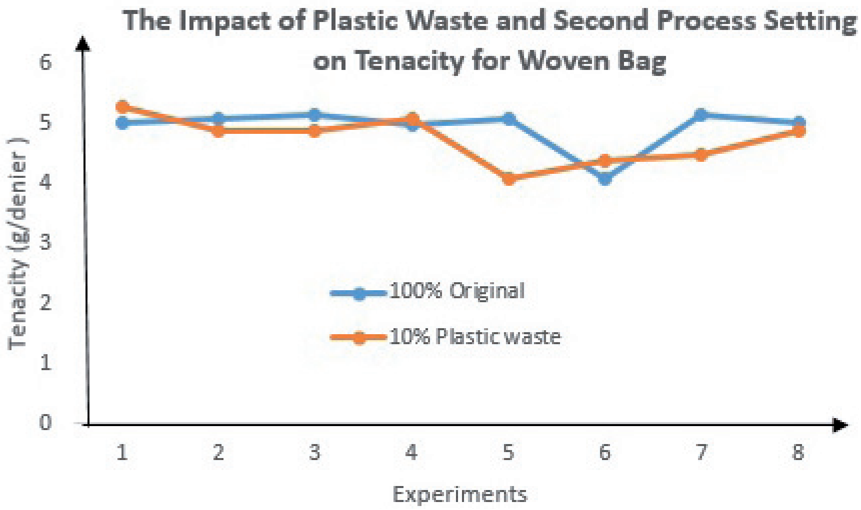


FIGURE 6. The result of tenacity measurement in the setup machine condition 2 for wastes materials 0% and 10%

pared, which are machine setting 1 and 2 that have the temperature 10°C higher than all the extrusion machines. Based on the comparison of average tenacity tests, acquired the data that tenacity value for the first machine setup has tenacity = = 3.38 g per 1 denier and for the second machine setup = 4.76 g per 1 denier. It can be concluded that the setup temperature in the second machine is able to meet the SNI standard, which is around 4–6 g per 1 denier. It indicates that the setup temperature of the extrusion machine used in the woven bags production is important to be studied. Increasing the extrusion temperature is even able to cut the gap of tenacity between the raw materials of original plastics and raw materials mixed with 10% of plastic wastes. It requires a further investigation of the relationship between the characteristics of raw materials polypropylene ($C_3H_6$), operational machine temperature, and the number of wastes added to the mix. An experimental design with an in-depth chemical analysis is expected to be able to find the right composition that contributes to the implementation of green manufacturing. Zhang, Wang, Lu and Yu (2005) state that; the PP melting duration around 48 s is also needed to be considered in optimizing the woven bags' tenacity.

## Conclusions

Based on this research, it can be concluded that the addition of plastic cup wastes has a good chance that can be beneficial as an additive substances in the production of woven bags with the raw materials of polypropylene ($C_3H_6$). The tenacity in the second experiment condition with the 10% of plastic bottle wastes is able to generate a good value of 4.76 g per 1 denier, which is also allowed by the government (4–6 g per 1 denier). Statistically, the difference of tensile strength between two materials is not significance. The comparison between the first and second experiment shows that the setting of the extrusion machine's temperature is very influential to the products of woven bags. The increase in temperature as much as 10°C could improve the tenacity up to 40.38%. The understanding of the PP chemical characteristics and machine setting is helpful to generate an optimal tenacity. Therefore, in the future, the complete research design is required to increase the use of wastes in the production of woven bags.

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## Summary

**The product strength analysis of woven bag made from recycled mineral water plastic cups based on the polypropylene content.** The increasing amount of plastic wastes has become a threat to the sustainability of all ecosystem in this Earth. This paper aims to provide an alternative utilization of plastic wastes as the raw material in the manufacturing process of woven bag products with a quality control in its tenacity. The initial phase of this research is a literature review on the concept of green manufacturing, woven bag quality, compositions of plastic wastes and woven bag manufacturing proses. Furthermore, it is followed by a data measurement in a form of tenacity test using a thread test gauge (tenacity). There are two types of the condition in the manufacturing process of woven bag production compared by increasing the temperature as much as 10°C in all the extraction machines. The measurement result shows that the average tensile strength in the production process of the woven bag made from the wastes of mineral water plastic cups with 10% composition and extraction temperature for the first condition is 3.38 g per 1 denier and the second condition is 4.76 g per 1 denier. The result of second condition manufacturing (increasing the extraction temperature by 10°C) after comparing it with the quality required by Standard National Indonesia (SNI) as much as 4 to 6 g per 1 denier is considered

good quality. Therefore, through the concept of green manufacturing, the utilization of plastic wastes might provide a substitution to the part of plastic core raw material in the woven bag production. This research is designed to be the beginning of innovation to acquire raw materials for the woven bag, furthermore, the optimization toward the machine setting and innovation on plastic wastes raw materials become the foundation in increasing the tenacity.

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