International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 6, Nov-Dec-2020, ISSN (Online): 2395-566X

Solvent Extraction Study of Injection Moulded M2 High Speed Steel Using Palm Stearin/Waste Rubber Based Binder

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***Abstract*- Metal Injection Moulding (MIM) has undergone development of various binder systems with the aims of shortening the overall debinding time duration. In the present work, a novel binder system based on waste rubber has been utilised in injection moulding of Molybdenum High Speed Steel (M2 HSS). The feedstock consisted of M2 HSS powder with mean diameter particle size of 16µm and binder which comprised of palm stearin, polyethylene, waste rubber and stearic acid. The moulded part was immersed into n-heptane at 60°C in order to remove the paraffin wax and stearic acid, followed by sintering in a controlled vacuum atmosphere. Results showed that solvent extraction debinding technique allowed complete removal of paraffin wax and stearic acid from the injection moulded part within 2 hours without swelling or distortion of the debound part. Scanning Electron Microscopy observation showed that large pores were formed from the surface to the interior of the debound part during the process. In addition, this technique was found to be suitable to shorten the debinding time, which consequently resulted in a debound part**

Index words- Metal Injection Moulding, M2 HSS, solvent extraction, thermal pyrolysis

I.INTRODUCTION

Metal injection moulding (MIM) is a cost-effective technique for producing small, complex geometry, precision engineering components in high volume. The four basic steps in MIM are mixing, moulding, debinding and sintering [1]. Each step in MIM process plays a vital role in order to achieve high quality final components. The debinding step which requires the largest processing time plays a crucial stage and necessitates primary improvement.

As most of the defects, such as blistering, cracking and bloating are formed in this step, long debinding times increases the risk of component distortion and have been a major challenge for the economic success of MIM [2], [3]. Therefore a considerable work has been carried out to improve the classical debinding technologies and to develop alternative of a proper binder system with the aims of shortening the overall debinding time duration and minimizing the formation of defects. The use of n-heptane, a water-soluble solvent, has been reported with good results in reducing the debinding time and defects formation during thermal debinding of organic binders[3-11]. In this research work, the complete removal of binder from injection moulded Molybdenum High Speed Steel (M2 HSS) with a new developed binder based palm stearin and waste rubber was investigated.

II. MATERIALS AND METHOD

1.Feedstock Preparation

The M2 HSS powder used in this experiment has a mean diameter particle size of 16µm and was largely spherical in shape. The powder loading used was 65 vol. %, while the binder system consists of palm stearin (55%), polyethylene (21%), waste rubber (14%) and stearic acid (10%). Mixing process of the metal powder and binder system was carried out in a sigma blade mixer for 2 hours at 160°C before it was removed from the bowl, cooled and then granulated into a feedstock. The granulated feedstock was molded into tensile bars by using MCP HEK-GMBH vertical injection moulding machine. In order to obtain defect-free molded parts, a suitable set of molding parameters were established. Injection molding temperature and pressure were 180°C and 350 bar respectively.

2. Solvent Extraction Process

The green molded parts were subjected to a solvent extraction process where around two third the volume fraction of the binder was removed. During the process, the parts were immersed in a bath of n-heptane and held at a temperature of 60°C for 5 hours. A glass container was use to cover the bath to prevent evaporation of the n-heptane. Upon completion of the solvent extraction process, the brown parts were dried in an oven at a temperature of 40°C for 2 hours to remove the remaining n-heptane. The brown parts were weighed to calculate the amount of binders removed and Scanning Electron Microscopy observation was performed to observe the fracture surface of specimens debound for different elapsed times.

III. RESULTS AND DISCUSSION

1.Solvent Extraction Study

In order to help M2 HSS powder to flow easily into the mold cavity, polymer based binder is used to bind the powder particles together. Hence, the binder will act as a temporary vehicle for homogenously packing a powder into a desired shape and therefore hold the particles in that shape from the beginning of sintering.

The major goal of the binder system which comprised of palm stearin (PS), polyethylene (PE), waste rubber (WR) and stearic acid (SA) is to provide the necessary flowability and to enable filling of a cavity during the injection molding process. The binder is subsequently removed from the mixture during debinding and the first stage of the sintering process (Kowalski and Duszcyk [7]). In order to reduce the total debinding time, solvent debinding was conducted by immersing the parts in a bath with n-heptane where PS and SA are soluble. Figure 1 shows the correlation of binder removal efficiency with debinding time (1–5 h) at a temperature of 60°C which indicate reduction of debinding rate with increasing debinding time. It has been observed that the part achieved 90% binder removal after immersion in n-heptane for duration of 60 minutes without defects such as cracking, slumping and sagging.

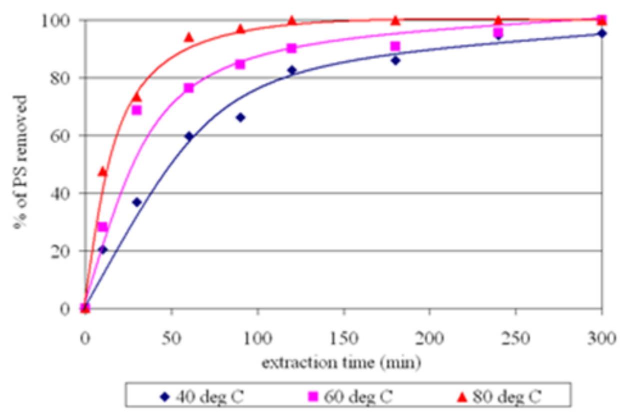


Figure 1: The correlation of binder removal efficiency with debinding time (1–5 h) at a temperature of 40,60 and 80 °C

As shown in Figure 2, the transport mechanism inside the particle controlled the debinding since the experimental points fitted well with straight lines especially for the immersion at the temperature of 60 oC. This behaviour is typical of systems in which diffusion is the controlling step of the whole extraction process. In addition, the good correlation indicated that the diffusivity was approximately constant Different positions, including the fractured surface and the outer part of the as-molded parts were examined by using Scanning Electron Microscopy (SEM) in order to observe the binder distribution and evolution of interconnected porosities resulted from the leaching process. Fig. 3 (a) and (b) show scanning electron micrograph of the fractured surface and surface of the green body respectively which indicate that the binders are fairly distributed between the metal particles. It also appeared that there are some voids between the metal particles owing to shrinkage of the binder that occurred during cooling.

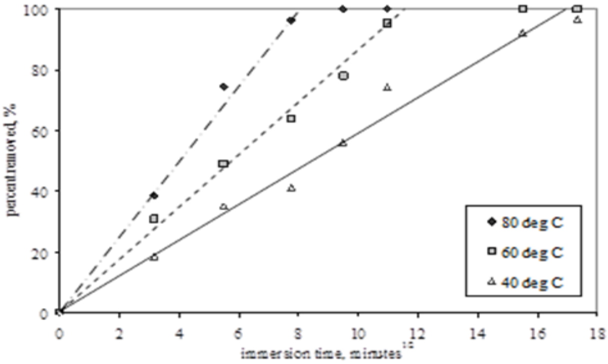
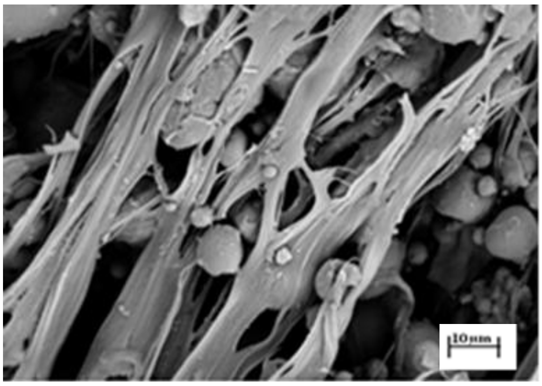


Figure 2 : Fraction of PS extracted with square root of immersion time at different temperature.

When as-molded parts were immersed in the preheated solvent bath, heptanes diffused into palm stearin. The heptane content decreased with the depth of specimen because the heptane diffused into the specimen from the exterior to interior slowly through the open pores. Only paraffin wax at the surface began dissolving into the solvent at this stage. As debinding continued, owing to the increase of heptane content in the interior of as-molded part, the solvent-debound depth increased with the debinding time [4]. As the debinding time continued to 60 minutes, the pore size and pore volume increased and the distribution of pores broadened obviously in the as-molded as shown in Fig. 3 (a) and (b).



30 minutes

60 minutes

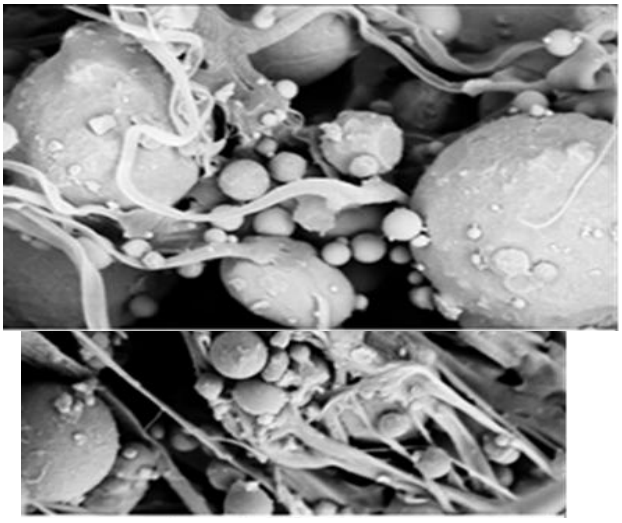


Figure 3: Scanning electron micrographs after 30 minutes and 60 minutes of solvent extraction process. At this stage, 50% of palm stearin has been removed. Very little of the waste rubber and polyethylene (PE) can be seen in the micrograph taken at the outer edge of the sample and none in the micrograph taken at the centre. As the solvent extraction progresses, the removal of the palm stearin in these regions reveal a network strands of waste rubber and PE. This shown in Fig 4. On these basis of these and other observations, it is proposed that during cooling, the waxes either separates from waste rubber and PE, where this is possible, and then crystallises , or crystallises to exclude the PE and waste rubber where this is possible.

Figure 4: Scanning electron micrographs after 180 minutes of solvent extraction process, fracture and surface morphology.

The solvent extraction study, the weight loss of waxes has been found to be a parabolic function of extraction time for a fixed extraction temperature.it is proposed that from this results from diffusion of hydrated wax molecules out of the moulding into surrounding water in the extraction bath. Solvent extraction is an apparently simple operation. Which involves immersing the green body into heptane and leaving it immersed until essential all of the Palm stearin has been removed. However, actually very complicated because several processes involved. These are thought to be hydration of the palm stearin, its dissolution and then diffusion out of the green samples.

VI. CONCLUSION

It is observed that waste rubber (WR) had significantly affected the debinding behaviours of as-molded parts M2 HSS. The results obtained from solvent extraction process by using n-heptane at a temperature of 60°C, indicate that after 3 hours all soluble binders which are PW and SA have been removed from the as-molded part without cracking, slumping or sagging. This suggests that WR is a very effective ingredient for effectively reducing the overall debinding time of M2 HSS injection molded parts

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