Applied Mechanics and Materials Vol. 660 (2014) pp 38-42
© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.660.38

Submitted: 09.06.2014
Revised: 15.06.2014
Accepted: 12.08.2014

THE INFLUENCE OF SEWAGE FAT COMPOSITION ON RHEOLOGICAL BEHAVIOR OF METAL INJECTION MOULDING

A.M Amin[1a], M.H.I Ibrahim[1b], R Asmawi[1c], N. Mustapha[1d]

[1]Faculty of Mechanical and Munufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Batu Pahat, Johor.

[a]azriszul@uthm.edu.my, [b]mdhalim@uthm.edu.my, [c]roslias@uthm.edu.my, [d]nj.wawa@gmail.com

Keyword: Sewage Fat or Fat Oil Grease , Metal injection moulding, rheological behaviour, binder ratio

Abstract: Influence of sewage ratio or Fat Oil Grease (FOG) on the feedstock rheological characteristic for optimal binder formulation in metal injection moulding is evaluated besides Polypropylene (PP) as a backbone binder. Powder loading of 62% of water atomised SS316L being used here to determine the possibility of the best binder formulation which 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, 50/50 and 40/60 accordingly with the powder loading of 62% 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 from rheological result views, binder with composition of 60/40 and 50/50 exhibit pseudoplastic behaviour or shear thinning where the viscosity decrease with increasing shear rate. For 40/60 binder ratio is not suitable since the behaviour of the flow indicates dilatants behaviour. After considering all the criteria in terms of flow behaviour index, activation energy, viscosity and mouldability index, binder with ratio of 60/40 is evolve as a good selections.

1.0 INTRODUCTION

Metal injection moulding is a manufacturing process with an advantage of producing complex and intricate parts in high volume production with a few shot as compare to other fabrication process[1–3]. After being injected, the parts will undergo debinding process and finally sintering process.

Mixing is the process of making a feedstock for injection moulding process. Usually binder components serve as backbone binder, lubrications and surfactant. Backbone binder acts as particle shape retention since usually this type of binder has high melting temperature as compare to other components and good toughness at room temperature. Secondary binder usually is for reducing viscosity and improve flowability of the binder system besides filling the voids among the powder particles and backbone binder. The third components of binder is surfactant or additives which acts as oriented molecular chain or bridging the polymer between metal powder particles where increasing the wettability and provides lubrication for the powder particles for slippery conditions between particles and therefore reducing the viscosity and consequently increase the powder loading of the feedstock [4], [5]. Some system may consists of two backbone binder due to improving shape retention during debinding and also improving dimension stability [6]. It's also improving one to another disadvantages of the backbone binder.

Besides acting as a medium of transportation, good binders ratio also prevent powder binder separation phenomena and provides good mechanical strength to the green parts especially polymers with polar group [7]. Content of the proportion between backbone binder to the secondary one also influence the green parts during injection moulding phase and prediction of the shape of the compact in the debinding process [6], [8]. Here in this paper, powder loading of 62% of stainless steel with different sewage fat contents will be used in predicting its influence on rheological characteristic of MIM feedstock. Polypropylene as a backbone binder will be used and being mixed.

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 40 wt%, 50wt% and 60wt% of total binder percentage weights. Water atomized stainless steel 316L powder having irregular in shape with mean size d_{50} 6 µm and tap density of 8.0471 g/cm^3 supply by Atomix Epson Japan. The particles size distribution are given in **Figure 1**. The Critical Powder Volume Concentration (CPVC) is found to be approximately 65%. Melting temperature of Polypropylene (PP) and Sewage fat (SF) was analysed using DSC Q20 V24.10 TA Instruments which is 165°C and 50°C respectively (**Fig. 2**).

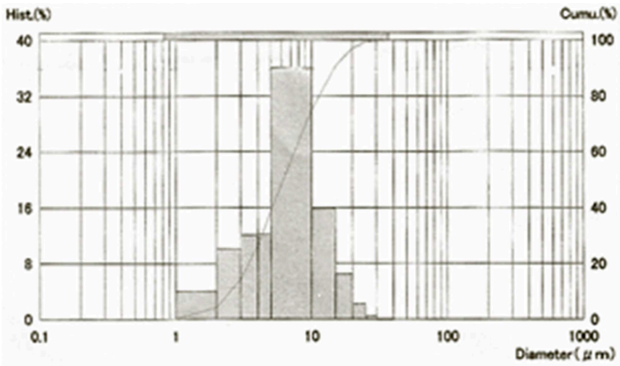
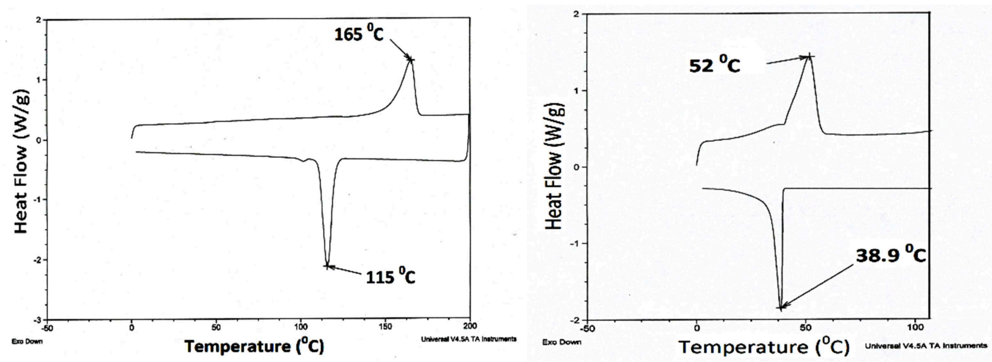


Figure 1: Particle size distribution of water atomised SS316L (PF-10F)

Table 1: Three different binder weight percentage with the same 62% powder loading

Binder	B1	B2	B3
Polypropylene, PP (%)	40	50	60
Sewage Fat, SF (%)	60	50	40



(a) (b)

Figure 2: DSC analysis of (a) Polypropylene and (b) sewage fat (SF)

Degradation temperature of both binder constituents was found to be 358.8°C and the lowest is 274.1°C[9]. Degradation temperature is needed to be known here since mixing temperature should not exceed the lowest degradation temperature which results in losing the capability of one of the functions of binder components.

2.2 Mixing process

Three polymer-wax composition ratio binder system were mixed with water atomised stainless steel powder 316L at the temperature of 175°C slightly above the melting temperature of PP (160°C) with rotational speed of 30 rpm by using Brabender plastograph EC rotary mixer for 1 hour. The 175°C temperature was selected to prevent the binder constituent from degrade since the lowest degradation temperature of the binder constituents is 274°C and allowing complete melting of PP and SF. This is important to avoid one of the binder components being loss during mixing which will affect the outcomes of the rheology characteristic [10]. To confirm this criteria, the feedstock will undergo DSC analysis (**Fig. 3**) and seem that both binder components are still tack by looking at the melting temperature of both binder constituents in the feedstock[11].

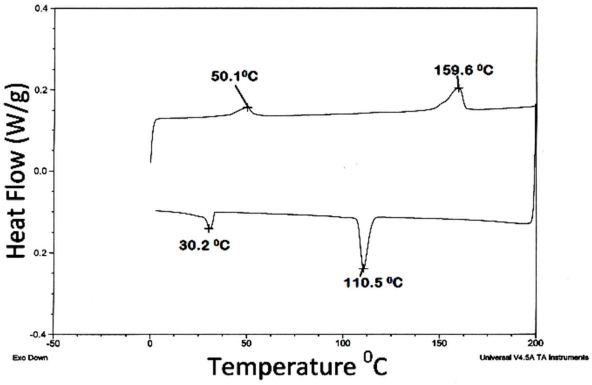


Figure 3: Meting temperature (Tm) and glass temperature (T_g) of feedstock

2.3 Rheological properties test

In MIM, rheological properties contributes very important criteria in avoiding possibilities of feedstock to stop flow into the die cavity[12] during injection moulding due to powder-binder separation[5] and other defects related with injection moulding[6]. The rheological properties test will be done using capillary rheometry CFT-500D Shimadzu[9]. Feedstock will undergo three different temperature which are 150°C, 160°C and 170°C and five different loading which are 20kgf, 30kgf, 40kgf, 50kgf and 60kgf for each binder composition which the measurement of the pressure drop and volumetric flow rate through the capillary, the shear rate, viscosity and flow rate can be determined.

3.0 Results And Discussion

3.1 Rheological Characterization

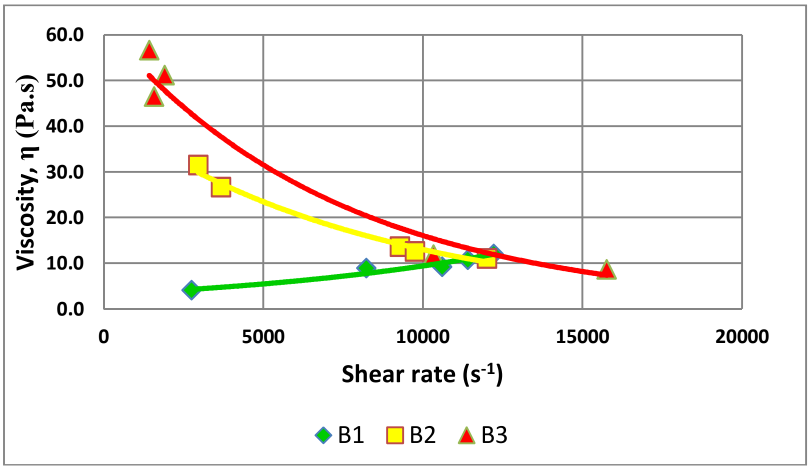


Figure 4: Viscosity (Expressed by power law model) vs. Shear rate for the Binder B1, B2 and B3 at T=160°C

Table 2: Comparison of n, E, η and α_{stv} at shear rate 1000 s^{-1} of different binder ratio

Binder ratio	Temp (°C)	n	E(kJ/mol)	η(Pa.s)	α_{STV} (10^{-6})
B1	150	0.267	6.93E+02	60.64	0.145113
	160	1.6813	6.93E+02	375988.4	2.17517E-05
	170	1.6327	6.93E+02	808655.1	9.39212E-06
B2	150	0.523	2.98E+04	47.11352	2.82216
	160	0.25	2.98E+04	71.14742	2.93839
	170	0.192	2.98E+04	68.86145	3.27072
B3	150	0.257	8.61E+03	74.98505	9.5671
	160	0.217	8.61E+03	74.89796	10.0939
	170	0.098	8.61E+03	83.82408	10.3897

In order to find the best binder formulation between sewage fat (SF) and Polypropylene (PP), the plotted graph of viscosity versus shear rate is presented (**Figure 4**). Binder B2 and B3 curves show pseudo-plastic behaviour where too high in viscosity will results in parts defect during injection process[5]. Binder B1 is out of consideration in here since the curve indicates that the feedstock undergo dilatants behaviour and not suitable for injection process possible of binder separation[6]. The test is conducted at temperature of 160°C and it shows that the binder B2 has the lowest viscosity with increasing shear rate which indicate the easiest flowability of the feedstock. For activation energy analysis, the B3 shows the lower values which indicates that the feedstock has less temperature effect which results in lower stress occurs. For mouldability index, B3 has the highest one which account from criteria of flow index, activation energy and viscosity. This indicates binder formulation 60/40 is acceptable and being able to undergo injection moulding process. This is true since too high in viscosity of feedstock will faces mould filling difficulty and will lead to part defects[5].

4.0 Summary

This paper summarizes experimental investigations carried out on micro MIM process based on water atomised SS316L powders (D_{50}=6.0µm). Suitable ratio between the SF and PP being analysed base on powder loading of 62% slightly below CPVC. The results will be looking on mixing homogeneity and rheological characteristic base on viscosity, shear rate, activation energy, power law index and mouldability index.

From the results above B3 was selected since it shows good flow behaviour index, activation energy, viscosity and mouldability index.

5.0 References

[1] H. Abolhasani and N. Muhamad, “A new starch-based binder for metal injection molding,” *Journal of Materials Processing Technology*, vol. 210, no. 6–7, pp. 961–968, Apr. 2010.

[2] M. Afian, I. Subuki, and N. Abdullah, “The Influence Of Palm Stearin Content On The Rheological Behaviour Of 316L Stainless Steel Mim Compact,” *Journal of Science and Technology*, pp. 1–14, 2012.

[3] S. Ahn, S. Jin, S. Lee, S. V Atre, and R. M. German, “Effect of powders and binders on material properties and molding parameters in iron and stainless steel powder injection molding process,” *Powder Technology*, vol. 193, no. 2, pp. 162–169, 2009.

[4] Y. min Li, X. quan Liu, F. hua Luo, and J. ling Yue, “Effects of surfactant on properties of MIM feedstock,” *Transactions of Nonferrous Metals Society of China*, no. 200 135, pp. 1–8, 2007.

[5] X. Kong, T. Barriere, and J. C. Gelin, “Journal of Materials Processing Technology Determination of critical and optimal powder loadings for 316L fine stainless steel feedstocks for micro-powder injection molding,” *Journal of Materials Processing Tech.*, vol. 212, no. 11, pp. 2173–2182, 2012.

[6] R. M. German and A. Bose, *Injection Molding of Metals and Ceramics*. Metal Powder Industries Federation, 1997, p. 413.

[7] M. Song, M. S. Park, J. K. Kim, I. B. Cho, K. H. Kim, H. J. Sung, and S. Ahn, “Water-soluble binder with high flexural modulus for powder injection molding,” *Journal of Materials Science*, vol. 40, no. 5, pp. 1105–1109, Mar. 2005.

[8] S. Supriadi, E. R. Baek, C. J. Choi, and B. T. Lee, “Binder system for STS 316 nanopowder feedstocks in micro-metal injection molding,” *Journal of Materials Processing Tech.*, vol. 188, pp. 270–273, 2007.

[9] A. Mohd Amin, M. H. I. Ibrahim, and R. Asmawi, “MIXING HOMOGENEITY AND RHEOLOGICAL CHARACTERIZATION FOR OPTIMAL BINDER FORMULATION FOR METAL INJECTION MOULDING,” in *3rd ICMDME 2014 Conference proceeding Bosi Edu*, 2014, p. 19.

[10] L. Moballegh, J. Morshedian, and M. Esfandeh, “Copper injection molding using a thermoplastic binder based on paraffin wax,” *Materials Letters*, vol. 59, no. 22, pp. 2832–2837, Sep. 2005.

[11] R. Supati, N. H. Loh, K. A. Khor, and S. B. Tor, “Mixing and characterization of feedstock for powder injection molding,” *Journal of Materials Letters*, vol. 46, no. November, pp. 109–114, 2000.

[12] M. H. . Ibrahim, N. Muhamad, and A. B. Sulong, “Rheological Investigation of Water Atomised Stainless Steel Powder for Micro Metal Injection Moulding,” *International Journal of Mechanical and Materials Engineering*, vol. 4, no. 1, pp. 1–8, 2009.