# Metal Parts From Selective Laser Sintering of Metal-Polymer Powders

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## Abstract

This paper deals with the manufacture of metal parts using polymer as an intermediate binder. Copper electrodes for Electric Discharge Machining were made by Selective Laser Sintering of copper - polymethylmethacrylate powder mixtures followed by gradual binder burnout and subsequent metal sintering. The low density of the fired parts obtained from the present process method results in low strength and mechanical properties. Polymer coating of the metal powder as well as use of optimal particle size distributions can result in higher densities and strengths.

## Introduction

Selective Laser Sintering for manufacture of metal parts by using a polymer binder is being developed at University of Texas at Austin. In this process a polymer is used as a binder for the metal powder in SLS processing to form a green metal part. The green part is subsequently fired under reducing conditions to obtain the pure metal part. The SLS process has been described in detail in literature[1, 2]. We are currently using Polymethylmethacrylate (PMMA) as the polymer binder for copper powder in SLS. PMMA has good flow, is stable under the laser beam, and readily decomposes cleanly to gas in a reducing atmosphere.

## Results and Discussion

Copper Electrodes for Electric Discharge Machining(EDM) were manufactured using PMMA as binder in SLS followed by a gradual postprocessing step in a hydrogen furnace. Fig 1 shows the firing cycle used for the manufacture of the copper electrodes. Fig 2 shows the green and fired electrodes. The fired electrode was tried out for EDM to make a mold in a steel block and this was compared with an electrode made by investment casting. The electrodes made by SLS showed a high rate of erosion. This is due to the fact that the fired density of the copper parts was 48% of the theoretical density. We feel that increasing the final density of the parts would go a long way in making the parts competitive to those made by casting. Strength of a part is proportional to its porosity. Knudsen[3] reports that the equation by Bal'shin could satisfactorily represent the relation of some data on the porosity and tensile strength of porous sintered copper powder compacts. Equation (1) shows the relation between strength and porosity.

$$S = S_0 D^m \qquad (1)$$

where $S$ = Strength of porous part

$S_0$ = Strength of the fully dense part
D = Relative density (1- porosity)

The value of m varies between 3 and 6 for metal-ceramics. The copper parts made by SLS showed a strength of 1164 psi which is about 4% of the tensile strength for copper.

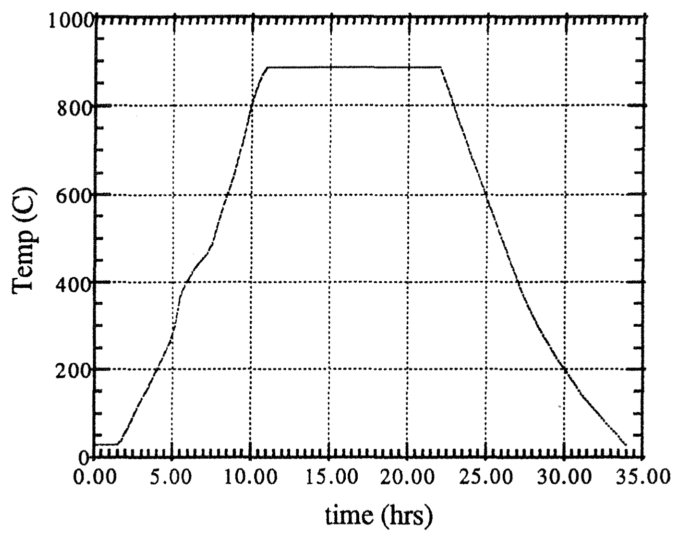



**Fig 1. Firing Cycle for Copper-PMMA Parts**

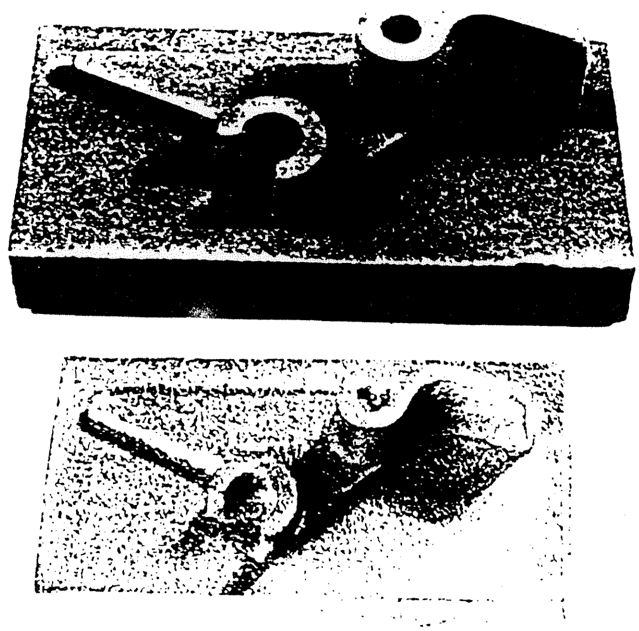


**Fig 2. Green and Fired Copper Parts from SLS**

High fired densities result from having a high green density and optimal firing conditions. Green density of parts can be enhanced by increasing the bed density in SLS. Reed [4] has reviewed the particle packing characteristics of powder systems. Use of mixtures of particle sizes increases the bulk density of powder compacts because the smaller particles can fit into the interstices between larger particles. Fig 3 shows the effect of bimodal distribution on packing density for a copper powder system. An increase of 12% in bed density is seen when we have 60% powder as large particles.

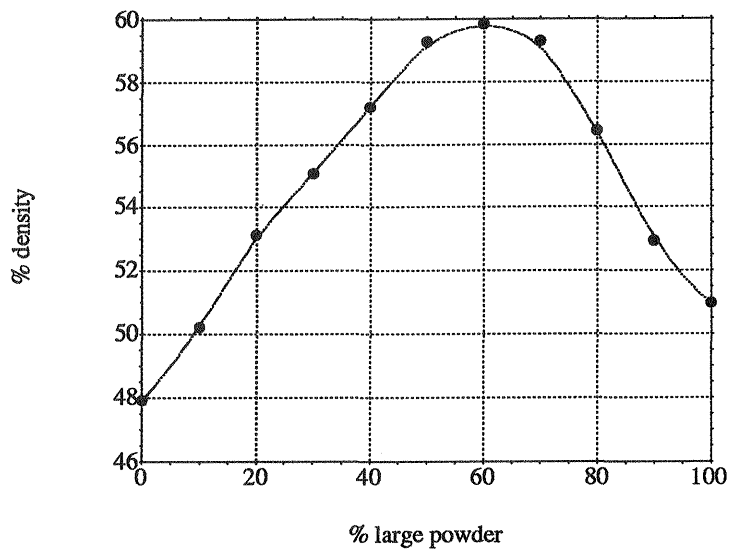



**Fig 3. Effect of bimodal size distribution on bed density**

Processing of polymer coated powders in SLS has shown that polymer coated powders on SLS processing yield parts that have greater green strength and density than mixed powders. This has been studied for the ceramic system[5]. The data for the polymer coated ceramic powder shows a twofold increase in strength for the same polymer composition. Moreover coated powders are homogenous in composition at all points. This provides the rationale for using coated metal powders for making metal parts. Coating of metal powders was carried out by suspending the metal powder in a polymer emulsion and spray drying the same. The result is a polymer coated metal powder which can be directly used for SLS processing. The main issue in the spray coating of the metal powder is that the metal powder settles down and clogs the feed tube and atomizer wheel in the spray dryer assembly. This problem was overcome by using a viscosity enhancing gum to prevent the settling. Figure 4 shows the atomizer used for spray coating metal. Fig 5 shows the solution viscosity data for different viscosity enhancers. A vaned atomizer was designed to prevent clogging in the wheel. The spray dryer operating conditions for coating copper (5-10 μm) with a UCAR 430 latex (styrene - methyl methacrylate - acrylic acid copolymer ) and polyox 6000 as viscosity enhancer are given below :

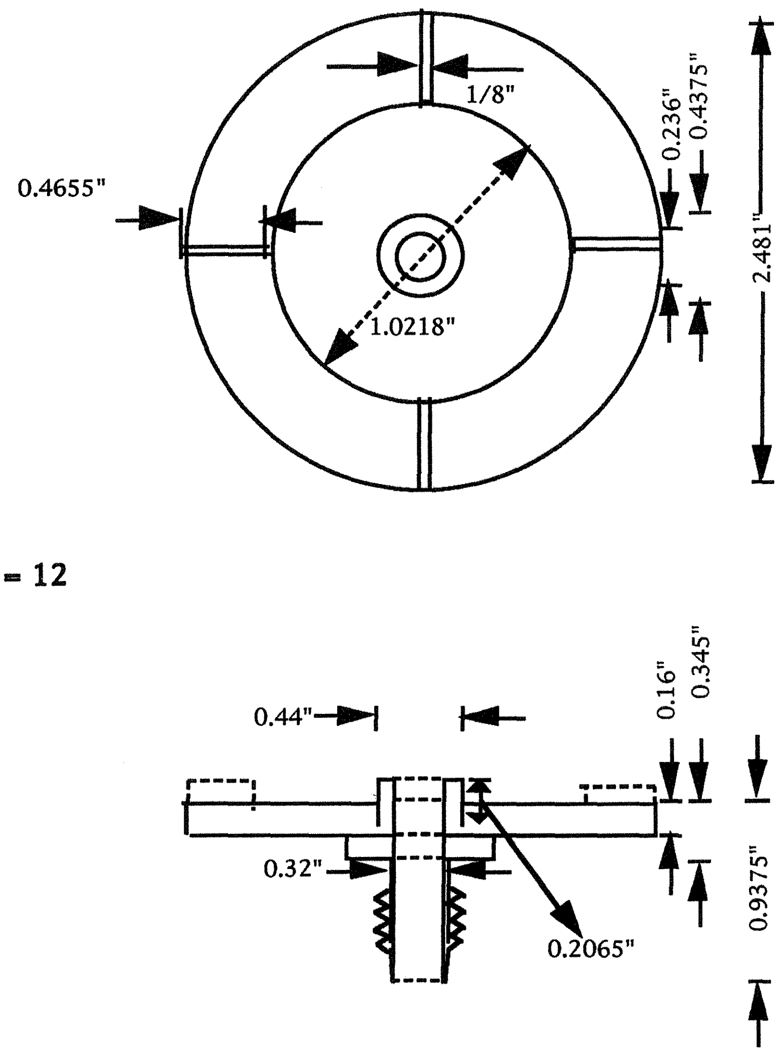
| | | |
|---|---|---|
| Inlet temperature | = | 125 ° C |
| Outlet temperature | = | 150 ° F |
| Atomizer Speed | = | 32000 rpm |

Figure 6 shows the Scanning Electron Micrograph of a polymer coated copper agglomerate.

**Top View**

**Number of slots = 12**

**Cross Section**




**<u>Fig 4. Vaned Atomizer Wheel for Spray Coating of Metal Powders.</u>**

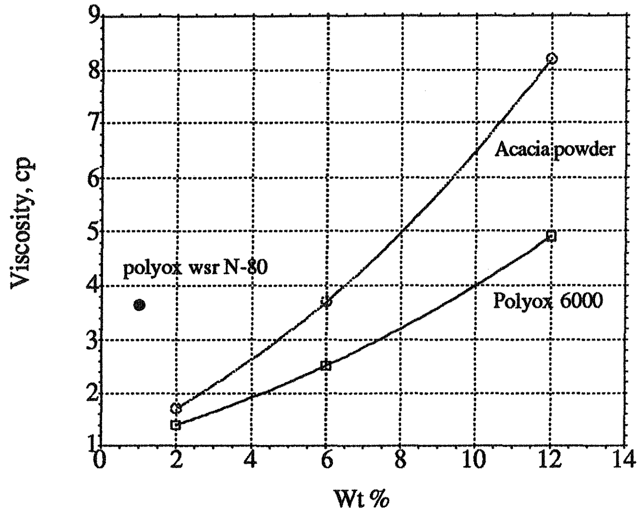



**Fig 5. Viscosity vs concentration for different viscosity enhancers**


**Fig 6. SEM picture of Copper coated with UCAR430 polymer**

## Summary

The SLS process has been used to manufacture metal parts using polymer as an intermediate binder. This process would be profitable if we could manufacture high density metal parts. High fired density of parts depends on the green density of parts from SLS and the firing cycle. Future work will focus on use of polymer coated metal powders and optimzation of firing cycle.

## References

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