FUSED DEPOSITION MODELLING USING POLYMER BINDED METAL

[1]Deepak Raj P.Y,[2]Abhishek anand,[3]Sowmya B, [4]Junaidahemad Misrikoti,[5]Praveen Haridas
[1]Associate Professor,[2]Student,[3]Student, [4]Student,[5]Student
[12345]Department of Aeronautical Engineering,
[12345]Srinivas Institute of Technology, Mangaluru,India

Abstract :
Fused deposition modeling (FDM) is a type of additive manufacturing process. In FDM melted material is deposited selectively in a pre-determined path layer by layer to build a model. The challenge in this project is to use metal injection molding feedstock in FDM. It is basically a hybrid mix between Metal Injection Molding (MIM) and Additive Manufacturing (powder metallurgy). This can be used by individuals as well as industries. In this research several topics of the MIM process were studied to understand how the feedstock is prepared using metal powder mixed with polymer\wax binder. The experimental study was done on aluminium powder feedstock by varying the percentage of powder content in the mixture. The extruder design, the extrusion temperature, nozzle size and shape. It was obtained from the results that why powder loading should be higher and suitable extrusion temperature for stable flow.

I. INTRODUCTION

1.1 Metal injection molding

The metal injection molding is most useful manufacturing process to produce large amounts of small and complex parts. It takes less than a minute to produce 35 parts in one go and has been ruling manufacturing industries all around the world. The problem of metal injection molding is how to make metal flow into the mold. The problem is solved using metal powders of size less than 25 micron dissipated into a binder which can melt at lower temperatures and easily flow into the mold. This process includes feedstock preparation, injection molding, debinding and sintering.

The feedstock should prepare with good flow ability and uniform structure. The preparation of feedstock for MIM is most challenging one. Second important step is die cavity filling. The rheological properties of the feedstock plays important role in this manufacturing method. This process is based on the injection of a fluid material composed of powder of the desired material for the final part. The pat is then subjected to debinding to remove the binder and the it is sntered to obtain dense part.

- **Binders:** The binder is very important for metal injection molding process. The fluidity for the feedstock mixture and adhesion of the powder to stay the molded shape throughout injection molding is obtained through biners. It also provides strength and cohesion for the molded part and must be easy to remove from the molded part.
- **Debinding:** Its mainly dependent upon the type of polymer used, where binders get eliminated from the parts leaving only the metal structure, but the problem here is quick heating or excess binder elimination will result in loss of structure.
- **Sintering:** Debinded parts are then sintered to obtain the final part, which is smaller than the actual mold size due to contraction of metal powders and loss of polymers from the parts. The green molds are then sintered gradually for hours with very slow rate of heating until it reaches the temperature below the melting temperature of the metal powder used. And finally the sintered parts are finished by filing and machining the outer surface.

1.2 Additive manufacturing

Metal additive manufacturing is also known as rapid prototyping or 3D printing, the method uses powder to form parts, wire or sheets which proceeds or prints layer by layer. This process include critical products such as those required for use in aerospace. Some of the metal AM systems are powder-bed, selective laser sintering, wire-fed processes based on electron beam or plasma melting. Till now 29 types of metal powder materials are experimented for AM, including stainless steel, aluminium, nikel, cobalt chrome, and titanium alloys.

- **Selective laser sintering:** Selective Laser Sintering is an additive manufacturing technique that uses a laser as the power source to sinter powdered metals pointing the laser automatically at points in space defined by a 3D model, binding the material together to create a solid structure. SLS involves the use of a high power laser to fuse small particles of plastic, metal, ceramic, or glass powders into a mass that has a desired three-dimensional shape. The laser selectively fuses pulverized material by scanning cross-sections generated from a 3-D digital description of the part on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed.
- **3D printer:** 3D printing is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together. Rapid prototyping and additive manufacturing both uses 3D printing technique. Parts can be of almost any shape or geometry and typically are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file (usually in sequential layers). There are many different technologies, like stereolithography (SLA) or fused deposit modelling (FDM). Thus, unlike material removed from a stock in the conventional machining process, 3D printing or Additive Manufacturing builds a three-dimensional object from a computer-aided design (CAD) model or AMF file, usually by successively adding material layer by layer.

II. METHODOLOGY

2.1 Material selection

High density polyethylene and paraffin wax are chosen as binders. The metal powder selected is aluminium 6061. The HDPE component provides shape retention and mechanical strength, while the low molecular weight and the low melting point of the paraffin wax provides high flowability to the binder.

Table 1 Materials used

Metal powder	Aluminium 6061
Polymer	High density polyethylene
Wax	Paraffin Wax
Catalyst	Stearic acid

2.2 3D modeling using CAD

.The filament extruder on a FDM printer is the part that extrudes the metal filament in a liquid form and deposits it on a printing platform by adding successive layers within the 3D printing volume. The fan blows cold air onto the heat sink, so the heat sink deflects from the upper part of the column and the filament stays rigid. The rigid filament pushes down on the molten filament and additionally creates a pressure or force on the molten filament, thus extruding it out of the small hole in the nozzle. In this project the extruder frame is designed by using the computer aided drawing (CAD) a universal joint designed.

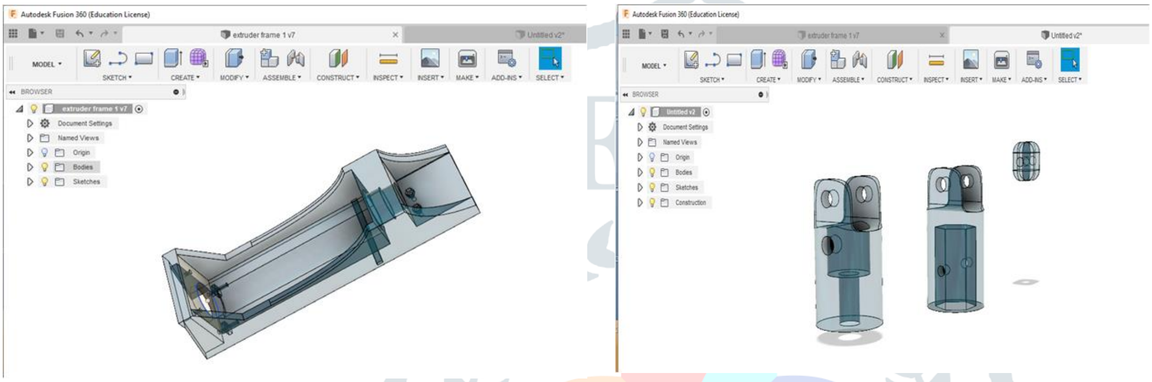

Figure 1 Extruder frame and part

III. EXPERIMENT AND DISCUSSION

3.1 Material composition

For the formation of optimised feedstock different metal and binder composition experimented and for the 3D metal printing process 50%-50% volume composition was chosen. The different composition experimented was listed in below table. The materials used in the study are: paraffin wax, high density polyethylene, stearic acid and aluminium 6061 metal powder.

Table 3.1 Binder composition

HDPE (%)	Wax+stearic acid (%)	Binder name
50	49+1	B_1
30	69+1	B_2

Two type of binder composition prepared and the different properties of binders studied such as viscosity, extrusion temperature and flowability.

Table 3.2 Metal and binder composition

Metal (%)	Binder (%)	Binder Name
50	50	B_1
40	60	B_1
50	50	B_2
40	60	B_2

The first composition rheological behaviour studied which gives high viscosity and highly brittle feedstock was formed. High viscosity could obstruct the capillary impeding the injection process. The rheological properties of feedstocks are important to determine the eligibility of prepared compositions. If viscosity is too low then green parts will produced with low strength. Second composition gives thermoplastic behaviour and the final part is non sinterable. The binder B_2 (40% metal + 60% binder) undergoes elasticity and also it is non sinterable. The binder B_2 (50% Metal+ 50% binder) is chosen for this project. The PW has low viscosity when it is added to the binder it considerably decreases the viscosity. After metal loading, viscosity of the feedstock increases. Feedstocks prepared with this composition with high powder loading do not give any processing problem. So the binder B_2 (50% Metal+ 50% binder) chosen which is optimal for this study. The mixing process was done at 160 degree Celsius temperature in the ratio of 79:20:1. This composition gives good viscosity and is sinterable. The table 3.3 gives the density and weight of the materials used for the feedstock formulation.

Table 3.3 Specifications of materials used

Materials	Density (kg/m^3)	Weight (gm)
Paraffin Wax	900	100
High density polyethylene	970	10.77
Aluminium 6061	2700	23.33
Stearic acid	941	1%

Figure 2 Feedstock before mixing

Fig 3 Feedstock After mixing

IV. CONCLUSION

A new feedstock formulation composed by HDPE and Paraffin Wax was developed to produce aluminium 6061 parts by fused deposition modeling. A systematic mixing and rheological properties study of the different formulations was conducted. The optimum binder mixture was 30/70 with its adequate viscosity value considered. On the basis of viscosity value and torque values, the composition with 50 vol.-% metal powder loading was chosen as the optimum mixture. Bas on different values of composition this was chosen as suitable for fused deposition modeling process.

V. REFERENCE

[1].Fraizer, W.E.J. of MateriEng and perform (2014) Metal Additive Manufacturing: A review, 23: 1917.
[2]. Witkin, D.., Patel, D.N., Helvajian, H. et al. J. of MateriEng and perform (2018).
[3]. Samuel Clark Ligon, Robert Liska, JurgeStamfl, Matthias Gurr, Rolf Mulhaupt., Polymers for 3D printing and customized Additive Manufacturing . Vol.117: issue. 15.
[4]. G. Herranz, B. Levenfeld, A. Varez & J.M. Torralba (2005)., Development of new feedstock formulation based on high density polyethylene for MIM of M2 high speed steels, Powder Metallurgy, 48:2, 134-138.
[5]. Wright, M. Hughes, L.J. & Gressel, S.H> JMEP (1994), Rheological Charactrization of FEddstocks for Metal Injection Molding, Print ISSN 1059-9495.