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MIXING HOMOGENEITY AND RHEOLOGICAL CHARACTERIZATION FOR OPTIMAL BINDER FORMULATION FOR METAL INJECTION MOULDING

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Keyword: Mixing homogeneity, Sewage Fat or Fat Oil Grease (FOG), Metal injection moulding, rheological characteristic, binder formulation

Abstract: Mixing homogeneity and the feedstock rheological characteristic for optimal binder formulation in metal injection moulding is evaluated between Polypropylene (PP) and Sewage fat (SF) or Fat Oil Grease (FOG). Difference powder loading of SS316L also being used here to determine the possibility of the best binder formulation selected could be optimised for optimal powder loading base on rheological characteristic analysis. Two binder formulations of PP to SF being selected here are 60/40 and 70/30 accordingly with the powder loading of 60% and 55% for each binder formulation. The analysis will be base on viscosity, shear rate, temperature, activation energy, flow behaviour index and moldability index. It is found that rheological result shows all the two binder formulations with both powder loading exhibit pseudoplastic behaviour or shear thinning where the viscosity decrease with increasing shear rate. Feedstock viscosity also decreases with increasing temperature indication of suitability for moulding. Results from all the analysis conducted shows that the volumetric powder loading of 60% with binder volumetric of 24% for PP and 16% for SF contributes significant stability and suitability for optimum powder loading.

1.0 Introduction

Metal injection moulding is a manufacturing process with an advantage of producing complex and intricate parts with a few shot as compare to other fabrication process. Due to its versatility, near net shape and less materials waste, it's become attracted to many researchers in explore it into new dimensions whether in the view point of its binder, powder characteristic, injection moulding conditions, debinding and sintering. Before metal injection moulding could be realised, several steps need to be done, first is the kneading process where here the metal powder will be mixed with binder formulation with typical binder volume percentage lies between 20 to 50% to form homogeneous feedstock. Secondly the debinding process is the process of removing the binder from the components following by the sintering process.

Sustainability in MIM has gained much attention since its establishment as one of the most attraction manufacturing process. Many researchers are try to manipulate others potential environmental substance to be added and used in MIM for a green MIM. Examples of such efforts are by using Carnauba Wax[1], Beeswax[1], Palm Stearin[2] and palm kernel[3] as the environmental friendly binder components. Others are trying to use water soluble binder like PEG[4] where the debinding process is by using water leaching since this type of wax doesn't pollute the environment. Although most of its are environmental friendly, some of it has conflict with human needs which is food and still unfavourable as components of binder. Due to this issues, waste fat which come from sewage are being analysed in terms of its rheological characterization, thermal, and homogeneity of the kneaded as a potential binder in micro MIM.

2.0 Experimental

2.1 Materials

Polypropylene (PP) supplied by Titan (M) Sdn Bhd was used as a major binder system with binder composition for this PP is 60 wt% and 70wt% of total binder percentage weights. Water atomized stainless steel 316L powder having irregular in shape with mean size d_{50} 6 μm supply by Atomix Epson Japan. The particles size is 5.96 μm with the critical Powder Volume Concentration (CPVC) is found to be approximately 65%. Thermal properties of Polypropylene and Sewage fat with different formulation are shown in **Table 1**.

Table 1: Binder formulation for 60% and 55% volumetric powder loading

Powder Loading			**60%**	
Feedastock Label				
Binder constituents	**Density (g/cm^3)**	**T_m (°C)**	**F1**	**F2**
Polypropylene, PP	**0.9**	**170**	**24%**	**28%**
Sewage fat	**0.90156**	**60**	**16%**	**12%**

2.2 Mixing process

Three composition polymer-wax binder system were mixed with stainless steel powder 316L at the temperature of 175°C with rotational speed of 30 rpm by using Brabender plastograph EC rotary mixer for 1 hour.

2.3 Homogeneity test

Homogeneity of the feedstock are analysed by the methods of density [6] measurement (**Table 3**), scanning electron microscope (SEM) with Back scattered electron (BSE) imaging and Thermalgravimetric Analysis (TGA). For TGA, the F1 will be burn out in the air atmosphere at heating rate conditions will be from 30°C to 500°C by using a rate of 10°C/min and the results of the percentage of the weight loss will be compared to the actual calculated of the binder composition.

Table 2: Density measurement of various feedstocks

Feedstock no.	Average Density	Standard Deviation	Variance	Median
F1	4.27732	0.1742875	0.030376147	4.3001
F2	4.47386	0.530027	0.280928588	4.392

2.3 Rheological properties test

In MIM, rheological properties contributes very important criteria in avoiding possibilities of binder-powder to stop flow into the die cavity during injection moulding, powder-binder separation and other defects related with injection moulding[1]. The rheological properties test will be done using capillary rheometry CFT-500D Shimadzu with. In order to monitor the flow, a die (L/D=40) was placed at the bottom of the barrel. Three different measurement temperatures was used here which are 140°C, 150°C and 160°C.

3.0 RESULTS AND DISCUSSION

3.1 Homogeneity analysis

In general, the feedstock density increase with increasing the powder loading for both binder formulation[6]. From the **Table 2**, F2 shows the highest density measurement as compare to F1 but the deviation between the feedstock densities is higher as compare to F1 where the standard deviation value for F1 is lower as compare to F2. This indicates that the F1 gives good homogeneity mixing since it gave small deviation. Higher values of deviation indicate inhomogeneous mixture. Although there is variation of density value during measurement, the differences are considerably minimal due difficulty to produce perfect homogeneity binder[7].

The calculated weight percentage of binder in the feedstock could be compared by using Thermogravimetric curves[8]

3.2 Rheological Characterization

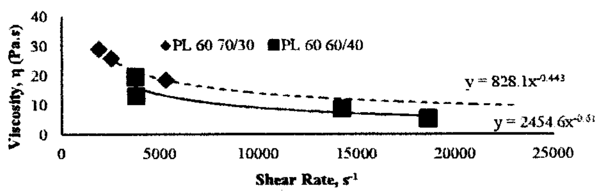

Figure 1: Viscosity (Expressed by power law model) vs. Shear rate for the feedstock F1 and F2 at T=140°C

Figure 7 shows both curves exhibit pseudo-plastic behaviour, as it is well known that too high in viscosity will results in parts defect during injection process[1]. The test is conducted at temperature of 140°C and it shows that the binder 60/40 has the lowest viscosity with increasing shear rate which indicate the easiest flowability of the feedstock.

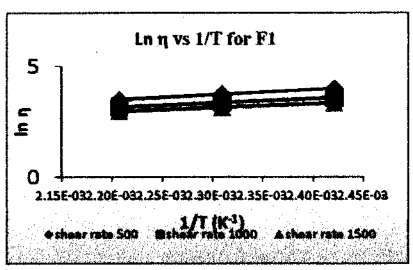

Figure 2: Vscosity versus Temperature for F1 and F3

Table 3: Comparison of n, E, η and α_{stv} at shear rate 1000 s^{-1}

Feedstock	Temp (°C)	n	E(kJ/mol)	η(Pa.s)	α_{STV}
60%	140	0.39	16.4818	36.31	8475.78
	150	0.453	16.4818	29.25	9435.04
	160	0.518	16.4818	23.76	10233.64

Both feedstock shows increment in moldability index with temperature, but the highest value was come from the feedstock with 60% powder loading which indicates the best general rheological properties and most suitable for injection moulding[9].

4.0 Conclusion

Two binder formulation of 70/30 and 60/40 between PP and SF have been tested for best rheological results base on viscosity, shear rate and power law index. It shows that binder formulation of 60/40 gives the good results although both formulations show pseudo-plastic behaviour which is suitable for injection moulding. Finally In this study, sewage has shown great potential for being used as the major binder component for MIM process after undergo several major test of MIM (Mixing homogeneity and capillary rheometer). From this experimental results, binder formulation of 60/40 will be the choice base on the rheological analysis results and will be further analysed for optimal powder volume loading.

5.0 References

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