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Investigation of Clothes Recycling as Colouring Agent for Polypropylene-Nanoclay Nanocomposites

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Abstract: Most of polymers can be recycled and reused to make new products or new inventions. Basically, some of the clothes were made up from polymer and it can be recycled as a compound or filler material in the process of injection moulding. The purpose of this research is to investigate the potential of recycling used clothes made from polyester, as a colouring agent for plastic product through the injection moulding process. This research started with shredding the used clothes into a powder and mixing the clothes powder with Polypropylene-Nanoclay Nanocomposites (PPNC). The samples were produced in three different colours which were red, blue, and yellow according to the colour of the recycled cloth. All samples produced from this process went to several testing, such as tensile, warpage, shrinkage, and thermal analysis. According to the results, each of the samples produced the same colour as the used clothes which were red, blue, and yellow. Besides that, the highest value of Youngs Modulus for sample of used clothes was 525 MPa, which was better than the samples of unused clothes. The quality of the samples was better when the values of warpage and shrinkage were acceptable, which were in the range of 0.01 mm to 0.048 mm for warpage and 0.0141% to 0.0156% of shrinkage. Based on the thermal analysis, the peak temperature was 167.2°C which is not far different from pristine polypropylene. The outcome of this research should be beneficial in the future of plastic manufacturing process, in terms reducing cost of raw material and, at the same time, the environmental pollution impact also can be reduced.

Keywords: *Injection moulding, clothes recycling, polypropylene nanoclay, colouring agent*

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I. INTRODUCTION

The objective of this research was to explore the usage of recycled cloth as a colouring agent for the injection moulding process. This experiment was conducted by using several colours of recycled cloth/fabric made from polyester, which were red, yellow, and blue in order to produce variations of colour in the sample. These recycled clothes then had been compounded with polypropylene nanoclay, and then the compound was injected mould to prepare the test samples. Several tests were conducted to this sample in order to find the properties and quality of the injected mould samples. The expectation for this research is to prove that the cloth can be a good colouring agent in the injection moulding process.

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II. LITERATURE REVIEW

A. *Clothes Recycling*

In a study based in the United Kingdom, it was found that the amount of 4% to 5% of the municipal solid waste stream was from clothes/textiles. Approximately 25% of this amount was recycled by the Salvation Army Trading Company Limited (SATCOL). This company provides a collection and distribution infrastructure for donated textiles. These textiles went through a processing stage and entered a recycling stream or can be reused [2, 3].

To quote one example as the proof of reusing textiles in recycle stream, a researcher had proposed a system to reconstitute the recycled waste fabric materials (including from cotton denim waste), whereby the reconstituted waste fibers were incorporated into a needle-punched or a hydro-entangled product without additives or binders. The final process (finishing) was also characterized as a fiber web by a uniform directional orientation of fibers. This process made the fibers more amenable for hydro-entanglement condition. Therefore, this non-woven product can produce a high strength, good fiber integrity and high uniformity artefact. It also can be cross-lapped to offer greater absorbency and strength [1, 4].

Furthermore, a patent explaining the method using recycled fabric scraps for producing high quality fabrics also had been revealed. By controlling the pre-gin contact with the virgin carrier fibers, and moistening the recycled fiber scraps, fiber uniformity percentages and length have been maintained higher than the typical fiber attained by the prior art. This novel process has many advantages, such as minimizing the requirement for redyeing the resulting fabric product, as well as decreasing the shrinkage behavior [5].

Therefore, based on these findings, there are potentials to utilize the recycled clothes for other purposes in manufacturing industries and the needs to identify the possibility of utilizing recycling clothes waste and covert them to something valuable.

B. *Polypropylene-Nanoclay*

Among the available thermoplastic polymers that can be used in injection moulding, polypropylene was proposed as matrix because it was well-versed for its steadiness and versatility of modulus, strength, elasticity, and thermal and chemical resistance [6]. This material has many prospective applications in many commercial merchandises which demand in stiffness, creep resistance, and some toughness with the offers of cost and weight savings. Moreover, the usage of additional fillers, such as talc and Nanoclay, could deliver a better physical and chemical environment for this material. Nanoclay is organically modified to change the Nanoclay from hydrophilic to organophilic. This modification was made through an ion exchange reaction between organic cations and inorganic cations, and may increase the interlayer spacing of clay as well [7].

Polypropylenenanoclay-nanocomposites are increasingly boosting the research interest due to the advanced properties, whereby with the addition of low clay content, it could become a valuable and effective cost additive [8]. Quite a few preliminary researches have been conducted with different types of material, products, and properties. The methods and discoveries of these experiments were used as guidance for this research [9, 10, 11].

Therefore, based on the previous findings, this study proposed the used of clothing to be compounded with polypropylene-nanoclay matrix, and thus, compounding can be used as a secondary raw material in the manufacturing process. By using this approach, the disposal of these clothes that can cause pollution to the environment can be reduced and the plastic manufacturing industries may gain benefit from the applications of this new material in terms of reducing the cost and consumption of raw materials.

III. METHODOLOGY

Previous research had been conducted and the method had been used as the reference in this project [9, 10, 11]. The experimental method starts with selection of cloth recycling method. The process through injection moulding was selected due to the good quality of the sample produce. Before starting the injection moulding process, types of polymer cloth and plastic polymer were selected. The clothes were collected from football jersey which is made up of polyester. Polypropylene with 5 wt.% of nanoclay (PPNC-5 wt.%) was used as the polymer matrix. The composition of recycled cloth was 1% and 99% of PPNC-5 wt. %. The colours of the cloth used were red, yellow, and blue. These three colours have produced three different colours for the sample. The number of samples produced was 15, consisting of 5 samples for each colour.

Fig. 1 shows the injection moulding machine (Type: Nissei NP7-1F) that had been utilised for this project. The experimental test consists of tensile, warpage, shrinkage, and thermal analysis. The properties of the samples were then analysed and compared between the samples from PPNC-5 wt.%, without the existence of clothes fibre.

Fig. 1. Tonne Nissei NP7-1F injection moulding machine

A. Tensile Test

The tensile test of the sample was measured by using Universal Testing Machine (UTM)-GOTECH with the capacity of 50kN. The procedure of ISO 527-2 test method has been referred to in this test, with the speed of the testing being 1mm/min. The value of Youngs Modulus, E of sample was measured, which defined the strength of every sample. This value was originated from graph of stress vs strain produced from the computerized system of the machine.

B. Warpage

After ejection from the mould, a post-processing was needed by removing the runners and the flashes. The thickness of sample was measured at 10 different places by using a micrometer screw gauge. The reading of maximum height was recorded using dial gauges three times and the average value was considered at the end of measurement.

C. Shrinkage

Before measuring the shrinkage, the samples need to allow cooling down under room temperature for 24 hours. This is to avoid the sample from having any shrinkage while the reading is recorded. The value of shrinkage of each sample was found by using calculation of sample length against the actual mould length, with the consideration of mould thermal expansion coefficient.

D. Thermal Analysis

Thermal analysis was conducted to investigate the thermal behaviour of a material. This analysis was made to obtain the precise value of melting temperature for the compounding. The type of analysis conducted is Differential Thermal Analysis (DTA). The rate of heating is 10°C min-1, from 35°C to 550°C. During the injection moulding process, the melting temperature for this compounding will be needed. The machine used for the thermal analysis is Linseis L81/1550 types as shown in Fig. 2.

IV. RESULTS AND DISCUSSION

In this part, the analysis of dog bone samples for mechanical strength (Youngs Modulus) and defect (warpage and shrinkage) has been carried out. Besides, the colour intensity of the sample was analysed to improve the quality of colour. Thermal analysis was analysed to obtain melting temperature of the sample. The samples were produced with three different colours. For the red colour, the intensity of the colour was bright. But for the blue and yellow, the intensity of colour was dull.

Fig. 2. Linseis L81/1550 machine

A. Tensile Test Results

Based on Table 1, sample trial for no. 3 showed the highest Youngs Modulus, E with value of 525 MPa while trial no. 4 showed lower value of 383 MPa for the red-coloured samples. For the blue samples, sample trial no. 5 showed highest Youngs Modulus, E with value of 500 MPa while trial no. 4 showed lower value of 250 MPa.

For the yellow samples, sample trial no. 4 showed highest Youngs Modulus, E with value of 457.14 MPa while trial no. 5 has the lowest value of 250 MPa. Besides that, the value of Youngs Modulus, E of 300 MPa was attained for the sample of PPNC-5 wt.%.

As for the samples that consist of fibre from polyester and clay, it showed a higher value of Youngs Modulus compared to the sample consisting of fibre from clay only. The average of Youngs Modulus for sample from 1% polyester with PPNC-5 wt.% was 464.7 MPa. While, sample from PPNC-5 wt.% showed the lower value of 300 MPa. In structural composites, 70%

to 90% of the load is carried by the fibre [12]. Therefore, the amount of fibre that is contained in a sample will influence the strength of the sample. So, the sample from 1% polyester and PPNC-5 wt.% showed higher strength because it contained higher amount of fibre compared to PPNC-5 wt.% sample. Furthermore, the value of Youngs Modulus for sample of 1% polyester and PPNC-5 wt.% is different from each other. Basically, the sample produced was an anisotropic material with value of Youngs Modulus, E influenced by the orientation of the fibre. The difference occurred due the orientation of fibre in the samples was not similar. The sample with fibre oriented in the same direction along the stress became stiffer because the stress applied was carried by fibre. Meanwhile, the strength of the sample will reduce if the orientation of fibre has a different direction from the stress applied. Specifically, the load will be carried by polymeric matrix when the fibre orientation is different from stress. So, the strength of the sample will be improved once the fibre orientation is set up along the load [13].

TABLE 1
YOUNG'S MODULUS OF SAMPLES

Samples	Trial	Maximum Force (*N*)	Young Modulus, E (MPa)
Red	1	21.92	421
	2	24.52	450
	3	24.09	525
	4	24.34	383.33
	5	23.56	450.00
Blue	1	24.34	342.86
	2	24.72	275.00
	3	24.50	375.00
	4	24.61	250.00
	5	24.33	500
Yellow	1	23.85	420.00
	2	23.49	375.00
	3	24.81	428.57
	4	24.31	457.14
	5	23.90	342.86
PPNC-5 wt.%	1	25.84	300

B. *Warpage*

After the samples were ejected from the mould, the process of removing the flashes and runner was performed and the reading of thickness was measured as well as the maximum height of the sample.

TABLE 2
VALUES OF AVERAGE WARPAGE

Trial	Height (mm)	Thickness (mm)	Warpage, *Z* (mm)
1	2.014	1.966	0.048
2	2.014	1.966	0.048
3	2.040	2.014	0.026
4	2.012	1.978	0.034
5	2.065	2.055	0.010

Then, the value of warpage could be calculated. The values of average warpage are displayed in Table 2.

Based on the values obtained from Table 2, it showed that trial no. 4 had the lowest warpage with the value 0.010mm compared to other trials.

As for trial no. 1, the highest warpage had occurred about 0.048mm, followed by 0.034mm from trial no. 3.

C. *Analysis of Shrinkage*

Before the mould was heated up, the result of length for the mould cavity was measured. Table 3 shows the value of average shrinkage.

Based on the values in this Table 3, samples of trial no. 4 had the minimum shrinkage with the value 0.0141mm.

On the other hand for trial no. 1, it produces sample which brings the largest shrinkage occuring about

0.0156mm and followed by trial no. 3 with a value of 0.0154mm.

TABLE 3
VALUES OF AVERAGE SHRINKAGE

Trial	Length (mm)	Cavity Length (mm)	Shrinkage, S (mm)
1	73.864	75.037	0.0156
2	73.963	75.037	0.0143
3	73.882	75.037	0.0154
4	73.982	75.037	0.0141
5	73.934	75.037	0.0147

D. Analysis of DTA

For this analysis, firstly, the sample was heated from 35°C to 550°C at the rate of 10°C min^{-1}. The plot of temperature differentials versus the temperature peak is called endotherm. The peak occurred at 167.2°C and represented the melting point of the sample. Within this temperature, the sample will melt at maximum. While at temperature 123.8°C, melting process starts to occur and at 207.1°C, process of melting will stop. Fig. 3 shows the DTA curves. The determination of the melting temperature of the sample is very important because it will affect the quality of the resulting sample. Therefore, this temperature was used as the melting temperature during the injection moulding process.

Based on previous study, the amount of colouring agent composition that was used was from 0 to 5.0%, preferably at 0.5% to 2.0%. This amount could be referred as the amount by weight of the plastic granules [14]. Therefore, the colour intensity of the sample can be improved by increasing the percentage of cloth in the compounding.

V. CONCLUSION

As for the conclusion, according to the results obtained, the objectives of the research have been achieved. It has been proven that clothes can be used as a colouring agent in the polymer injection moulding process. In addition, the sample had been produced and tested according to the standards of ISO527-2 for tensile test. Besides that, the samples were measured for shrinkage and warpage to evaluate the quality of samples. The thermal test was successfully carried out and it was intended to determine the appropriate temperature for PP 5% nanoclay mixture with recycled clothes (polyester) melting temperature used during the injection moulding process. According to the result, the average value of Young's modulus, E for samples containing 1% of polyester and PPNC-5 wt.% is 464.7 MPa. Meanwhile, Young's modulus, E for sample PPNC-5 wt.% is also just as much as 300 MPa. Furthermore, the samples produced are having their colour, and the quality of the sample was acceptable based on the value of warpage and shrinkage.

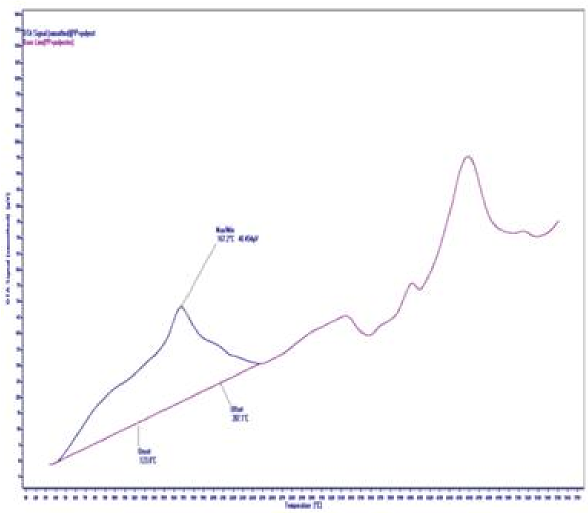

Fig. 3. DTA curve

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