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Fibre Insert Mould for Injection Moulding

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ABSTRACT

Insert moulding is equivalent to over-moulding. Both processes are achieved by inserting different materials into one another in the same mould to improve product's capability. This process will increase the value of a resulting product because of the additional material price, material insertion process and cycle time. Such moulding process directly increases the overall price of a product but the price is cheaper compared with that of other processes or materials that have the same shape and strength. This insert moulding process requires two moulding materials. The first material is coated by the injected material, which then becomes solid and hardens to cover the second material. In general, the second material is placed permanently in the mould section. When the mould is closed, the injection moulding process is performed. The parts placed in the mould are made of metal, which will attach and reinforce the product. Dumbbell-ready injection is released along with kenaf yarn content in the middle, which is called the fibre insert mould. The fibre insertion technique is conducted by finding the problem of fibre. Then, the small fibre is cut while inside the barrel (either through moulding or compounding). Yarn-shaped fibres are placed on the core of a mould and clamped. Subsequently, a plastic material is injected into the mould. Consequently, the tensile strength of polypropylene (PP) will increase by 55%. A cheaper material (kenaf yarn) can increase the strength of the PP through an easier and cheaper process. The number of processes is reduced from three (before: cutting > compounding > moulding then finished) to two (after: insert and moulding then finished).

Keywords: Injection moulding; kenaf; insert moulding; natural fibre

INTRODUCTION

Plastic is firstly invented and produced by Dr. Montgomerie in 1843. In the same year in Malaysia, scrap rubber was processed through heating and produced via a hand lay-up technique, and the products were mostly applied on kitchen utensils. In 1845, Peluoze successfully synthesised sulphide nitrate from scrap rubber (Wisnial et al. 2002). The first plastic mould is produced in 1862 by Baldwin, and the first product is daguerreotype cases. This mould has been widely used, and the plastic materials are reinforced with a mixture of scrap rubber with various fillers.

Plastic manufacturing technology started in the 1800s. In 1868, John Wesley Hyatt produced billiard balls by injecting celluloid into the mould. In another research, John and Isaiah Hyatt made the first injection moulding machine in 1872, and celluloid is used as the raw material. Shoeab et al. 2018 stated that celluloid is used in various applications such as in sports, fabric, paints and varnishes and as a film material for photographs.

Han et al. (2012) defined manufacturing as the processing of new advanced materials in manufacturing industry, such as fibreglass plastics. In another study, Tan et al. (2001) confirmed that the manufacturing industry began with a hand lay-up technique. Moreover, manufacturing involves the production of products using advanced composite materials (Lee 2017). Razak (2018) defined manufacturing as a process of obtaining new advanced materials and products through several techniques and methods. Hassan et al. (1998) reported that manufacturing is a process that involves composite materials and can be divided into two primary methods, namely, open and closed moulds. Therefore, manufacturing is producing materials or products via several steps and processes.

A: Open Moulds
- Hand Lay-up
- Spray-up
- Vacuum or Pressure Bag
- Filament Winding
- Centrifugal Casting

B: Closed Moulds
- Hot-press Moulding
- Cold-press Moulding

- Injection Moulding! Resin Transfer Moulding
- Pultrusion

DISCUSSION

Recently, different types of processes have been used to obtain the best blending of two substances: polymer and filler from natural sources. One library review has been conducted in connection with the process used to produce this polymer composite. Some of the related literature reviews are listed in Table 1.

TABLE 1. Literature Reviews for Polymer/ Natural Fibre Processing

No.	Journal Info	Polymer/Natural Fibre	Process
1.	Vermaa et al. 2018	HDPE/Kenaf	Mixing -> Compression moulding
2.	Ibraheem et al. 2016	Polyester/ Kenaf	Mixing -> Bulk moulding Compounds -> cutting sample
3.	Sultan 2010	Phenol formaldehyde/ Kenaf	Mixing -> pressing -> cutting
4.	Radzi et al. 2015	Polypropylene (PP)/Kenaf + NaOH	Mixing -> Injection Moulding
5.	Saad 2011	Polypropylene (PP)/Kenaf + MAPP	Compounding -> cutting to pallet -> pressing
6.	Amran et al. 2014	Polypropylene (PP)/Kenaf + MAPP	Compounding -> compression mould
7.	Mustaffa et al. 2018	Polypropylene (PP)/Kenaf + PPMAH	Grinder (powder) > melt mixing > hot-press machine
8.	Alam et al. 2016.	Carbon + Epoxy/ Kenaf	Hand Layout
9.	Rowell R.M. et al. 1999	Polypropylene (PP)/Kenaf + MAPP	Blend (compounding) > Granulated and dried -> injection moulding
10.	Lee et al. 2017	Polypropylene (PP)/Kenaf + MAPP+MH	Blend mixer -> compressed (press machine)
11.	Shamsuri et al. 2017	LDPE/Kenaf core	Mixer machine -> compressed (press machine)
12.	Loh et al. 2016	Polypropylene (PP)/Kenaf + MAPP	Mix -> crush
13.	Chow et al. 1998	Polypropylene (PP)/Kenaf + PE (film)	Compound -> pellet and dried -> injection moulding
14.	Mirbagheri et al. 2007	Polypropylene (PP)/Kenaf + wood	Grinding -> blend (mixer) -> injection moulding
15.	Sarifuddin et al. 2013.	Polyethylene (PE)/Kenaf + Sago starch	Blend mixed -> Compression Moulding
16.	Radzi et al. 2018.	Polypropylene (PP)/Kenaf fillers	Melt-bled -> crushed -> Injection moulding
17.	Razak et al. 2018	Polypropylene (PP)/Kenaf + MAPP	Crusher -> Compounding -> Injection Moulding
18.	Chung et al. 2018	Polylactic Acid (PLA)/Kenaf	Mixed -> Compounding -> Injection Moulding
19.	Sanadi et al. 2008	Polypropylene (PP)/Kenaf + Wood + MAPP	Compounding
20.	Han et al. 2012	Polylactic Acid (PLA)/Kenaf	Melt compounding -> Injection Moulding
21.	Yassin et al. 2016	Polyester/Kenaf	Pultrusion

A new invention is found based on the injection moulding process and an additional process called insert moulding (Grujicic 2014).

The injection moulding process for thermoplastics is concise. This process depends on whether the material used is hygroscopic or non-hygroscopic can determine the difficulty of negligence (Ibrahim et al. 2014). Material or resin is moved into the hopper of the machine from either the dryer or barrel used for charging. Hygroscopic materials should be dried before further processing to prevent moisturisation (Ibrahim et al. 2014). Hopper dryer is used to demoisturise the contaminated material. However, non-hygroscopic materials are not required to be dried for the moulding process.

The material removed from the filling barrel is loaded onto the hopper dryer located on the barrel using the auto loader. After the material or resin is loaded onto the barrel, the material is heated and diluted by heather on the barrel or the friction effect of the barrel when the screw is rotated. After the material is sufficiently liquified, the screw is injected into the mould through the sprue and gate system. Pressure is applied through the gate to fill the cavity, and the product is formed in the mould.

After the mould is filled, the material enters the cooling phase, during which the mould is completely closed until the cooling time is over. The mould should also be cooled down through certain methods. Once the material is cooled, the mould is opened. The product is removed using the ejector system built into the mould and adjusted by the machine. The product is produced according to the mould design used. Coordination is necessary on the parameters to achieve the shape and the required quality.

Insert moulding is a method of inserting the component into the mould before the material is melted and injected into produce a complete product (Jha et al. 2018), such as knives, key metal, batteries and motors. The insert process is appropriate in improving product’s strength and in reducing operational cost and production time (Jha et al. 2018). In addition, insert-type moulding processes are comparable to other moulding methods such as injection moulding and over-moulding. Jha (2018) defined that the injection moulding process consists of single or multiple injecting liquid plastic resins into moulds to product.

In another research, Grujivic (2014) has claimed that over-moulding process is better than injecting moulding processing due to reduction in operation time. By contrast, a study conducted by Jha (2018) proved that the insert mould process is similar to over-moulding because of the presence of separate component assemblies in both moulding systems.

RESULTS

PP and kenaf partnerships (Tholibona et al. 2019, Hassan et al. 2017) are one of the major topics discussed by composite researchers. Therefore, two-material combination-related experiments have been conducted. The discovery of the kenaf entry method into PP (known as fibre insert mould) is achieved in accordance with the following steps (Figure 1).

The studies related to kenaf habituality included in the mould are achieved using the Dakumar injection machine located at the Institut Kemahiran Tinggi Belis Negara (IKTBN), Sepang. Testing is conducted in numerous parameters to obtain the characteristics of kenaf and PP kenaf products. The present study found the parameter for products without failures, such as no sink marks and curved effects. The same parameters are maintained in certain temperature, but parameters for the pressure speed have decreased and increased the value. Five dumbbell samples are collected for sampling purposes. Hence, the produced dumbbell is used for modulus test, whereas the parameters for the injection pressure, pressure strength and barrel temperature are maintained due to the following reasons:

INJECTION SPEED

The injection speed has a major effect on the molecular orientation level of the barrel. Moreover, the injection speed will affect the contraction and development of the resulting product. Strong molecular orientation results from rapid cooling near the wall and towards the product. In general, surface quality and bond strength are high in injection speed (Geminger et al. 2016).

INJECTION PRESSURE

Pressure control is required particularly for the movement of molten materials into the mould. The first part of the plastic injection process is where the majority of the molten substance is injected (through the get) into the moulding cavity. This reality will be the only step in which the material is injected and will subsequently fill the empty space in the mould. Based on a theory in physics, any melted material will freeze according to the composition of the material and the temperature involved when the material is injected. The injection pressure should be increased to prevent the freezing material before the entire moulding cavity is melting (Tan et al. 2001).

PRESSURE STRENGTH

As explained earlier, the injection phase is followed by holding pressure. In the injection phase, over 90% of molten substances are included using high pressure and speed. When the mould cavity is almost full (approximately 90%–95%), lower pressure and speed compared with the initial pressure are used; this process is known as the steady pressure phase (Hakimian et al. 2012).

Machine operators need to determine the change-over/switch-over from the first stage to the second stage in the correct and precise location.

INJECTION TEMPERATURE

Four controlled temperature zones are identified in the injection unit, such as the rear zone, the middle zone, the front zone and the nozzle zone. Each zone is controlled separately. The injection unit is designed to make plastic materials through the four zones and heat such materials gradually as it moves through the heating cylinder. Temperature should be lower in the back zone than in the front zone, and the nozzle zone should be equal or approximately equal to the front zone. However, temperature is adjusted on the basis of the type of material and the shape of the product (Hakimian et al. 2012).

A few effects are observed on product status changes based on each parameter that is synergised but are relatively small compared with the tensile pressure value produced after the machine test.

Testing material (dumbbell) is labelled, and the tensile test is performed. Tensile testing is conducted to measure the ability of a substance to withstand forces that tend to divide it and the extent to which material is stretched before it breaks. The strength of the material represented by the tensile modulus can be determined from the stress–strain diagram.

ASTM (D638) (Testing 2004) reported that a dumbbell (type 1) specimen is required for reinforced composite tests. The detailed dimensions for this specimen are shown in Figure 2 and Table 2. Testing is performed in a standard laboratory environment of 22 °C ± 2 °C under plastic conditions not less than 40 h before testing according to the ASTM D618 procedure. Universal Testing Machine (GOTCH) is used at 10 mm/min speed. Figure 2 shows the Universal Testing Machine (GOTCH) used for PP–Kenaf stress test. The specimens are positioned vertically in the grip of the test machine. The grip is tightened evenly and firmly to avoid any slip with the length of the gauge directly at 50 mm. The precisely tested five results are selected for each PP–Kenaf fibre load in the PP matrix.

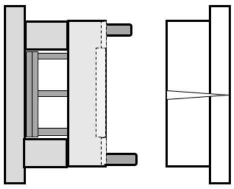
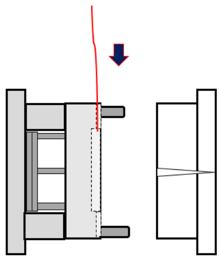
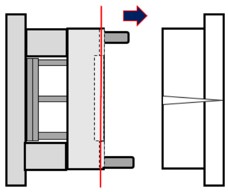
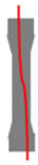
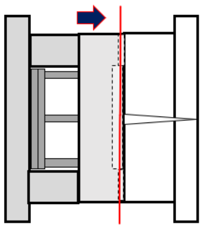
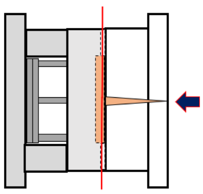
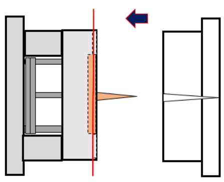
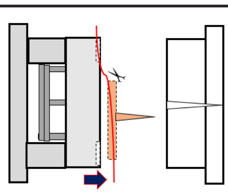
1		The mould injection method for this process is similar to the commonly used reference moulding method generally used in industry or by researchers. The addition of the kenaf fibre admittance formed into yarn becomes a new storage process. For this experiment manual entry method is conducted.
2		The kenaf fibre yarn is inserted into the mould through the moulded holes on the top and bottom of the dumbbell form found in the mould. The yarn will go through the centre of the dumbbell and will only be held at the top and bottom.
3		The mould is closed slowly to make sure the kenaf yarn is in the dumbbell cavity space. Determine yarn fibre not clipped between moulds. 
4		The mould is closed using high pressure. If the Yarn is stuck between two platen moulds, then the machine will automatically open if it is aligned properly. If the mould is opened due to the Yarn, then the Yarn position should be readjusted.
5		Substances are injected into the mould; coordination in terms of injection pressure, holding pressure, time and barrel temperature is considered in the present study. Parameter adjustment is required to maintain any effect on dumbbell strength. All parameters should be recorded to determine the effect of any changes in pressure or time of separation as an example.
6		After cooling, the mould is opened automatically. Dumbbell-ready injection is released along with kenaf yarn content in the middle, which is called the fibre insert mould.
7		Dumbbell is issued through a mould using the linter system in the mould. Kenaf yarn is pulled together with dumbbell; kenaf yarn is cut to the top to remove the dumbbell.

FIGURE 1. Fibre Insert Processing

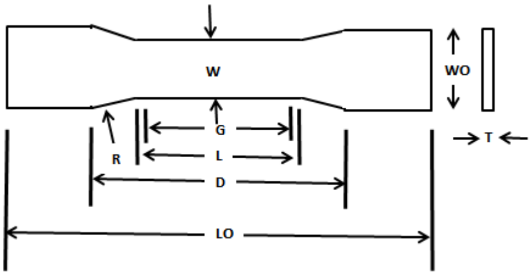


FIGURE 2. Dumbbell size

TABLE 2. Dimension for specimen

Code	Dimension	Value
T	Thickness, 7 mm	1.0±
W	Width of narrow selection	13
L	Length of narrow selection	57
WO	Width overall	19
LO	Length overall	165
G	Gauge Length	50
D	Distance between Grips	115
R	Radius of fillet	76

When the tensile test starts, the specimen extends. The specimen resistance increases and is detected by the load cell. The load value (*F*) is recorded until the specimen fraction occurs. The instrument software provided together with the equipment will calculate the tensile properties, such as tensile strength, strength and elongation during the break. A basic relationship to define the aforementioned attributes is calculated as follows:

$$\text{Tensile strength} = \frac{\text{Pressure}}{\text{Cross section area}}$$

$$\text{The tensile strength} = \frac{\text{Maximum load of the product}}{\text{Cross section area}}$$

$$\text{Tensile strength} = \frac{\text{Load during break}}{\text{Cross section area}}$$

RESULTS AND DISCUSSION

The insert fibre mould test is conducted using different parameters while maintaining the other parameters. For example, the value of the injection speed adjustable and the other parameters is maintained as shown in Table 3.

TABLE 3. Parameter value during testing

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Injection speed	50%	55%	60%	65%	70%
Injection pressure	70%	70%	70%	70%	70%
Holding pressure	50%	50%	50%	50%	50%
Temperature (nozzle)	1800C	1800C	1800C	1800C	1800C

Similarly, with other parameters, Sample one (1) for each parameter represents the smallest percentage.
Based on the information in reference to the table, the value of the tensile stress imposed for the desired sample is shown in Table 4.

TABLE 4. Injection Moulding Results

Sample	Injection Speed	Injection Pressure	Holding Pressure	Barrel Temperature	PP Only
1	71.9	77.3	81.1	72.4	31.0
2	70.5	77.0	83.3	73.0	31.0
3	77.4	77.2	81.7	65.7	31.0
4	79.4	77.7	83.5	77.0	31.0
5	80.3	77.3	83.7	79.0	31.0

Each of the five samples collected for each parameter level is tested. A total of 1000 samples for PP and kenaf and 15 samples for PP were run. The result of tensile strength test is presented in a graph shown in Figure 3.

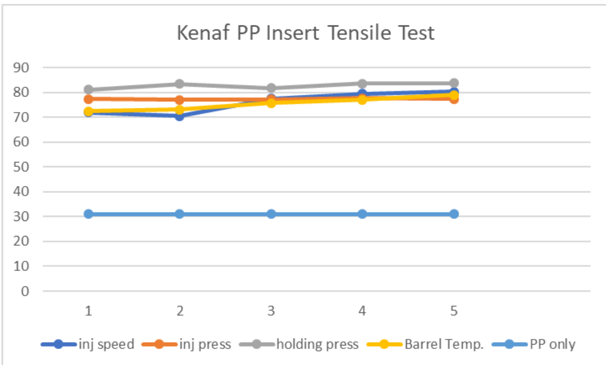


FIGURE 3. Tensile Test Based on Parameters

The parameter change rate does not affect the tensile strength results, which could be due to the size of dumbbell that is ineffective when the parameter changes. Although there are Journal mention that Parameters can affect the results of a product. (Tamri. N. et all. 2020). However, when viewed from another angle, the inserted kenaf/PP obtained amazing results.

CONCLUSION

The insert fibre mould innovation effect will receive huge success because of the resulted kenaf/PP that is produced without any cost in mould modification. PP/kenaf dumbbell is compared with plain PP, and the results for tensile strength are quite remarkable. PP + kenaf has obtained amazing results, where tensile strength is recorded at 70 MPa compared with of plain PP which only logged at 31 MPa. This outcome shows a positive increase of 55%. In the future, the test will be expanded using add-on equipment to produce a product injected using this insert fibre mould method. This equipment can automatically insert kenaf yarn into moulds to obtain optimum yield.

DECLARATION OF COMPETING INTEREST

None.

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