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The Optimum Powder Loading of Different Binder Ratio Between HDPE and RWL as Binder in Metal Injection Molding

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Abstract

The binder ratio, which refers to the proportion of binder to metal powder in the feedstock mixture, affects the flowability and formability of the material during molding. Adjusting the binder ratio can control the viscosity and rheological behavior of the feedstock, enabling it to flow properly into the mold cavities and achieve the desired shape. This study is focused on different binder ratios of high-density polyethylene (HDPE) and restaurant waste lipids (RWL) in order to find the optimum powder loading of aluminum powder size of 25um. The amount of metal powder combined with a binder system to create a feedstock for the MIM process is referred to as the powder loading. The ideal powder loading range that delivers the best balance of strength and toughness is determined by evaluating mechanical qualities, including tensile strength, hardness, and impact resistance. This experiment is carried out by measuring the weight of powder loading and the binder component before it is mixing process. Once the feedstock is done in the mixing process, the come out with a dough shape and it goes to crusher process to make it look like a small pallet. Density test is done using mettler tolendo device to measure the homogeneity for each of the feedstock that has been made. From the result obtain from the test we can find the binder formular of 50%HDPE 50% RWL with 88% of aluminum has the highest optimum powder loading among all of the binder formular.

1. Introduction

Metal injection molding is a manufacturing process with a capability of producing complex geometry and intricate parts from mixing of metals, ceramic or cermet powder with combination of polymers, wax and surfactant with a few shot as compare to other fabrication process. Due to its versatility, near net shape and less materials waste, it's become attraction to most researchers in exploiting it into new dimensions whether in terms of its binder, powder characteristic, injection molding conditions, debinding and sintering. [1]

The pelletized mixture of powder and binder used in injection molding is termed the feedstock. Five factors determine the attributes of the feedstock powder characteristics, binder composition, powder: binder ratio, mixing method, and pelletization technique. Ideally, the feedstock design adequately considers the ease of molding and the need to attain control over final dimensions. To achieve this balance, the feedstock often uses low molecular weight polymer to reduce viscosity and to ease molding.

The problem statement of this project is impact of different ratio on the aluminium powder-binder system, as well as to develop a predictive model that can be used to optimise the binder system and aluminium powder loading for the MIM. Aluminium also is a critical material in injection molding because it contains a few qualities that make it ideal for use the manufacturing process

Next in molding process, the feedstock is fed into injection molding machine where is heated and injected into a mold cavity under high pressure. After the Injection Molding, the molded part will move to the next step called Debinding or binder removal process. Binder removal can be accomplished by multiple methods, the most popular being solvent extraction. In sintering process, the debind parts are place on ceramic setters which loaded into a high temperature, atmosphere-controlled sintering furnace. Once the binders are evaporated, the metal part is heated to a high temperature where the void space between the particles is eliminated as the particles fuse together.

One of the main goals of this research is to find homogeneity of aluminium powder using HDPE and RWL as binder. We also find the optimum powder loading using different binder ratio of HDPE and RWL

2. Experiment Methods

There are several experiment must be conducted to obtain the data experiment. The experiment are measurement are measuring the powder loading, mixing process, crusher process, measurement density of feedstock

2.1 Metal powder and binder preparation

For this experiment metal powder has been used is aluminium with 25um in size. First process is measuring the weight of powder loading and binder component using a few type of device and equipment. The equipment used are beaker, spoon while the device is Mattler Toledo MS-TS Analytical Balance.

2.2 Mixing parameter

The measurement of weight of powder loading and binder components are important to know the quality weight use of both powder loading and binder component to form a feedstock. We use brabender sample weight calculation to find sample weight since brabender machine can only do 50g per cycle.

$M=55\times(0.96+2.7)\times0.2= 40.26$ g

80% aluminium powder

0.8 x 40.26 = 32.208g (weight for aluminium powder)

40.26 – 32.208 = 8.052 (weight)

Table 1 *Mixing parameter for aluminium feedstock*

	Weight (g)		
Binder Component	Binder Formulation		
	60/40(%)	50/50(%)	40/60(%)
Restaurant waste lipids	3.221	4.026	4.83
High-Density Polyethylene	4.83	4.026	3.221
Total weight (g)	40.26	40.26	40.26

2.3 Mixing Process

Insert HDPE at 150°C

↓

Insert the aluminum powder at 150°C after 10 minutes

↓

Insert the Restaurant Waste Lipids 150°C after 5 minutes

↓

After 25 minutes, complete mixing process

The mixing process procedure where the Plastograph Brabender need to set the temperature to archive 150°C and the rotational A speed at 30 rpm. After the temperature and rotational, speed are archived, the HDPE insert into the mixing machine. After 10 minutes or the HDPE are completely melts, insert the metal powder loading into it to mix homogeneous of metal powder loading with polypropylene. Make sure the metal powder are completely homogeneous with the HDPE. After 20 minutes, insert restaurant waste lipids into it. Lastly, hold time until 25 minutes to complete the mixing process and form a feedstock. Table 1 show the mixing parameter for aluminium feedstock.

Fig. 1 *After mixing product*

2.4 Crusher Process

After mixing process the feedstock are not in consistent shape because during the mixing process the metal powder and the binder component are completely melt and not in any shape form. So in this part, crusher process are needed to reshape the feedstock using Granulator Crusher machine at Polymer Laboratory. Figure 2 show the Granulator Crusher Machine used to crushed the feedstock.

Fig. 2 *After crusher process*

2.5 Density Measurement

The density are important to know the mass of object are compact and to measure the homogeneity of feedstock. To measure the density of feedstock, using a Mettler Toledo Density device at Ceramic Laboratory to get the value for every sample was taken. In this experiment, sample will be taken to measure the weight in air, weight in liquid and density. Figure below show the Mettler Toledo Density device.

Fig. 3 *Density testing machine*

3. Results and Discussion

From the data table above, it can analyse that the total weight used for this experiment are not more than 50g per cycle where it contain 40.26 g of metal powder loading and other 8.052 g are HDPE and RWL. The binder formulation are used to varying the weight of High-Density Polyethylene and restaurant waste lipids. The binder formulation is used to varying the weight of High-Density Polyethylene with 60/40 (%), 50/50 (%) and 40/60 (%) means that the High-Density Polyethylene are 60% and the restaurant waste lipids 40%.

3.1 Homogeneity Analysis

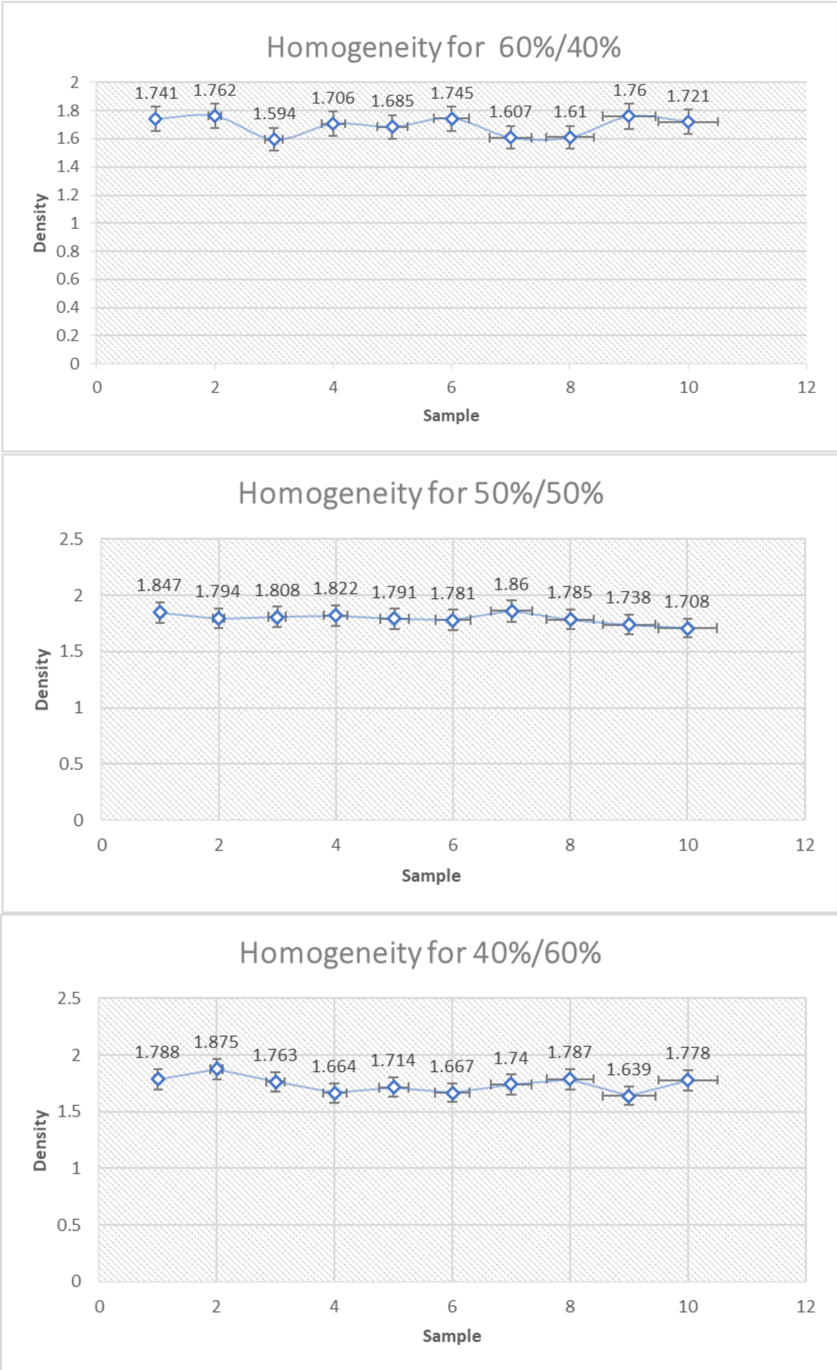

Fig. 4 *Graph of Homogeneity for 10 sample of 86% aluminium powder*

Figure 4 illustrates the homogeneity feedstock density of HDPE 50% - RWL 50%, which is measured at 86 percent. The selection of 86% as the testing point for the homogeneous feedstock density of HDPE 50% - RWL 50%, which is calculated at 86 percent, is shown in graph. Since 86 to 88 percent reflects the best powder loading ratio for this specific combination, it was chosen as the homogeneity testing threshold. This percentage falls within the density ranges of 1.708 and 1.860 g/cm3.

3.2 Optimum powder loading

The density and its optimum powder loading are related in the context of aluminium powder processing and formulation. The optimum powder loading refers to the ideal amount of powder that should be present in a system to achieve the desired properties or performance.

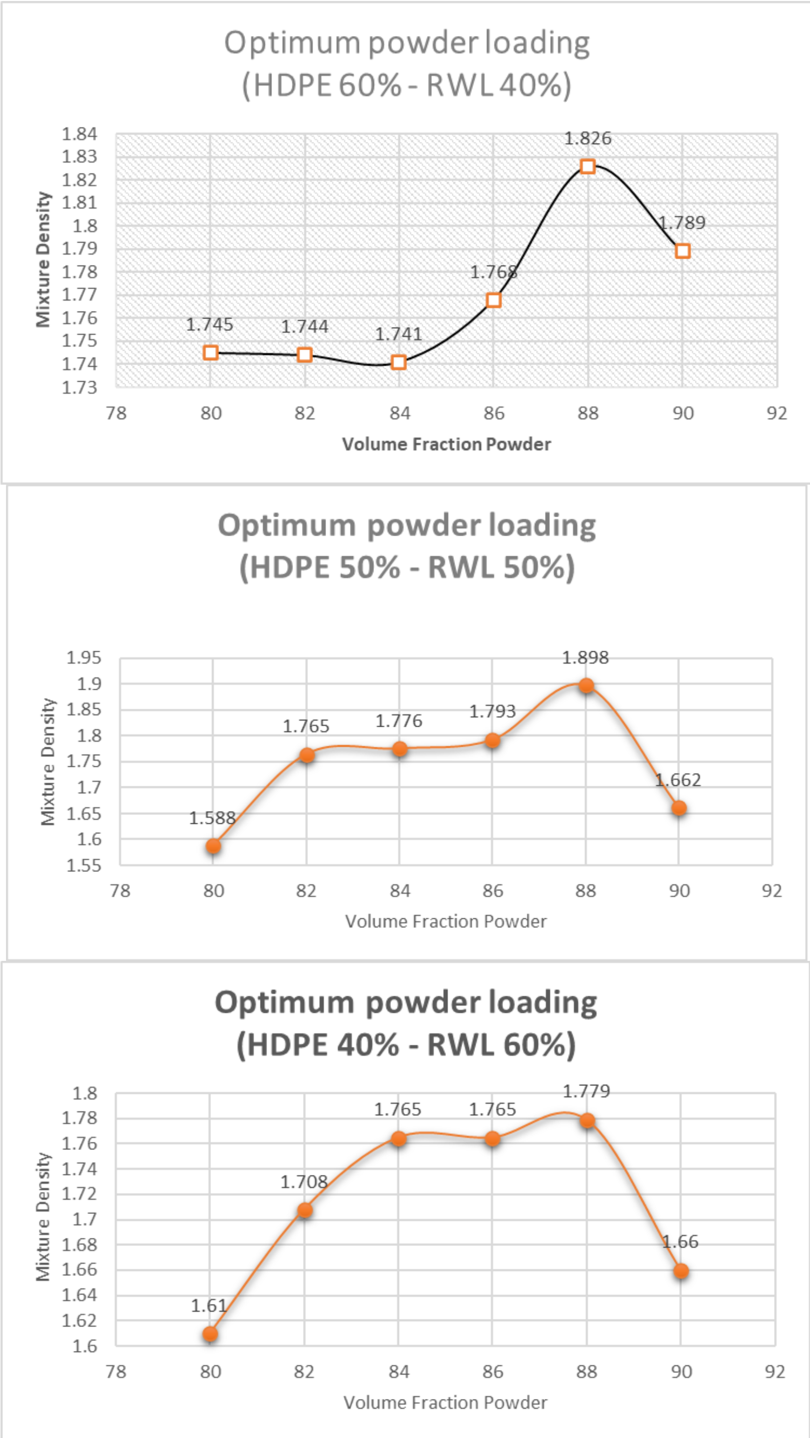

Fig. 5 *Graph of Optimum Powder Loading for all binder formulation*

Figure 5 shows the density of all binder formulation and we can see that 50% HDPE and 50% RWL has the highest density is 1.898 and it will be the critical point before its go down to 1.662. The density increases slightly at 82 till 86 before it reaches it optimum powder loading at 88. As we can see binder of 50% HDPE 50 % RWL has the best optimum powder loading of aluminum powder.

3.3 Surface Morphology

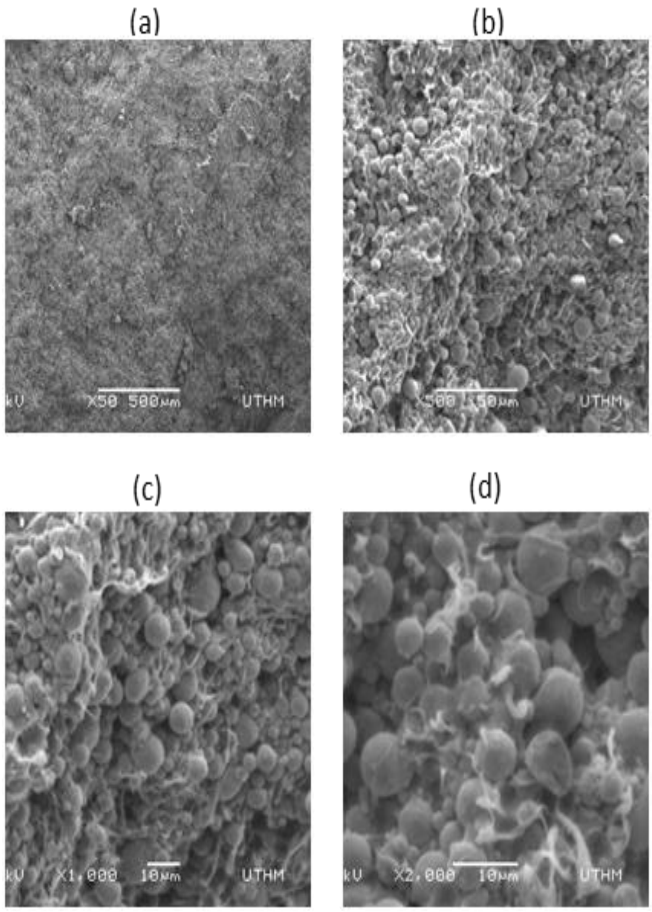

Fig. 6 *Scanning Electron Microscopy of 88% aluminium powder 50% RWL 50% HDPE by magnification of (a) x50 (b) x500 (c) x1000 (d) x2000*

Figure 6 shows picture of feedstock under SEM machine to see the surface morphology of the feedstock refers to the appearance and structure of the feedstock surface used in binder of 50% HDPE 50% RWL. It provide a visual representation of the surface condition of the feedstock and as we can see at magnification x2000, it can see the shape of particle for aluminium are in spherical shape and the particle are closely pack together. If the shape of particle are spherical shape, promoting excellent mouldability in the injection moulding process because of a low inter-particle friction. There are also less void in this mixture since we are taking at the optimum and this will decrease the porosity of the product. This is why we choose this binder formula as the best result in our experiment.

4. Conclusions

It was concluded from the findings and discussion that, independent of the binder ratio, the ideal powder loading could be established by assessing the feedstock's density. Based on three optimum powder loading graph we can conclude that the best binder ratio for our feedstock in 50% HDPE 50% RWL because it has the highest reading in density. To support my statement above, we can observed homogeneity graph for 50% HDPE 50% RWL and we can see uniform distribution and the data point are clustered closely together compare to other two ratios.

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