Optimization of mixture strength ratio of LDPE and HDPE in plastic granules and incorporating a novel agglomerator to process the mixture

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Abstract - *Plastic recycling industry is one of the most necessary industries in today's age. The amount of plastic being used per day in India is 3.5 million tonnes. Plastic granules are one of the recycled products from this industry. Different types of plastics are segregated and processed based upon their density. The types most widely used are HDPE, LDPE and PP. Each type has their own properties. A mixture between HDPE and LDPE is sought so as to achieve optimal strength ratio and better material flow index. Special machinery is required to manufacture each plastic's type of granules, such as crusher, agglomerator, extruder. One such industry is taken as the subject of the study and a novel agglomerator has been designed and manufactured according to the industry's requirements. This paper presents optimization of mixture strength ratio between low density and high-density plastics as well as incorporating a novel agglomerator which can process both types so as to increase the overall efficiency of the process.*

Key Words: Agglomerator, Plastic recycling, granules, HDPE, LDPE

1.INTRODUCTION

This paper is subjected towards improving the overall efficiency of a plastic granule factory which recycles different types of plastics. Plastic granule manufacturing is a difficult process when you consider the types of plastics to be recycled. There are High density polypropylene (HDPE), low density polypropylene (LDPE) and polyethylene. The stages of plastic granule making begin from the segregation of types of plastics based of their density and then they are crushed in the crusher. The scraps are then sent to the agglomerator, which acts as a preheater and also helps to remove the moisture content from the plastics. It is an important process which is followed by extrusion, where the scraps are put into the extruder. The scraps are melted and extruded through a filter and then cut into granules by a palette cutter. Granules of high- and low-density polyethylene are manufactured and stored separately. This is done because the properties of both types differ a lot but some of them are important in making plastic products from the granules such as pipes, wire insulations, etc. This paper targets two aspects of the plastic granule industry-1) designing and manufacturing a novel agglomerator which can process plastic of all densities at a larger volume, but in a cost-effective way 2) obtaining an optimum mixture ratio of HDPE and LDPE which results in enhanced tensile strength and melt flow index.

1.1 Agglomerator

The designing of the major parts of the agglomerator is to be done, which is due considering the strength of the material used to manufacture it and also factor of safety.

1.2 Optimal mixture of HDPE and LDPE

The optimum mixture ratio of plastic is to be obtained by mixing HDPE and LDPE in various ratios, in order to obtain only the desirable properties of each type and then performing various tests on them to obtain the highest tensile strength and melt flow index of each mixture.

2. DESIGNING OF AGGLOMERATOR

Agglomerator is a device used in plastic recycling process which is used to dehumidify the plastic raw material coming from washing unit and according to the requirements of injection Moulding machine plastic scrap is reduced in size.

Agglomerator is composed of Electric motor, Gear reduction unit, Transmission shaft, Impellor blades, Tank, Belt pulley system, Bearing and Shaft. The components designed revolve around the factors like torque, speed, strength, shaft loads and transmission units.

Steps-

- Selection of drum(tank) dimensions
- Impellor blade design
- Power requirement and motor selection
- Power transmission

2.1 Selection of tank dimensions

The tank designed is to allow a capacity of 100kgs of plastics to be processed per cycle. The material used should be strong enough to withstand the bombarding of plastic granules rotating at around 800 to 1000 rpm. Let,

DT	=	Diameter of the tank
H	=	Height of the tank
Da	=	Impellor diameter
V	=	Volume of the tank
M	=	Mass of the raw material = 100kg
δ	=	Density of plastic = 920 kg/m^3

We know t V=M/ δ

=0.108 m3

Therefore, volume of the plastic = 108 m3

Assuming, DT=1/2 H

$V=\pi/4.DT^2 .H$

H=0.82m

After due considerations, tank dimensions are:

H = 1.25m

D = 0.8m

2.2 Impellor Blade design-

Impellor blade design consists of 3 sets of blades. Considering the mass of plastic to be processed and height of the tank 3 sets of blades are to be designed.

Parameters considered:

- Blade thickness
- Speed
- Diameter

Let,

d be the diameter of the impellor and D be the diameter of the drum

Therefore,

d = 0.9D

d = 0.9m

Width of the blades= w = d/10 = 0.9m

Thickness of the blades = 0.009m ~ 0.01m

Blade material= Steel alloy 12

Number of blades= n = 3

Assuming rotor speed of 800 rpm, stress in blades given by -

Let, σ = Shear force on the blades

F = Shear force on the blades

A = Blade area

Where F = Mixing force / Shear force

= 100 x 9.81

= 981 N with a speed of 800 rpm

Therefore,

$$\sigma = \frac{981\ x\ (10\ x\ 450)\ x\ \frac{800}{60}}{} = 588 \text{ kNm2}$$

Shear force on the blade = 588 kNm2

Therefore, the blades are considered safe.

2.3 Power Requirement and Motor Selection

The 3 Phase DC Electric Motor used for power. It uses a standard unit called power number to determine power required.

Total power required = Power required by 1st impellor + Power required by 2nd impellor + Power required by 3rd impellor

Power required to drive 1st impellor blade set –

$P1 = Np \times \rho \times \omega^3 \times d^5$

Where, Np is power number obtained against Reynolds number in graph

Np = 1.9 [5]

$P1 = Np \times \rho \times \omega^3 \times d^5$

=5530.2 watts

Similarly, P2 & P3 will also be 5530.2 watts respectively.

Total power required,

P = P1 + P2 + P3 + Losses (10%)

= 18249.6

$\sim 18250\ watts$

Which is equal to 18250/746=24.46 hp

We can use motor of 25 to 30 HP for safe operation running at 1440 rpm.

2.3 Power Transmission

A belt and pulley system is used with a V belt due to its anti-slip feature, high power transmission efficiency and easy availability.

Speed Ratio = N2/ N1 =D1/D2

800/1440=15/D2

Therefore D2= 27 cm (Agglomerator pulley)

Centre distance = 2(D1+D2) = 57cm and

belt length = L = 2C + $\frac{\pi}{2}(D_1+D_2) + \frac{D1+D2}{4C}$

L = 1.8 m

Belt contact angle = $\rho = \frac{D2-D1}{2C}$ = 6.03

Belt tension = $\frac{T1-mv2}{T2-mv2} = \varepsilon f a$

T1 = 415N

T2 = 69N

For reduction of shippage, 3 belts of 2.5cm width made up of synthetic rubber are used.

Power of motor used = 30 HP

Hence, the Transmission system is designed.

2.5 Calculated Results

Volume of drum = 108 m^3

Height of Drum =1.2 m

Diameter of Drum = 0.8 m

Width of Blade = 0.9 m

Thickness of Blade = 0.01 m

Blade impeller Diameter = 0.72 m

Ultimate Tensile Strength of Blade material = 588 kN/m^2

Power Required for 3 sets of Blade Impeller = 25 HP

C-C Distance Between Two Pulley is 0.57 m

Length of V Belt is 1.88 m

Belt Tension T1=415N, T2=69N

Hence the design of agglomerator is completed.

3.0 Optimum Mixture Ratio for LDPE and HDPE

High density polyethylene and Low-density polyethylene are two main types of polyethylene identification of these types of plastic is done by simple testing method, where plastic raw material is poured in container filled with water and due to the density difference, low density plastic floats on water and high-density polyethylene settle down in the container. These plastics are separately processed because of their following properties.

- LDPE has very less tensile strength
- LDPE properties change after 20° C
- HDPE is rigid and gets brittle after recycling, therefore difficult to machine
- HDPE has very low young's modulus

To increase overall tensile strength, young's modulus, impact strength and to maintain melt flow index LDPE and HDPE is used together to produce granules of improved properties. Different percentages of LDPE and HDPE are to be mixed and optimum ratio is to be determined.

The requirement for most applications such as pipes manufacturing, wire insulations, etc. is that the granules should have maximum melt flow index 0.8 gm/min. So, after producing granules of various compositions, melt flow index of each composition are checked on MFI machine. Followings are the results after conducting melt flow index test on MFI machine for various composition of HDPE and LDPE mixtures.

MFI for each composition of LDPE and HDPE respectively		
1.	90-10	0.381 gm/min
2	80-20	0.563 gm/min
3	70-30	0.767 gm/min
4	60-40	0.987 gm/min
5	40-60	1.002 gm/min
6.	20-80	1.531 gm/min

Table 1. MFI for LDPE-HDPE compositions

Granules with Melt Flow Index below 0.8 gm/min of various composition of LDPE and HDPE are tested for tensile strength on polymer UTM, in order to obtain the mixture with maximum tensile strength.

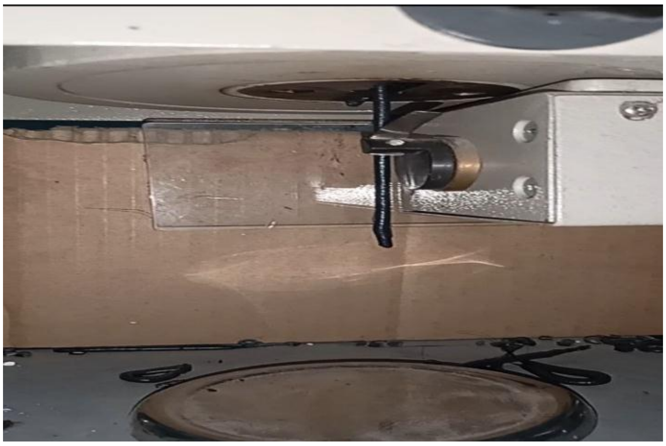
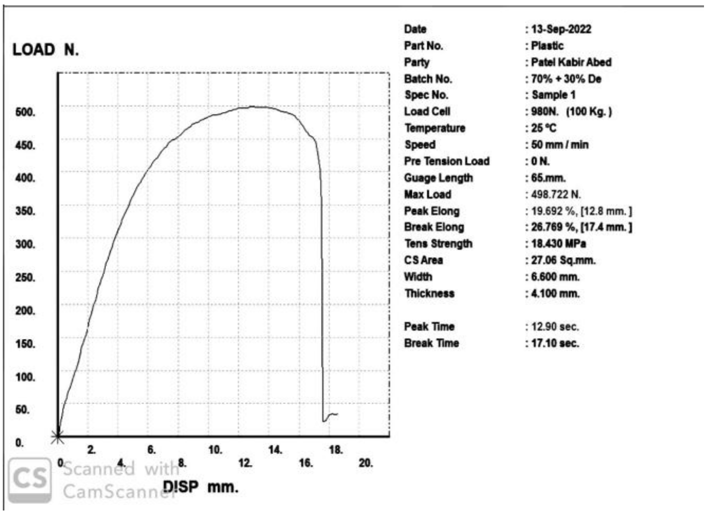


Fig 1 Strands of various granules composition produced in MFI machine.

Granules of various mixture compositions are tested in MFI machine for checking the melt flow index and strands produced by test are measured in terms of gm/min in density tester.

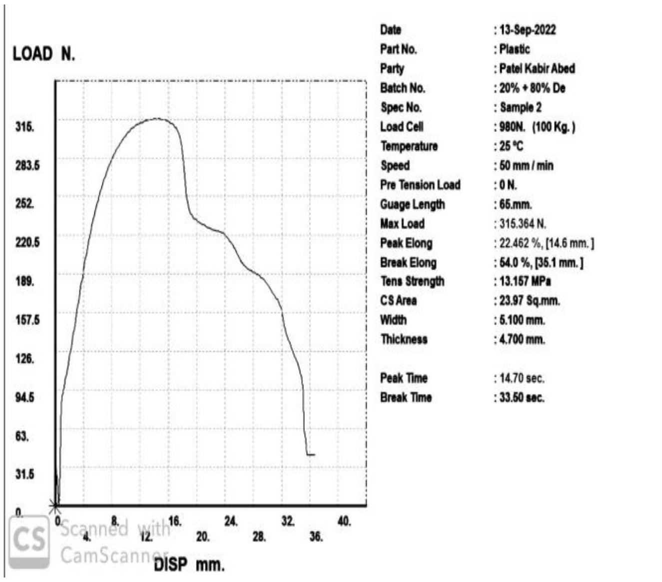
Fig 2 Tensile strength of strands of various granules composition of LDPE and HDPE.

Tensile strength and displacement of strands of various composition of granules is measured and plotted on a graph with applied load on Y axis and Displacement in mm on X axis. It will help determine various strengths of the mixtures, such as yield strength, ultimate tensile strength and Young's modulus.



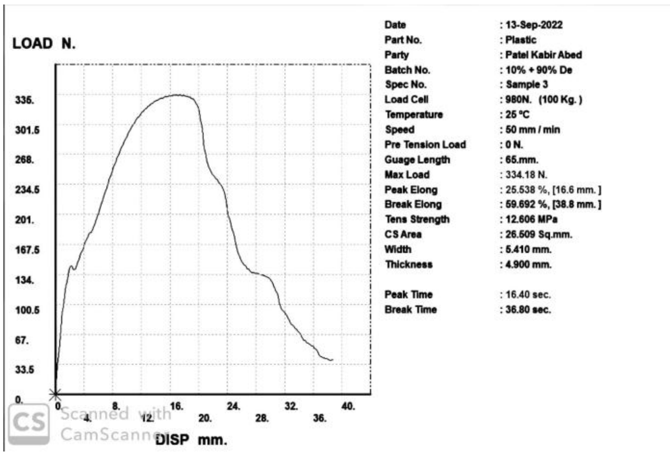
Graph 1 Tensile strength test results of 70-30%of LDPE and HDPE

In tensile strength test of granules composition 70-30% of LDPE and HDPE the tensile strength is 18.430 MPa and the Melt flow index is 0.706 gm/min.



Graph 2 Tensile strength test results of 80-20% of LDPE and HDPE

In tensile strength test of granules composition 80-20% of LDPE and HDPE the tensile strength is 13.157MPa and the Melt flow index is 0.563 gm/min.



Graph 3 Tensile strength test results of 90-10%of LDPE and HDPE

In tensile strength test of granules composition 90-10% of LDPE and HDPE the tensile strength is 12.606 MPa and the Melt flow index is 0.381gm/min.

From the test results it is observed that with increase in percentage of HDPE in LDPE the melt flow index and the tensile strength also increases.

4. Conclusion

This study demonstrates information of agglomerator mixer and its components. Studied and implemented is the design procedure for agglomerator and parameter like tank dimension, power calculation, power transmission and impellor blade design are calculated. A working model of said agglomerator is in the making.

Also, from this study it is observed that increase in proportion of HDPE in LDPE the melt flow index and the tensile strength also increases and flexibility decreases. Hence the application of plastic granules like garden pipes and electric wire insulation jacket where flexibility more important the granules should be produced with LDPE with certain amount of HDPE to improve the tensile strength as well.

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