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Melt Flow Index (MFI) as a critical parameter in determining the efficiency of the 6ft blow machine using different polymeric materials

Imoh UR, Okeke OR, Onu CE, Nwangbo TN, Onwe CU, Okereke EE

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Author Affiliation:
Plastic Production Unit, Scientific Equipment Development Institute, Akwuke, Enugu State, Nigeria

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ABSTRACT

This work studied the effect of melt flow index value as a function of the efficiency of a 6ft blow molding machine to be able to accelerate the production of plastic products from different polymeric materials. Virgin polymeric materials (nylon, polycarbonate, cellulose series, acrylic butadiene styrene, polyvinyl chloride, polystyrene) with strong bonding make-up, had MFI values ranging from 3875.84-3805.71 g/3min at full blown plastic product. Other virgin polymeric materials (high density polyethylene, low density polyethylene, polyethylene, linear low-density polyethylene, linear low-density polyethylene) with lower bonding make-up, had MFI values ranging from 3506.49-3412.98 g/min at full blown product. The MFI of the pure virgin at full polymeric product ranged from 3875.84-3412.98g/3min while the MFI values of the virgin mixed with crushed materials ranged from 3917.92-3483.12g/3min. For the 6ft blown molding machine, polymeric materials with weak bonding make-up are more amenable to heat and therefore has lower MFI values, an indication that more plastic products would be produced within a given period of time.

Keywords: Polymeric materials, 6 ft blow molding machine, melt flow index, process and parameters.

1. INTRODUCTION

Blow molding is one of the fastest growing polymer processes when compared with other techniques in the plastic industry. The products find its use in different areas of life such as agriculture, domestic applications, industrial equipment, medical devices, automobiles etc. Resins like polyethylene (PE), polycarbonate and elastomers can be blow molded. HDPE and LLDPE have been found by Bin, (2018) to have the largest consumption in blow molding industries. Melt Flow Index (MFI) as a critical parameter in determining the efficiency of the 6ft blow machine in producing plastic products from different polymeric materials.

It has been a very useful tool to deal with the intricacies surrounding different properties of the various polymeric products. Works has been done in knowing the mechanisms and properties of HDPE and other polymer materials. Guobin et al., (2004) has studied the mechanism of melt flow index using LLDPE in blow moulding machine. Archer et al., (2002) has studied the melt flow index characteristics of metal care-catalyzed LLDPE for rotational molding. Doroudiani et al., (1996) varied crystallization and morphology by controlling the cooling rate and predicted that Polybutylene (PB), Poly Propylene (PP) and Poly Ethylene Terephthalate (PET) has a higher crystalianity at a lower cooling rate.

In most plastic industries, production is given a certain time frame and the quality of such plastic products is also on serious consideration. Since Melt Flow Index (MFI) determination has been paramount in terms of checking how fast certain polymeric materials melt before a plastic product production process is completed. Therefore, there is a serious need for this work to X-ray the ease at which these machines are used to determine this index and the effects of such values in the time saving of a product. This work on the melt flow index calculation using the principles of the blow molding machine used in the plastic workshop Section in Scientific Equipment and development Institute Enugu (SEDI-E) was therefore undertaken in order to determine its effect in accelerating the production of plastic products in a timebound manner

2. MATERIAL AND METHODS

The polymeric samples (virgin and crushed) required in the production of 10 litre gallon were nylon, Poly Carbonate (PC), cellulose series, Poly Viny Chloride (PVC), Acrylic Butadiene Styrene (ABS), Poly Propyrene (PP), Poly Styrene (PS), High Density Poly Ethylene (HDPE), low density poly ethylene (LDPE) and Linear Low Density Poly Ethylene (LLDPE). All the materials were sourced from the plastic production workshop, Scientific Equipment Development Institute (SEDI), Enugu.

Description of the 6 ^{ft} blow molding machine

The 6^{ft} Blow machine operates in the following conditions:

The Hopper is always filled with 25 kg of the desired polymer materials.

The length of the Barrel is 6^{ft}

It works with a building pressure of 0.5Mpa

It takes 60secs for the pressure to gauge up in the pin 0.5Mpa

The height of the die head is 18 inches

The cone diameter is 8 inches

The length of the parison that fills the gap from the base of the cone to the base of the mold is 15 inches

It takes 1 min 17 secs to cover this length

The die head temperature is at around 190^{o}C

The barrel temperature (melting point of the plastic)

The blow molding machine operation process

Turn the main power Switch of blow molding machine and simple screw extruder.

Power the green power button on the extruder control panel to start the extruder.

Set the temperature of each part of the extruder barrel on the extruder control panel

Set the temperature of each part of the die head on the control panel of the blow molding machine

The material is added into the hopper

Press the green start button on the extruder control panel to start the screw from the panel to set the screw speed.

The material is then conveyed by the spiral screw down to the die head where the parison cutter cuts and send to the mold.

Press the blow Pin button to blow the material into the required mold and after sometime the product is ejected out from the mold as a plastic produced product.

Calculation of the melt flow index of the parison

The mass of these parison (hot molten pre-melt) from the mold for different blow machine dimensions has been taken and recorded for different polymer materials either crushed (recycled) or virgin.

The melt flow index (MFI) was calculated as shown below;

Mass of the parison for crushed material at a filled length = 1.5kg = 1500g

Time to fill the length (from the base of the die head to the base of the mold cavity) = 1 min: 17 secs = 77 secs
The running production time for a 10-litre gallon = 3mins = 180 seconds
Hence, deploying the calculating formula,

$$MFI = \frac{m}{t} X \frac{180}{1}$$

$$MFI\ of\ crushed\ material = \frac{1500}{77} X \frac{180}{1} = \frac{270,000}{77}$$

MFI=3506.5g/3min
The MFI value for all the polymeric materials were computed in the same way as can be shown in the tables presented below.

3. RESULT AND DISCUSSION

Table 1 shows that virgin materials such as nylon, polycarbonates, cellulose Series, polyvinyl chloride, acrylic butadiene, polyethylene, polystyrene, high density poly ethylene, low density poly ethylene and linear low density poly ethylene with extruded masses of 1658g, 1650g, 1645g, 1640g, 1638g, 1630g, 1628g, 1500g, 1480g and 1630g respectively had MFI values of 3875.84, 3857.14, 3845.45, 3833.77, 3829.10, 3810.39, 3805.49, 3506.49, 3459.74, 3412.98 g/3min. From Table 1 it can be observed that a decrease in the mass of the extruded parison indicates a decrease in Melt Flow Index (MFI).

Virgin LDPE was observed to have the least mass of extruded parison invariably at the least MFI of all the investigated polymeric materials. Weak bonding make-up of virgin LDPE which made it more amenable to heat, causing a quicker melt formation in the barrel could have been responsible for it's very low Melt Flow Index (MFI). Faster cycle of production of a plastic product (plastic materials) could be achieved under such conditions.

Table 1 Mean melt flow index values for polymeric materials

S/N	Polymeric Materials	Mass Extruded In (g)	AT^{o}C	Pressure Guage (Mpa)	Net weight (N)	Times of operation (S)	Molecular weight (g/mol)	MFI (g/3min)
1	Nylon Virgin	1658.00000	73.00	8.00	16580.0000	3.00	113.00	3875.8442
2	Polycarbonate	1650.00000	75.00	7.00	16500.0000	3.00	224.00	3857.1429
3	Cellulose series	1645.00000	76.00	7.50	16450.0000	3.00	104.00	3845.4545
4	PVC	1640.00000	78.00	7.20	16400.0000	3.00	40.00	3833.7662
5	ABS	1638.00000	80.00	6.90	16380.0000	3.00	53.00	3829.0909
6	PP	1630.00000	81.00	6.40	16300.0000	3.00	28.00	3810.3896
7	PS	1628.00000	82.00	6.00	16280.0000	3.00	104.00	3805.7143
8	Virgin HDPE	1500.00000	83.00	5.00	15000.0000	3.00	28.00	3506.4935
9	Virgin LDPE	1480.00000	85.00	4.90	14800.0000	3.00	28.00	3459.7403
10	Virgin LLDPE	1460.00000	86.00	4.20	14600.0000	3.00	28.00	3412.9870

From Table 2, it was observed that the MFI values for the parison from the virgin mixed crushed nylon, virgin mixed crushed poly carbonate, virgin mixed crushed cellulose series, virgin mixed crushed poly vinyl chloride, virgin mixed crushed acrylic butadiene styrene, virgin mixed crushed poly propylene, virgin mixed crushed poly styrene, virgin mixed crushed high density poly ethylene, virgin mixed crushed low density poly ethylene and virgin mixed linear low density poly ethylene samples were 3917.92, 3903.90, 3857.14, 3858.15, 3847.79, 3826.75, 3819.74, 3623.38, 3595.32 and 3483.12 g/3min respectively.

The mean MFI values of the parison of the polymeric materials decreased in the following order; virgin mixed with crushed nylon > virgin mixed with crushed poly carbonate > virgin mixed with crushed poly vinyl chloride > virgin mixed with crushed cellulose series > virgin mixed with crushed arcrylic butadiene stryrene > virgin mixed with crushed poly propylene > virgin mixed with crushed poly styrene > virgin mixed with crushed high density poly ethylene > virgin mixed with crushed low density poly ethylene > virgin mixed with crushed linear low density poly ethylene (Figure 2, 3).

Table 2 Mean melt flow index values for the Virgin + crushed polymeric materials

S/N	Polymeric In	Mass Extruded In (g)	AT°C	Pressure Guage (Mpa)	Net weight (N)	Times of operation (S)	Molecular weight (g/mol)	MFI (g/3min)
1	Virgin nylon + Crushed Nylon	1676.00000	71.00	8.40	16760.00	3.00	113.00	3917.9221
2	Virgin polycarbonate + Crushed polycarbonate	1670.00000	74.00	8.20	16700.00	3.00	224.00	3903.8961
3	Cellulose series virgin + Crushed cellulose series	1650.00000	76.00	8.00	16500.00	3.00	104.00	3857.1429
4	Virgin PVC + Crushed PVC	1650.00000	77.00	7.70	16500.00	3.00	40.00	3857.1429
5	Virgin ABS + Crushed ABS	1646.00000	78.00	7.20	16460.00	3.00	53.00	3847.7922
6	Virgin PP + Crushed PP	1637.00000	80.00	6.80	16370.00	3.00	28.00	3826.7532
7	Virgin PS + Crushed PS	1634.00000	82.00	6.30	16340.00	3.00	104.00	3819.7403
8	Virgin HDPE + Crushed HDPE	1550.00000	84.00	6.10	15500.00	3.00	28.00	3623.3766
9	Virgin LDPE + Crushed HDPE	1538.00000	86.00	5.10	15380.00	3.00	28.00	3595.3247
10	Virgin LLDP + Crushed HDPE	1490.00000	88.00	4.80	14900.00	3.00	28.00	3483.1169

Table 3 Mean mass of extruded pre-melt and melt flow index values for virgin and a combination of crushed and virgin polymeric materials

Samples	Mass extruded for virgin (g)	Mass extruded for virgin + Crushed (g)	MFI pure virgin (g/3min)	MFI virgin + Crushed (g/3min)
Nylon Virgin	1658.00000	1676.00000	3875.8442	3917.9221
Polycarbonate	1650.00000	1670.00000	3857.1429	3903.8961
Cellulose series	1645.00000	1650.00000	3845.4545	3857.1429
PVC	1640.00000	1650.00000	3833.7662	3858.1529
Acrylic ABS	1638.00000	1646.00000	3829.0909	3847.7922
PP	1630.00000	1637.00000	3810.3896	3826.7532
Ps	1628.00000	1634.00000	3805.7143	3819.7403
Virgin HDPE	1500.00000	1550.00000	3506.4935	3623.3766
Virgin LDPE	1480.00000	1538.00000	3459.7403	3595.3247
Virgin LLDPE	1460.00000	1490.00000	3412.9870	3483.1169

The implication of this finding is that the 6 ^{ft} blow molding machine would achieve faster production of 10 litre jerricans or any blow plastic products with the polymeric materials with low MFI values than the polymeric materials with high MFI values. The varying bond make –up and tacticty of these polymeric materials could have affected the amenability of the materials to heat and consequently, leading to their varying MFI values. Bin, (2018), corroborated the findings of this research when he stated that polymeric materials within isotatic bond arrangement have lower MFI values than those that are either syndiotactic or atactic.

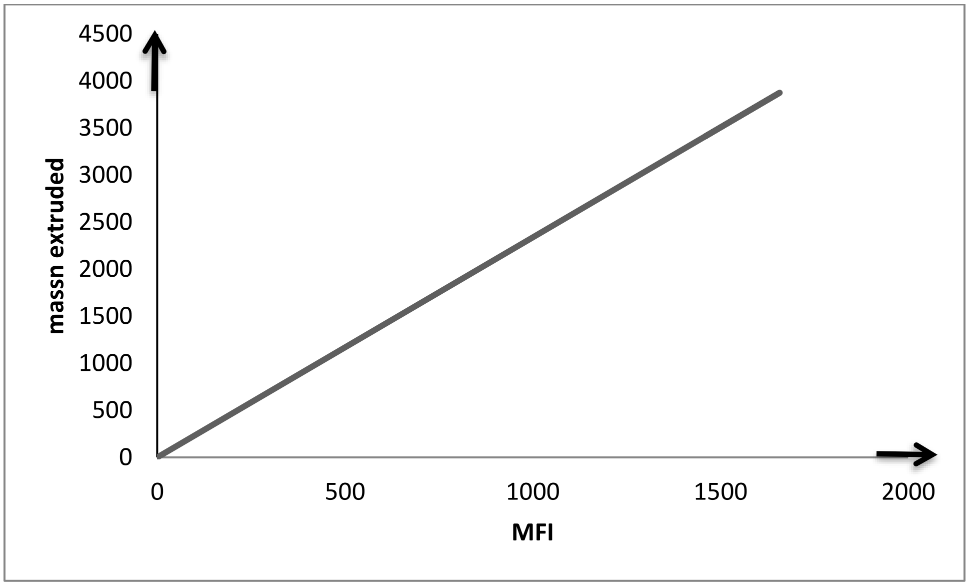

Figure 1 The graph of the mass of virgin material against MFI

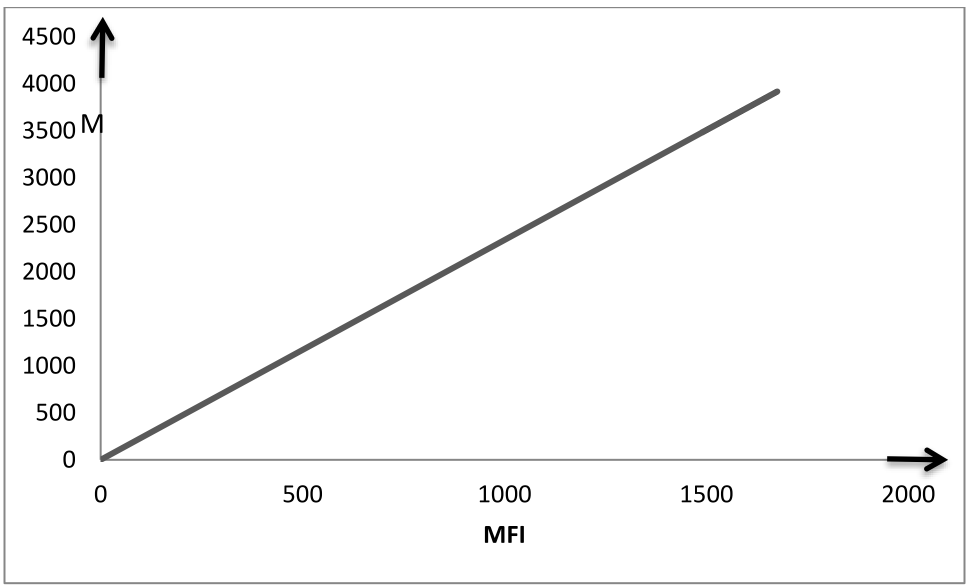

Figure 2 Graph of mass virgin + crushed vs MFI

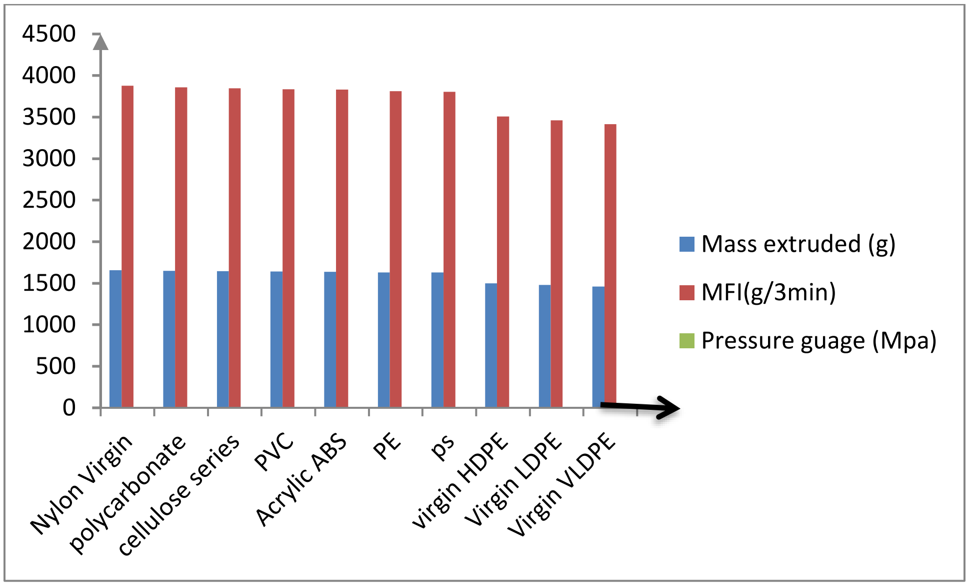

Figure 3 Chart Showing the Relationship between the Masses extruded With MFI Values for Various Materials

4. CONCLUSION

Decrease in MFI values of polymeric materials indicates an unhindered flow of polymer melt through the barrel into the die to complete the production process. Increased MFI values indicate a decrease in melt formation in the barrel as a result of increased bonding system of the polymeric material. For such polymeric material with increased MFI values, longer time will be required to complete the production process. Therefore, for the 6ft blow molding machine to work optimally to meet any job demand on a plastic product, the polymeric material to be used must be of low MFI value.

Ethical issues

Not applicable.

Informed consent

Not applicable.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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