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GREEN RECYCLING APPROACH TO PRODUCE HEAVY DUTY KIDS CHAIR FROM FACE MASK WASTE

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Abstract

The used of disposable surgical face mask during a pandemic generated a substantial waste flow to our environment. Surgical face mask waste creates big issues as it is made from polymer, non-degradable material and are being thrown away without proper recycling system. In this study, green recycling method of surgical face mask waste with different parts of the mask were done by using heat gun. The first composition is by using filter part of facemask. The second composition is by combining filter and ear loop component while the third composition combines filter and nose wire component. This paper discussed on the mechanical properties performance of all three compositions. Interestingly, combination of filter and ear loop component shows increase of IZOD impact and tensile strength by 15.9% and 46.7% respectively compared to composition of filter only. The improvement in impact and tensile strength could be attributed to good interaction between face mask and ear loop material. The composition with best mechanical properties were then molded into heavy duty chair for repurpose usage.
Keywords: Face mask waste, recycling, mechanical properties

1. Introduction

The outbreak of coronavirus diseases created a pandemic that has big impact on socio economy, mental health and environment aspects. Until this very moment, the dependency on face mask as one of the methods to reduce and protect community from infection is very high. This study has shown that the use of face mask could not only reduce the possibility of infection, but also help to minimize the virus transmission (Peeples, 2020 and Gandhi et al. 2020). According to Sangkham (2020), Kuala Lumpur alone used up to 154 tons of face mask per day contributing to 539 tons of plastic waste accumulated. Without proper disposal managed systems, face mask waste will create a long-term environmental risk with great impact on human health and ecosystems (Jahan, 2017).

Face mask effectiveness is related to the multiple layers of nonwoven material that acts as filters which were mainly made of polypropylene. The ear loop attached to the face mask is made from combination of polyester and spandex yarn, while nose wire is made from metal strip. All of these components were design to prevent any respiratory droplets from getting through the face mask. However, there are variations in products depending on the face mask manufacturer. This means that face mask can be treated as plastic waste that takes a very long time to decomposed. The decomposition of face mask creates microplastics contaminants that can be released continuously in watercourse, hence accumulate in the food chain of marine animals (Chamas et al. 2020). For this reason, appropriate collection, separation and recycling methods for face mask waste need to be carried out in parallel to the virus treatment research. In this work, face mask waste were treated as thermoplastic material where the polymer is soft when heated and harden back when cooled. This project focuses on green technology by considering environmental friendly production that exclude the usage of any solvent or hazardous chemical. It is also a very versatile and simple method that does not requires sorting of mask type, gridding or extrusion process. Face mask waste that have been collected and disinfected were melted by conventional heat gun directly in its mold with three different blend combination. The first blend includes filter parts of the face mask (A), the second blend include filter parts and ear loop (B) while third blend include filter part and nose wire (C). The nose wire and ear loop strap were included during melting process. Mechanical properties result from tensile and impact testing shows a promising result with properties acceptable for producing frame for chair (Gawande & Thombre, 2017). The molded blocks of face mask waste were assembled into a heavy duty kids chair. Face mask's components is mainly made from polypropylene, which have value added properties such as non-toxic properties, resistance to corrosion, not prone to chemical reactions, moisture and rain proof (Maddah, 2016). These properties make it a suitable and safe material for producing various types of furniture including kids chair. With this preliminary attempt in producing value added product from face mask waste, this study will continue by improving its properties for possible industrial use.

2. Literature Review

World Health Organization (WHO) has recommended the use of surgical face mask as one of the guideline to reduce the spread of COVID-19 virus. Most of the country in the world including Malaysia has made wearing face mask in public area as mandatory. In consequence of the enforcement for wearing face mask, tremendous face mask waste was created leading to a challenging waste management problem that could severely affect the environment. Hiemstra et al. (2021) reported a photographic evidence of fish and bird entrapped and entangled in PPE waste. The urban and domestic animals also affected with ingestion that caused by glove and face mask waste. These phenomenon shows that waste from PPE including face mask could cause long term effects on animals and marine life. Although guidance has been provided for disposing contaminated face mask such as wrapping it in a separate plastic bag, the face mask waste was not treated accordingly and were dump in landfills with other waste (Sangkham, 2020). Therefore, appropriate approach in managing and recycling for surgical face mask have to be developed in order to minimized the impact of face mask waste on the environment.

Battegazzore et al. (2020) reported on two recycling strategies scheme which involve extrusion using twin screw extruded and compressed molding of i) filter component at 190°C and ii) filter and ear loop component at different temperature of 190°C and 230°C. They found that tensile and strength of filter component is comparable with standard polypropylene while combination of filter and ear loop component depicted lower mechanical results. On the other hand, Crespo et al. (2021) reported on difference in mechanical properties of recycling face mask using the same type (FFP2) and mix of random type of surgical face mask. Both types of face mask were processed by extrusion and injection molding. They found that the mechanical properties of both materials are almost comparable. However, FFP2 masks mechanical properties were slightly higher then mix of random type of face mask. A student from Kaywon University of Art and Design in Uiwang city, Kim Ha-neul created designed furniture using heat gun from filter component of facemask waste (Park, 2020). However, there is no reported data on the mechanical strength of the produced product.

Remanufacturing and refurbishing of a used product by turning it back to functioning product is a new way to save energy and cost in furniture industry (Borga et al, 2009). For instance, Ecobirdy created children's furniture out of plastic toy waste as step to create awareness and reduce plastic waste problem (Silas, 2019). On the other hand, Green Furniture Concept based in Sweden apply a sustainable choice by using recycle material in production such as discarded planks, recycled plastic and steel (Silas, 2019). However, there are no reported mechanical properties on any of these products.

Among highly utilized methods in thermoplastic processing is mechanical blending technique which involve mixing and compounding by extruder and injection molding. It is also considered a versatile method as it does not involve any solvent during melting and mixing process. One of the main points of a successful recycling process is that the properties of the produced material is suitable for the application and are easy to be made. At this very crucial time with the quantity of face mask waste keep increasing, it is of great importance to investigate and develop alternative ways to recycle face mask with simple and inexpensive cost.

3. Methodology

The used surgical face mask for this study were collected among students of Politeknik Tun Syed Nasir. This process could be compared to hypothetical massive collection with no separation of brands, types, shapes and color. The collected face mask was cleaned using laundry detergent and disinfected using disinfectant liquid before processing. Face masks were segregated into three main components (filter, ear loop and nose wire) with the aid of scissors. All of the material will be used without any grinding and cutting steps.

Heat gun (MKS1800) with 220-230 volt, 50 hertz and 1800 watt will be used as melting tools to melt face mask components. The temperature range of the heat gun is in between 50-600°C. Melting process were done inside customized mold made of wood pallet wrapped with 0.1 mm thickness aluminum foil. The face masks were layered and melted one piece by one piece with five to ten seconds of contact time with the heated heat gun. Ear loop or nose wire were added, distributed and heated to the melted filter component based on desired weight ratio. Ear loop were heated until it is fully melted, however, nose wire is heated and pressed in the melted filter components until it is embedded in the polymer block. This heating process was repeated until the desired thickness of the mould were reached. The components weight ratio and layering sequence were presented in Table 1.

Table 1: Components ratio and layering sequence of filter component (A), filter and ear loop component (B) and filter and nose wire component (C)

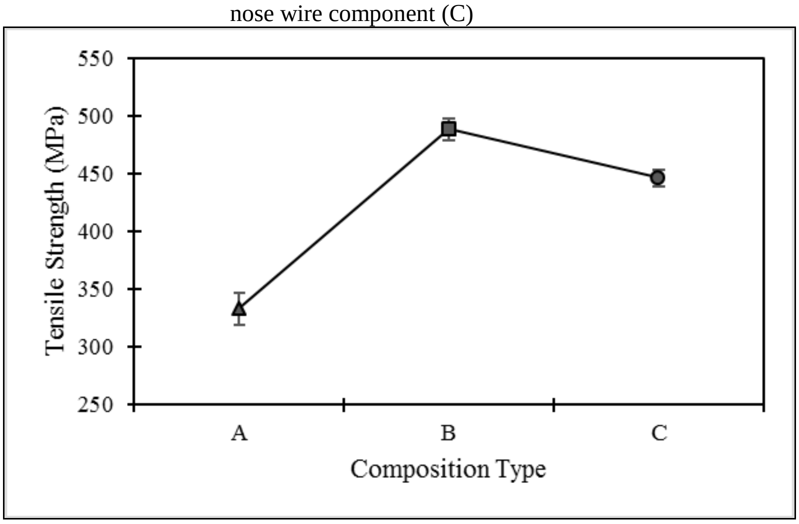
Components	*Weight Ratio (wt%)*	*Layering sequence*
Filter (A)	100	Filter only
Filter : ear loop (B)	95:5	Filter/ear loop/filter
Filter : nose wire (C)	95:5	Filter/nose wire/filter

Tensile tests were carried out according to ASTM D3039 using Instron Testing Machine with a loading cell of 50N. The cross head speed used in this study was 25 mm/min at room temperature. The thin film consists of strips with uniform width and length (15mm × 200mm). Three samples were used for tensile test and an average result was taken as the resultant value. The tensile test recorded the tensile properties of tensile strength and Young's modulus. Universal Pendulum Impact Tester were used for Charphy and IZOD impact test. Five samples were prepared according to ASTM D256 with width and length 0f (63.5mm × 12.7mm). The thin strips of tensile and impacts samples were produced by melting the face mask components in customized mold according to ASTM sizes using the same technique as producing the product blocks.

4. Finding and Analysis

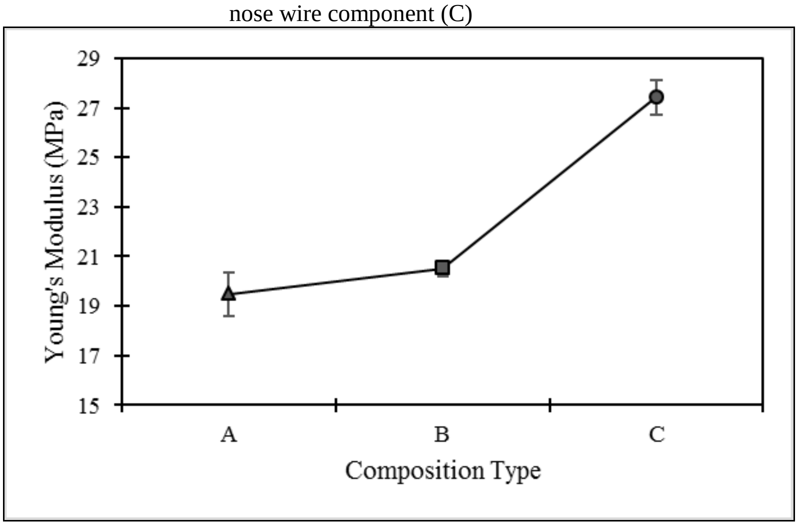
In order to investigate the effect of mechanical properties on different combination components of face mask waste, mechanical testing was performed. The result of tensile strength of component with filter (A), filter and ear loop (B) and filter and nose wire (C) were shown in Figure 1. Clearly, the incorporation of ear loop and nose wire enhanced the tensile strength compared to filter component only. A sharp increase with 46.7% were observed for component B while 34% increase for component C compared to filter mask only. Highest value of tensile strength was shown by component B probably because there is good interaction between polypropylene (from filter) and nylon (from ear loop). Although other researchers Shashidhara et al. (2009) & Battegazzore et al. (2020) report on the incompatibility of polypropylene and nylon this work interestingly shows vice versa. The difference in operating temperature while melting all of the components could play an important role in ensuring a good interaction between those two components. In this work, the components were melted at higher temperature between 100 and 500 °C as hot gun was used to melt the components. Nylon has a higher melting temperature compared to polypropylene (Afshari et al. 2002), thus with higher temperature at short contact time, polypropylene and nylon could mix well together. Component C showed decrement by 8.6% compared to B component. However, components C still project higher value of tensile strength compared to components A. The same observation was reported by Lucchetta et al. (2011) where polypropylene was reinforced with aluminum and showed increment of interface bonding strength. They reported that polymer can mechanically grasp to the metal protrusion and surface thus increased the mechanical strength. Interestingly, component A showed lowest tensile strength compared to the other components. This probably due to the facts that there are no added reinforcing components that could enhance its tensile properties. Reinforcement components especially in recycled material plays an important role in improving the degradation effects of recycling process (Raj et al. 2013).

Figure 1: Tensile strength of filter component (A), filter and ear loop component (B) and filter and nose wire component (C)



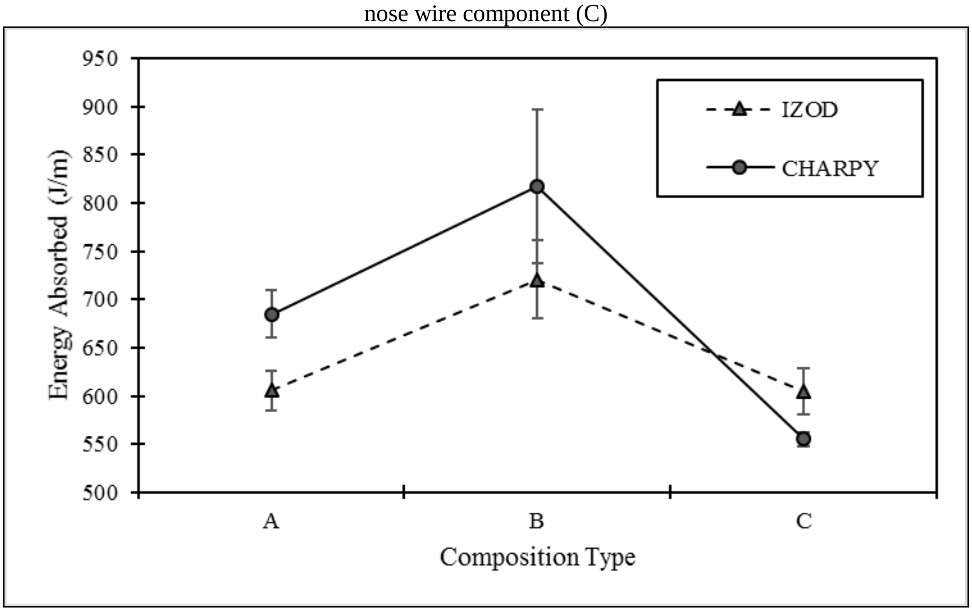
Meanwhile, Young's modulus of component C showed highest value and significant increment from component A by 28.9%. The addition of nose wire enhanced the stiffness of the material. The same observation was also found by Chawla et al. (2001) where metal matrix composite showed stiffer properties compared to the matrix. The incorporation of metal in the matrix results in an increase of hardening effect due to constrains imposed by the presence of metal reinforcement. Under a great constraint, the matrix is unable to undergo stress relaxation thus making the material stiffer. On the other hand, components with A and B showed almost the same values with 19.50 MPa and 20.51 MPa respectively. This probably due to the increase of mobility of the macromolecules without the presence of any metal substance. The same observation was also found by Premalal et al. (2002) where the filler with higher surface area results in less stiff materials due to increase mobility of macromolecules.

Figure 2: Young's Modulus of filter component (A), filter and ear loop component (B) and filter and nose wire component (C)



In this work two types of impact test were done which are IZOD and Charphy impact test to determine the impact strength and toughness of a material (Toshiro et al. 1986). Both of these impact testing applied almost the same principles except for several differences such as shape, and position of the specimen during testing. Results of IZOD and Charphy impact test are expressed in terms of impact energy (J/m) as shown in Figure 3. As depicted in the result, both Charphy and IZOD showed the same trend for all of the components A, B and C. Combination of filter and ear loop component result in highest value of energy absorbed compared to other variation of components. This could probably due to a good interaction between filter and ear loop component during heating and mixing process. Tensile strength value that were discussed earlier also confirmed that component B showed better mechanical properties compared to other composition. The ability to absorbed higher energy prior to fracture shows that component B is a tough material. The same observation was found by Abidin et al. (2019) where composite with better filler-matrix interfacial bonding enhance the impact strength of the composite. However, component C showed lowest absorbed energy for both Charphy and IZOD impact test. The factor that could affect toughness of component C could be due to the presence of the nose wire that lead to poor stress transfer upon impact hence reducing the resistance of the material from cracking.

Figure 3: IZOD and Charphy impact test of filter component (A), filter and ear loop component (B) and filter and nose wire component (C)



The blending of the three components in face mask waste showed different mechanical properties. In short, combination of filter and ear loop components showed better strength and toughness compared to other components. This work reported 488.43 MPa for component B tensile strength. Therefore, component B were utilized in developing a kids chair prototype that can be an alternative in reducing wood and raw polymer usage. However, effect of loading capacity on chair dimension needed to be done for further product development. Figure 4 shows the kids chair prototype that has been successfully assembled.

Figure 4: Kids chair prototype from combination of filter and ear loop component

5. Conclusion

This study demonstrated that it is possible to recycle face mask using simple and practical approach that could be done without the need of using any hazardous chemical solvent or high cost equipment such as extruder and injection molding. This recycling process offers interesting option for utilizing face mask waste to obtain any different product ranging from decoration item to furniture products. The facts that this method only required the use of heat gun without any additional chemicals or compatibilizer, it contribute to green, easy and economical way for recycling process.

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