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Study on Machinability of Laser Sintered Materials Fabricated By Layered Manufacturing System: Influence of Different Hardness of Sintered Materials

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Abstract

This paper investigates machinability of laser sintered materials fabricated by layered manufacturing system. Different types of sintered materials; chromium molybdenum (SCM) sintered material and maraging steel (MAS) sintered material were fabricated by using selective laser melting (SLM) method. Measurement of cutting force and cutting temperature were carried out by using ball end mill in order to understand the influence of different hardness of sintered materials on machinability. Bulk carbon steel (JIS S55C) was selected as reference steel. Experimental results show that MAS sintered material is difficult to machine material where cutting force of MAS sintered material was higher than SCM sintered material. However, even though MAS sintered material has higher hardness than SCM sintered material, cutting temperature was low due to high thermal conductivity. From these results, MAS sintered material can be considered as good material to produce mold due to its high hardness and good machinability.

Keywords: selective laser melting; high speed milling: hardness; cutting temperature; maraging steel; chromium molybdenem steel;

1. Introduction

Recently, layered manufacturing has become a popular topic among researchers and manufacturers, and one of the examples is milling-combined laser sintering system. Milling-combined laser sintering system is a rapid tooling machine that combines laser sintering of fine metallic powder and high speed milling processes. This system is developed to manufacture molds, prototypes and tools with high dimensional accuracy and good surface roughness in just one process. By employing this technique, even a complicated mold can be manufactured in shorter time and also requires less production cost[1]. However, due to the rapid heating and cooling during the laser sintering process, the repetition of thermal expansion and shrinkage generate residual stress within the sintered structure which causes deformation and micro crack problems[2]. In addition, laser-sintered material can be considered as difficult to machine material due to its porosity and inhomogeneous in terms of its mechanical and thermal property. Therefore, production of mold with superior strength, toughness and also good machinability are very important.

In this research, two types of metal powder were used to produce laser sintered materials by using selective laser melting (SLM) method. Fabricated sintered materials were totally different in hardness and in order to understand the characteristic of the sintered materials,

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hardness, thermal conductivity, residual stress and deformation were also measured. After that, high speed milling was performed to investigate the machinability of the sintered materials. Cutting force and cutting temperature of both sintered materials were experimentally measured using ball end mill with 6 mm of diameter. The cutting temperature was measured by using a three-color pyrometer which was developed by one of the authors[3]. Bulk carbon steel (JIS S55C) was selected as reference steel.

2. Properties of Sintered Materials

2.1. Milling-combined laser sintering system (MLSS)

Concept of milling-combined laser sintering system is illustrated in Fig.1. The system consists of two alternating processes, which are forming sintered part by selective laser melting (SLM) and high speed milling for surface finishing. By using CAD, a 3D model was divided into sliced layers and transferred to the MLSS. Before the sintering process started, a sandblasted steel base plate was placed on the forming table. The powder table was lifted up while the forming table was moved down respectively, and the predetermined layer thickness of metal powder was deposited on a base plate by the recoater blade. Subsequently, the laser beam was irradiated on the layer of the deposited metallic powder according to the CAD data. After forming a few layers of sintered material, the high speed milling process is executed at the periphery surface. These processes were repeated until a complete model was created and were performed in a nitrogen atmosphere at room temperature to prevent oxidization.

2.2. Metal Powder

In this paper, two different types of sintered materials; Chromium molybdenum steel (SCM) sintered material and maraging steel (MAS) sintered material were made by using selective laser melting (SLM) method. The sintered materials were fabricated using different types of metal powder. Fig. 1 shows scanning electron images of (a) SCM powder and (b) MAS powder, respectively. Characteristics of both metal powders are shown in Table 1. The mean particle size of both metal powders is 30 μm. Thermal conductivity of SCM powder is 9 W/m·K and MAS powder is 17 W/m·K, respectively, which were measured using a technique developed by the author[4].

2.3. Sintered materials

Sintered materials were made by the MLSS without performing the milling process for purpose of cutting force and cutting temperature measurement. The characteristics of the sintered materials were summarized in Table 2. Both SCM sintered material and MAS sintered material were fabricated by using selective laser melting (SLM) method at the optimum laser energy density. Thermal conductivity of sintered materials was measured by using laser flash technique where thermal conductivity of MAS sintered material was found to be higher than SCM sintered material.

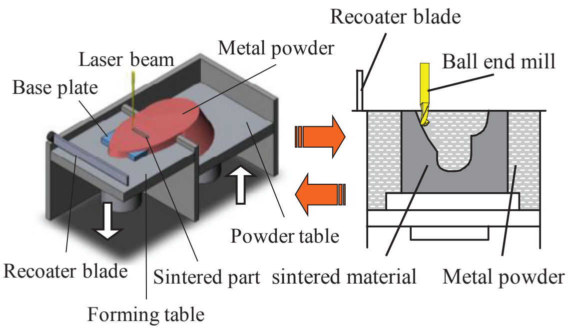

Fig. 1. Concept of milling-combined laser sintering system

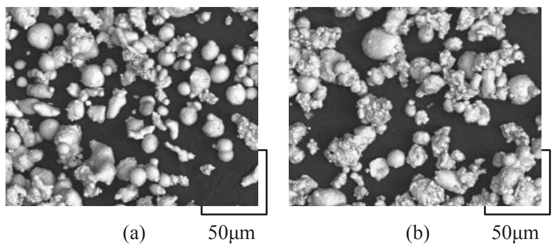

Fig. 2. Scanning electron image (a) SCM powder (b) MAS powder

Table 1. Properties of metal powders

Metal powder	SCM	MAS
Particle diameter (μm)	30	30
Powder density (kg/m^3)	4406	4260
Thermal conductivity (W/m·K)	0.15	0.25

Table 2. Properties of sintered materials

Sintered material	SCM	MAS
Energy density	4.5	6.1
Density (kg/m^3)	7680	7585
Thermal conductivity (W/m·K)	10	17