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

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Abstract

Metal Injection Molding (MIM) is a manufacturing technique that utilizes powdered metal and polymer as a feedstock to create intricate shapes for a single component. The selection of the appropriate binder in Metal Injection Molding (MIM) formulation holds utmost importance in ensuring the production of top-notch and durable components. This study is focused on evaluation homogeneity variation of feedstock for different binder ratio and determination optimal powder loading for different binder ratio. The binder formulation of LDPE and RWL being selected here are 60/40, 50/50 and 40/60 accordingly with the powder loading 80 percent to 90 percent for each binder formulation. The analysis will be based on density measurement and Scanning Electron Microscopy (SEM). Furthermore, different binder ratio depicts on different optimal powder on volumetric powder loading. The best powder loading for the 60/40 binder formulation of LDPE and RWL is achieved at 84 percent, corresponding to a density of 1.808 (g/cm3) at a specific point. Similarly, for the 50/50 binder formulation, the optimum powder loading is 86 percent at a density of 1.741 (g/cm3) at a different point. Lastly, the 40/60 binder formulation attains the best uniformity graph of homogeneity feedstock with an optimal powder loading of 86 percent at a density of 1.945 (g/cm3) at yet another point. The range of density presented smaller compared to the other. The integrity, reliability, and performance of the final components are directly affected by homogeneity.

1. Introduction

The Injection Molding is the primeval technology that has been used since the late 1800's [1]. Huge screws are included into injection moulding machines to push hot plastic into the mould under great pressure. Invention of this screw drive technique was created in 1946 and this method still employed by today [1]. Injection molding was only applied to polymers that melt on heating. Alternatively, metal and ceramics have property advantages over polymers higher strengths, higher stiffness, higher operating temperature, and they exhibit electrical, magnetic, and thermal properties not possible with polymers.

The new technology known as powder injection molding (PIM) that uses shaping advantage of injection molding but it applicable to metals and ceramic. The molding process is equivalent to thermoplastic injection moulding. The components are heated after cooling in the mould to remove the binder and sinter [2]. This

method combines a little amount of a polymer with an inorganic powder to create a feedstock that can be molded.

The project's problem statement focuses on examine the influence of various ratios on the aluminium powder-binder system. Additionally, it aims to create a predictive model to optimize the binder system and aluminium powder loading for MIM (Metal Injection Molding). Aluminium plays a crucial role in injection molding due to its exceptional qualities that render it suitable for the manufacturing process.

The objective of this research is about to evaluate homogeneity variation of feedstock for different binder ratio, and to find optimal powder loading for different binder ratio.

2. Experiment Methods

To gather experimental data, several experiments must be conducted. These experiments involve measuring the powder loading, analyzing the mixing process, assessing the crusher process, and determining the density of the feedstock.

2.1 Material preparation

Aluminium metal powder with size 25μm was utilized in this experiment. LDPE (Low-Density Polyethylene) and RWL (Restaurant Waste Lipids) as essential binders in this project. These binders play a vital role in forming a cohesive feedstock when combined with the metal powder. The equipment that used include beaker, spoon while the device is Mattler Toledo MS-TS Analytical Balances to measuring the weight of powder loading and binder components.

2.2 Mixing parameter

The formulation of the binder is employed to vary the proportions of LDPE and RWL, specifically using ratios of 60/40%, 50/50%, and 40/60%. The aluminium metal powder weight percentage from 80% to 90%. The total weight of binder and aluminium powder is 50g.

The total weight used for the project, including both the aluminium powder metal and the binder components was 50g.

$$M = V \times p \times K \quad Eq.1$$

$$Weight\ of\ powder = percentage\ of\ metal\ powder\ \% \times sample\ weight \quad Eq.2$$

$$Total\ weight\ binder = sample\ weight - weight\ of\ powder \quad Eq.3$$

$$Weight\ of\ binder = pecentage\ of\ binder\ \% \times total\ weight\ binder \quad Eq.4$$

The Brabender sample weight calculation is represented in Eq.1. because it is for consistency and repeatability in the mixing process. For determine the Weight of powder represent in Eq.2. For Eq.3 and Eq.4 is to find the weight percentage of binder. All the equations above must be in gram(g).

2.3 Mixing process

This binder formulation is used to determine the characteristic of combining metal powder with binder component which acceptable for metal injection molding process. For the mixing process, Plastograph Brabender that are used to combine or mixing the metal powder loading and binder component based on binder formulation. Table 1 represent the mixing process of aluminium to generate a complete feedstock, the specimen must be mixed until homogenous to achieve the homogeneity behaviour.

Table 1 *Mixing process of aluminium feedstock*

Type metal powder	Binder formulation	Temperature (°C)	Speed rotation (rpm)	Time (h)
Aluminium	60/40 percent	130	30	2
	50/50 percent			
	40/60 percent			

The Plastograph Brabender is set to a temperature of 130 based on the thermal properties of the polymer and a rotational speed of 30 rpm. LDPE is added to the mixing machine and allowed to melt completely for 30 minutes before adding the metal powder. The mixture is thoroughly homogenized. After 60 minutes, restaurant

waste lipids are introduced, and the mixing process continues for a total time of 120 minutes to form the final feedstock.

Fig. 1 *Dough aluminum feedstock*

2.4 Crushing Process

Following the mixing process, the feedstock lacks uniformity in shape as the metal powder and binder components have completely melted, resulting in a formless state resembling dough. To address this, a crusher process is employed to reshape the feedstock. The Granulator Crusher machine, located at the Polymer Laboratory, is utilized for this purpose.

Fig. 2 *Pelletized aluminum feedstock*

2.5 Homogeneity and Density Test

Once the crusher operation is finished, it becomes essential to determine the density of the feedstock. The density plays a crucial role in assessing the compactness of objects and measuring the uniformity of the feedstock. Mettler Toledo Density device enables the collection of samples, and for each sample, measurements were taken for weight in air, weight in liquid, and density.

Fig. 3 *Density testing machine*

3. Results and Discussion

In this experiment, two variables were held constant: LDPE (Low-Density Polyethylene) and RWL (Restaurant Waste Lubricant), which were utilized as binders in the study. These variables remained consistent and unchanged throughout the experimental process. LDPE is a type of thermoplastic polymer, known for its low density and flexibility, commonly used as a binder material. RWL, on the other hand, is a recycled lubricant that serves as an environmentally friendly alternative binder.

3.1 Homogeneity analysis
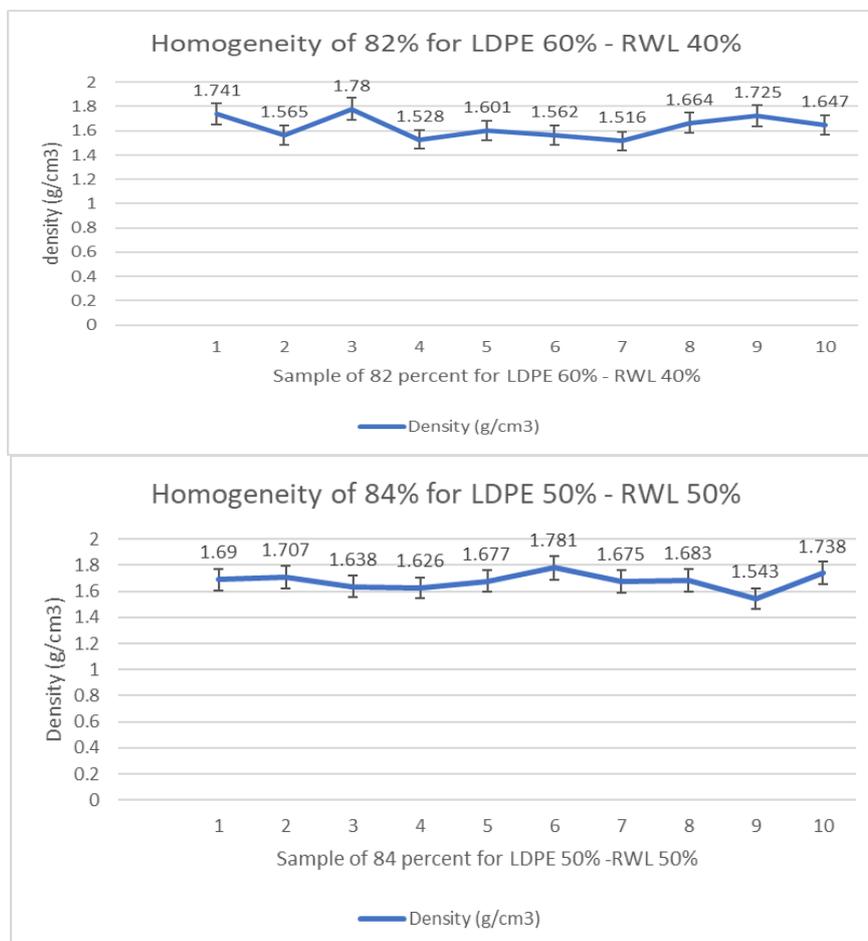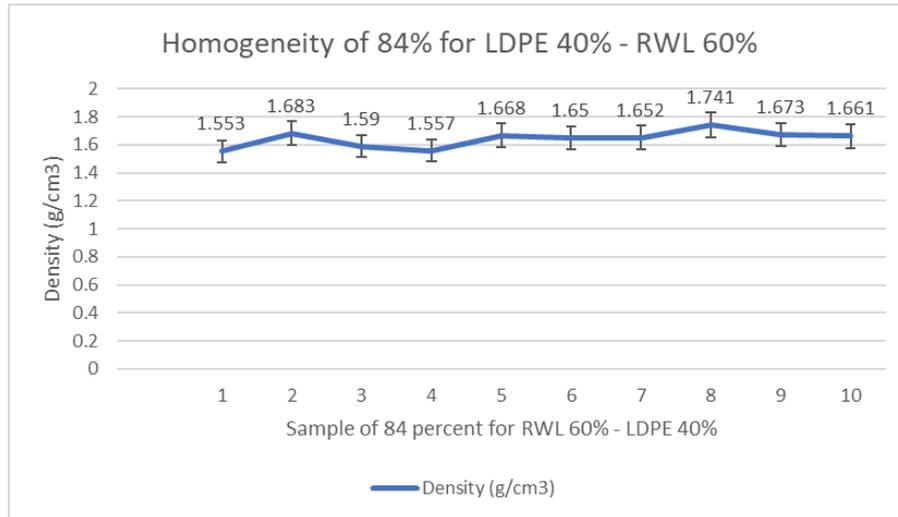
Fig. 4 *Graph homogeneity for 10 sample of optimum aluminum powder*

Figure 4 depicts the consistency of the LDPE 40% - RWL 60% feedstock density, which has been measured at 84%. The decision to select 84% as the point of evaluation for homogeneity was based on its alignment with the ideal powder loading ratio for this mixture. The graph visually represents the degree of uniformity in the density of the LDPE 40% - RWL 60% feedstock, specifically in relation to its suitability for use as a feedstock material in metal injection molding. The density values for the LDPE 40% - RWL 60% samples range from 1.231 g/cm3 to 1.412 g/cm3.

3.2 Optimum powder loading analysis

The relationship between density and the optimal powder loading is significant in the context of aluminum powder processing and formulation. The optimal powder loading denotes the perfect quantity of powder required within a system to attain the desired properties or performance.
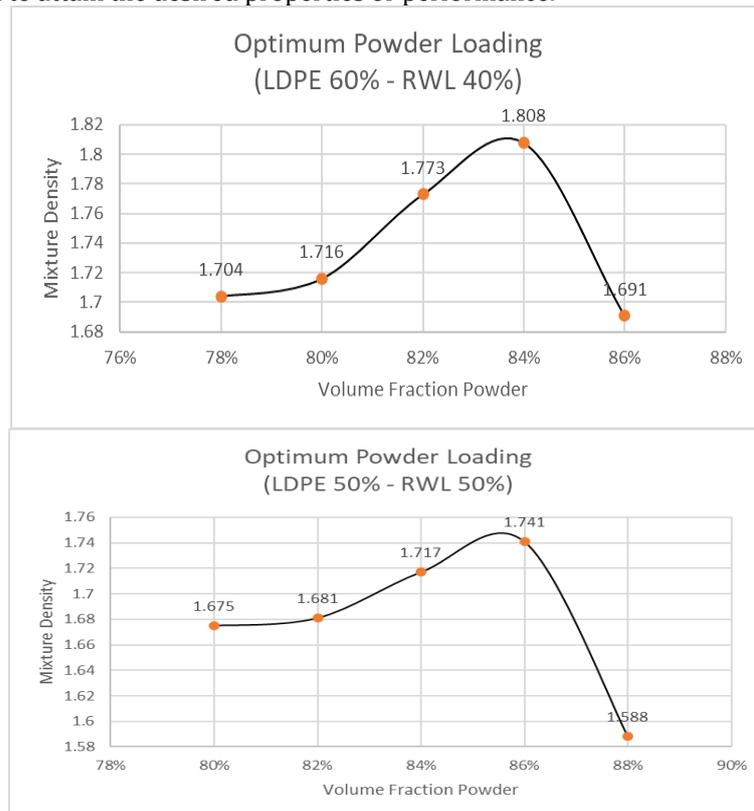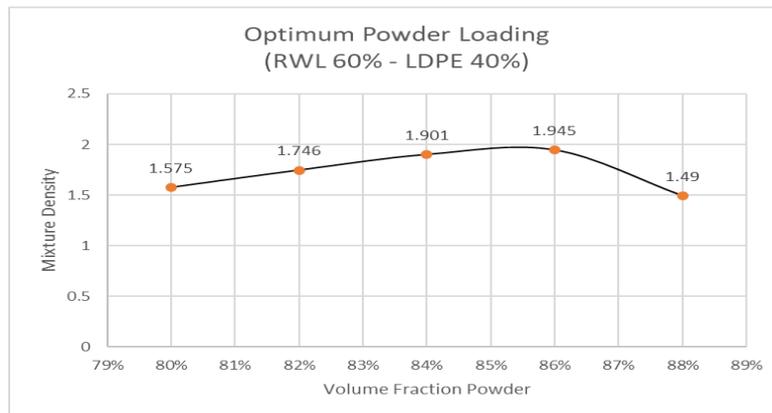
Fig. 5 *Graph optimal powder loading for all binder formulation*

Based on Figure 5, the range between 1.945 and 1.901 on the graph is considered the optimal level. This means that when the ratio of binder to metal powder falls within this range. It is considered the ideal composition for the desired application, intis case for metal injection molding. The mixture at this optimal level exhibits the desired properties and characteristics necessary for successful and efficient metal injection molding.

3.3 Surface morphology of homogeneity

The morphology of a surface refers to its physical structure, shape, and characteristics at a microscopic and microscopic level. It describes the overall appearance, features, and pattern exhibited by surface.
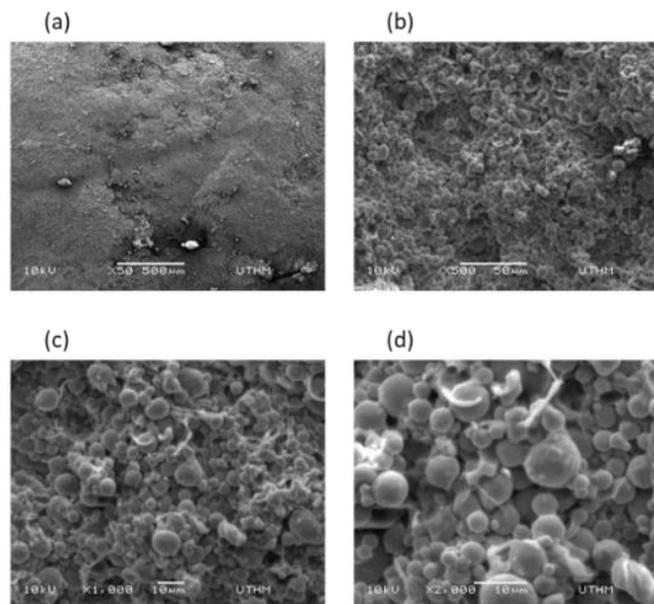
Fig. 6 *Scanning electron microscopy of homogeneous at 84% for LDPE 60% and RWL 60% by magnification of (a) x50 (b) x500 (c) x1000 (d) x2000*

In Figure 6 (d), it is observed that the particles of aluminium used in the injection molding process exhibit a spherical shape. This shape is considered favourable for the injection molding process. the size of the aluminium particles falls within the appropriate range of (4-20) μm for injection molding. This means that the particle size is well-suited for the specific requirements of the molding process, ensuring optimal flow and distribution of the feedstock material. the spherical shape of the particles plays a significant role in promoting excellent moldability. When the particles have a spherical shape, they tend to have a smooth surface and uniform dimensions, resulting in reduced inter-particle friction during the injection molding process.

4. Conclusions

Based on the homogeneity data from three different ratio graphs, it can be observed that the graph representing LDPE 40% and RWL 60% shows the highest level of uniformity. The range of density values in this graph is visually smaller compared to the others. Determining the homogeneity of feedstock in metal injection molding (MIM) is important firstly for component quality, homogeneous feedstock is essential for producing high-quality

MIM component. In MIM, achieving a uniform distribution of metal powders throughout the binder ensures consistent material properties, such as density, mechanical strength, and dimensional stability. Homogeneity directly impacts the final components integrity, reliability, and performance.

Acknowledgement

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