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EVALUATION OF POROSITY IN METAL INJECTION

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ABSTRACT

Metal Injection Moulding (MIM) is more like plastic injection moulding but with metals. Lubricated metal powder are prepared with a thermoplastic binder, and moulded in an injection moulding machine into a mould that is very similar to a normal injection mould [1]. After moulding, the "green compacted" moulding material is sent through a de-binding process and then through a sintering process. MIM is capable of producing in both large and small volumes, complex shapes and from almost all types of material including metals, ceramics, inter-metallic, compounds, and composites. With no official binder and also exact value for green optimal criteria in MIM, the process for MIM using powder far from been using massively in machining industries [2][3]. In this study, the 60% of Stainless Steel (SS316L) powder loading with binder ratio 50/50 of sewage fat or fats, oil and grease (FOG) and Polypropylene (PP) will be use and analyse for optimal injection and binder parameter. The objective is to determine the porosity and crack at the surface of the brown part using Non-Destructive Test (NDT) process. The percentage of weight loss after solvent and thermal debinding process also have been identified. Hexane has been used as the solvent to remove binder in solvent debinding process. Moreover, the best temperature for hexane to remove binder in sample has been identified which is 50 ˚C of hexane has been picked as the best temperature compared to 40 ˚C of hexane. Thermal debinding has been used to remove Polypropylene (PP) in sample. Both temperature for thermal debinding has been tested which is 40 ˚C and 50 ˚C. The best temperature for thermal debinding is 400 ˚C because it will produce higher percentage of ferum but lower percentage of oxygen. Forming less number of oxygen content will prebent oxidation on sample.

Keywords: metal injection moulding, injection moulding, binder, de-binding process, Non-Destructive testing, thermal debinding.

INTRODUCTION

MIM is more like injection moulding but with metals. Lubricated metal powder metals were prepared with a thermoplastic binder, and moulded in an injection moulding machine into a mould that is very alike to an ordinary injection mould. After moulding, the "green compacted" moulding material is directed through a de-binding process and then through a sintering process. MIM is capable of producing in both large and small volumes, complex shapes and from almost all kinds of material including metals, ceramics, inter-metallic, compounds, and composites.

In recent years, injection moulding was ordinarily used in many types of industries. Metal Injection Moulding (MIM) is one of the new methods that refers to a variety of processes. Regularly, it involves several processes such as forcing or injecting a homogenous mixture or "green part" into a closed mould. It combines two common processes which are plastic injection moulding and conventional powder metallurgy technologies. MIM process encompasses a net-shape process for a high volume and high precision manufacturing that could manufacture very complex-shaped part with or without secondary finishing. It comprises of several processes whereby the main four steps are mixing, injection moulding, debinding and sintering. Furthermore, debinding is the most crucial step among the entire steps involved which determines the success of the process. The failure to remove and extract all the binders may cause component distortion, cracking, and contamination. Therefore, Non-Destructive Testing was used to inspect the flaw on the surface of the brown part. Before Non-Destructive Testing inspection was introduced widely, people used the method called visual inspection to identify the existence of flaw or defect around the component. Nowadays, there are a lot of tests that can be done to get a better result from the inspection process. Some of the test includes visual inspection, magnetic-particle, ultrasonic, liquid penetrate, radiography, eddy current testing and fluorescents penetrant inspection. These type of tests do not damage the specimen, but give the result similar to the destructive method.

METHODOLOGY

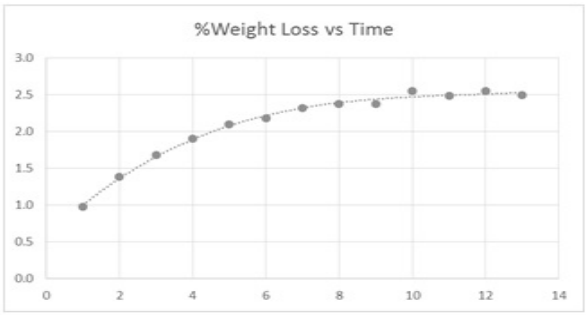
In conducting studies and research, the methodology is an important element in the process of doing research which involves the methods and ways doing the test. In this study, several method have been identified as a vital potential for success of this study such as materials selection, melting temperature and suitable NDT method used to determine cracks and porosity on the surface of the brown part. However, there are some conditions that need to be considered such as ratio between the metal powder and binder because the objective of this study focused on debinding and the appropriate utilization of NDT methods which is Dye Penetrant Inspection. This chapter will discuss in more detail starting from debinding process and several method to check porosity in sample.

Thermal debinding is a process which focus to remove binder from the green part. In this study, the type of binder used is Polypropylenes (PP). Moreover, the weight loss of the binder can be identified by plotting the

graph according to the experiment variables used. This process were designed to record changes by the weight loss due temperature. A scanning electron microscope (SEM) is a type of electron microscope that produce image of a sample by scanning it with a focused beam of electrons. The purpose of doing SEM is to identify the existing of PP in sample. After thermal debinding, percentage of PP in sample should be decreased. Moreover, the percentage of oxygen content also can be identified by using Energy Dispersive X-ray Spectroscopy (EDS). Lesser oxide content introduced during debinding was especially beneficial for obtaining better surface finish. With lesser oxide content also will reduce the existence of porosity in sample.

RESULT AND DISCUSSION

Solvent debinding process



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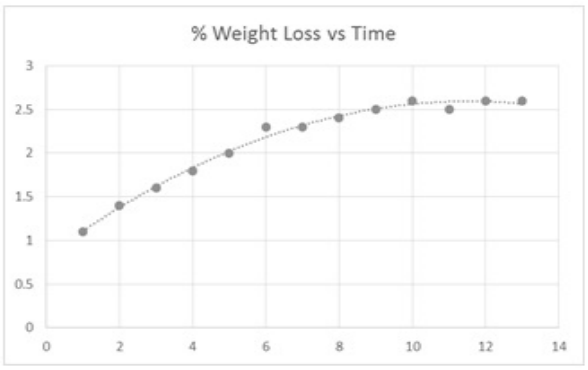

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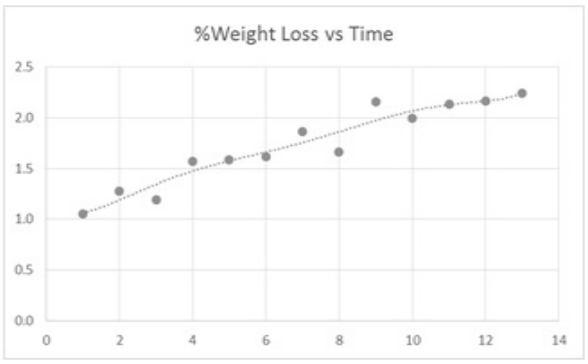

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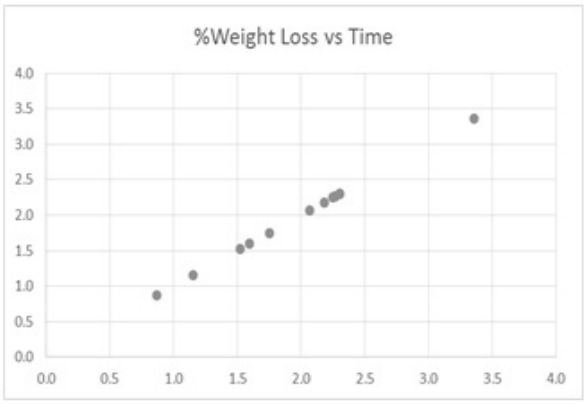
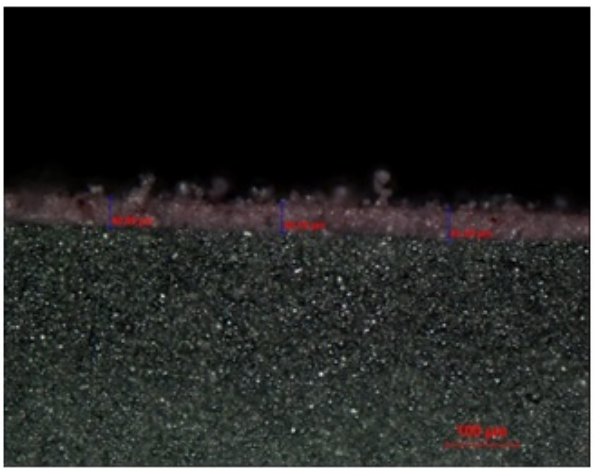


(d)

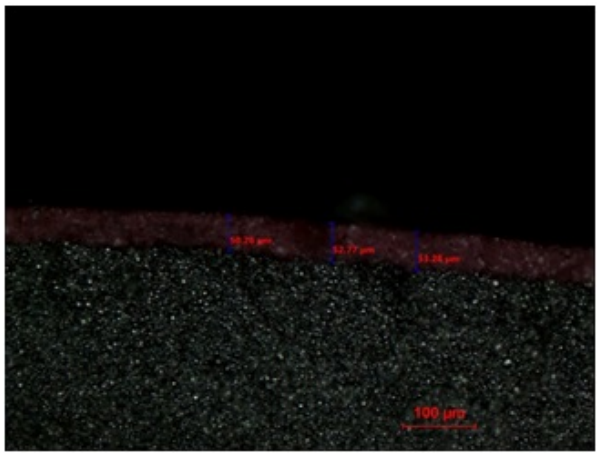
Figure-1. Shows the graph for weight loss against time for 50 ˚C of hexane with 7:1 solvent ratio, (b) 50 ˚C of hexane with 15:1 solvent ratio, (c) 40 ˚C of hexane with 7:1 solvent ratio and (d) 40 ˚C of hexane with 15:1 solvent ratio

From Figure-1, from four tests of solvent debinding by using Hexane as the best solvent for FOG, a) and b) was successful compared to c) and d). According to [4], higher temperatures induce a faster debinding rate and appear to be the most important parameter to reduce debinding times in the case of the feedstock evaluated. For a) and b), 50 ˚C of Hexane was used for solvent debinding to remove PP which is the best temperature for Hexane to react with PP, it is because the range for Hexane fully active is between 50 ˚C to 70 ˚C. For the c) and d), which 40 ˚C temperature of hexane are not suitable for solvent debinding. This is because, the Hexane are not fully active to remove wax as the solvent for the process.

Non-destructive testing (NDT)



(a)

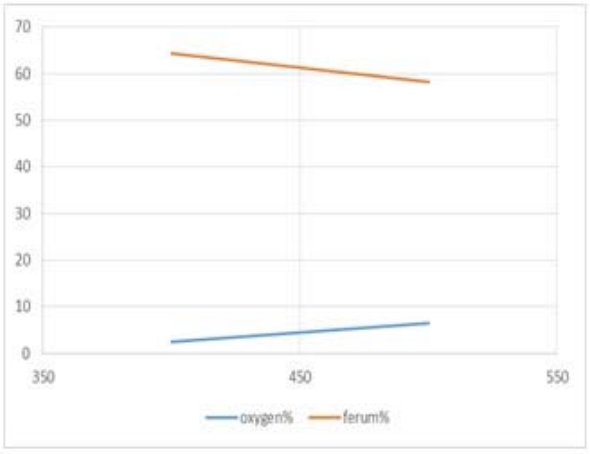


(b)

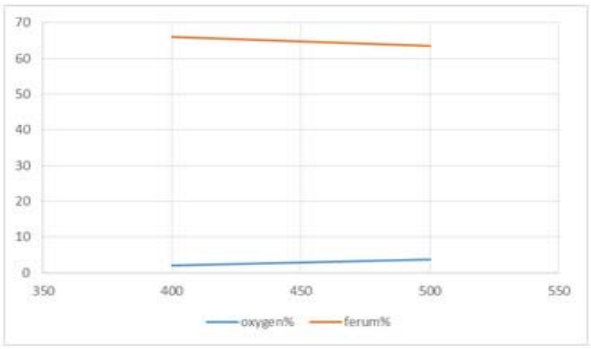
Figure-2. (a) 6 hours solvent debinding and (b) 11 hours solvent debinding.

NDT was used to check the porosity on the surface of the sample. Moreover, the depth of the dye penetrate into the sample also can be determine. Dye Penetrant Inspection (DPI) was used as the methods to inspect the porosity exist on the sample. Sample (a) and (b) has been tested by using DPI in order to inspect the depth of the dye penetrates into each sample. For (a) time taken for solvent debinding is 6 hours and (b) the time taken is 11 hours. For the conclusion, the depth can be determined by comparing the depth for the dye to penetrate into the sample. According from the results obtained, the depth for the dye penetrate into the sample is due to the time taken for each sample during solvent debinding process. For the conclusion, the longer time taken for each sample in solvent during debinding will affect the length of the dye penetrate into the sample increase.

Thermal debinding



(a)



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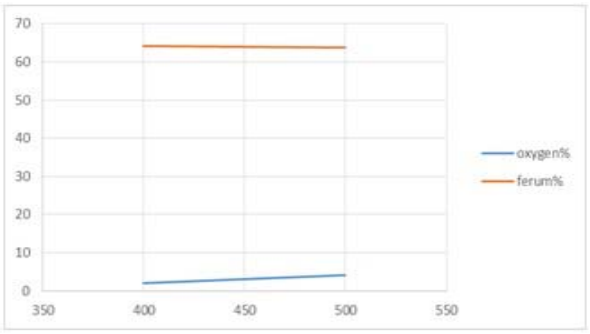
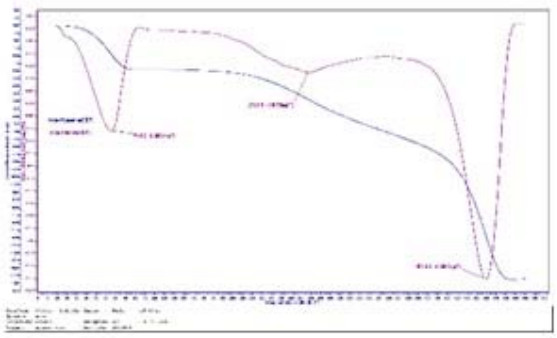


(c)

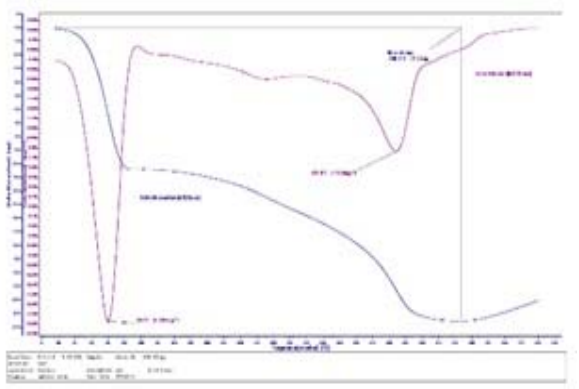
Figure-1. Shows the graph analysis between oxygen content and temperature (a) result for 10 ˚C/minute, heating rate, (b) result for 20 ˚C/minute, heating rate and (c) result for 30 ˚C/minute, heating rate

From this study, higher heating rate will distress the lower oxygen content in sample. In order to get fine surface finish with less oxygen content after thermal debinding, suitable heating rate can be identified by using Element EDS. Moreover, the porosity and binders left after thermal debinding can be detected by scanning sample. Based on this study, 10 ˚C/minute is better than 20 ˚C/minute and 30 ˚C/minute. According to [5], the oxides were formed because of incomplete oxide reduction due to low hydrogen content. Higher heating rates, reduced the chances for oxidation to occur and hence gave a higher weight loss.

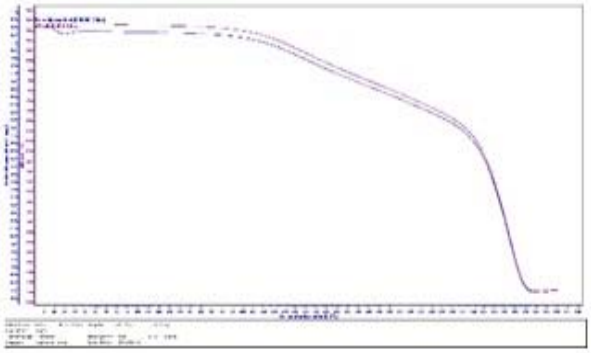
Thermogravimetric analysis (TGA)



(a)



(b)



(c)

Figure-4. (a) TGA result for Green Part, (b) TGA result for 1 hour after solvent debinding and (c) TGA result for 13 hours after solvent debinding.

Figure-4(a) shows the degradation slope of PP is more obvious compared to (b) and (c). It's due to the weight percentage of PP in green part are higher. According to Figure-4(b), there is a little slope of degradation which shows the existence of PP in sample after 1 hour solvent debinding. Lastly, smooth graph produced in Figure-4(c). Based on previous research, after 10 hours of debinding process, the debinding rate become stable. Thus, the smooth graph produced by (c) because of the number of PP in sample almost zero.

CONCLUSIONS

From all the results obtained, the conclusion has been made that the porosity will occurred in sample after debinding process. The existence of the porosity can be determined by several methods which were Scanning Electron Microscopy (SEM) and Dye Penetrant Inspection (DPI) have been used to inspect the existence of porosity in sample. Other than that, suitable temperature for Hexane in solvent debinding process to fully active as a binder remover has been determined which 50˚C is more suitable compared to 40˚C of Hexane. Moreover, in thermal debinding process, the best temperature for the process has been determined by comparing the result from both different temperature between 400 ˚C and 500 ˚C. From the result, 400 ˚C produced less oxidation compared to 500 ˚C.

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