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Susilo Adi Widyanto
Jurusan Teknik Mesin, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia, susilo70@yahoo.com

Alva Edy Tontowi
Jurusan Teknik Mesin, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

Jamasri Jamasri
Jurusan Teknik Mesin, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

Heru Santosa Budi Rochardjo
Jurusan Teknik Mesin, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

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DEVELOPMENT OF LOW FREQUENCY VIBRATION METHOD OF DIRECT-WRITE DEPOSITION RELEVANT TO LAYER MANUFACTURING APPLICATION

Susilo Adi Widyanto, Alva Edy Tontowi, Jamasri, dan Heru Santosa B.R

Jurusan Teknik Mesin, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia

E-mail: susilo70@yahoo.com

Abstract

The research of deposition process is the first step in development process of multi materials selective laser sintering. The deposition process enables to settle multi materials powder in horizontal formation on one layer. In this research we use low frequency (70 - 200Hz) to vibrate a hopper nozzle in which powder is settled. The research method consists of two steps, the first step is to determine flow-ability parameters and the second is to join flow ability parameter with other parameters such that the line width can be controlled. The results show that the line width depends on uniformity of particle size, particle size, frequency of vibration, deposition gap, particle shape and feed-rate of hopper-nozzle.

Keywords: deposition, low-frequency, particle shape, deposition gap

1. Introduction

The key in multi materials selective laser sintering development is the design of powder delivery subsystem. At present, commercial SLS machines use a roller device to sweep thin layers of a single powdered material across the built area. One construction of material delivery which can be possibly applied in multi material selective laser sintering is a hopper nozzle construction.

Many researchers have conducted material deposition based on using hopper nozzle. Tseng [1] developed Adaptable Filament Deposition (AFD) which used a resistively heated delivery head to melt thermoplastic wire-like filaments. With x - y position controller, semi molten filament can be deposited to the location where the object is to be fabricated. Tseng [2] also developed Planar Layer Deposition (PLD) which used an adjustable planar nozzle for the formation of variable wide semi-solidified sheets. The sheets pass through a pair of rollers for pressing, cooling and leveling. Gravity flow deposition was developed by Kumar *et al* [3]. His method uses modification of Beverloo's correlation Beverloo's *et al*. [4] given by:

$$G_s = C\,\rho_B \sqrt{g}(D_0 - kd)^{2.5} \text{ g/s} \qquad (1)$$

where G_s is the mass flow rate of particles (g/s), C is an empirical constant, ρ_B is the bulk density of powder (g/mm^3), g is the acceleration due to gravity (mm/s^2), Do is the hopper orifice diameter(mm), k is an empirical constant for particle shape, and d is the mean particle diameter. C and k are dimensionless constants and they take value 0.583 and 1.4 respectively. It was later shown Spink and Nedderman [5] that Beverloo's correlation is valid only for powders of particle size greater than 500µm. On the next step Kumar and Das have proven that the Beverloo's correlation is also valid for powders of particle size 63-150 µm, but with values of C = 0.604 and k=2.86. Kumar *et al.,* [3] also developed Pressure-assisted flow. Gas pressure assistance was used to fluidize these powders in hopper nozzle. But with this method, the powder spurted out with very high velocity in an undesirable manner when the column height was low.

In the same time, High frequency vibrated-assisted flow was developed by Kumar *et al* [3]. They used a range frequency up to 15 kHz with amplitude of 3 µm. In this research Kumar *et al* used a hopper nozzle of 0.5 mm orifice diameter and particle size on screen 270-325 and 325-400 mesh. The result is shown in Figure 1. According to Figure 1, powder flow-ability in frequency range under 8 kHz is not presented. Kumar *et al.* [3] used an extensional piezoelectric strip actuator contacting the nozzle exterior was placed in proximity to the tip of nozzle. This actuator has a resonance frequency of 29 kHz, free deflection of 3.4 µm and can be actuated in the 0-25 kHz range using a power amplifier.

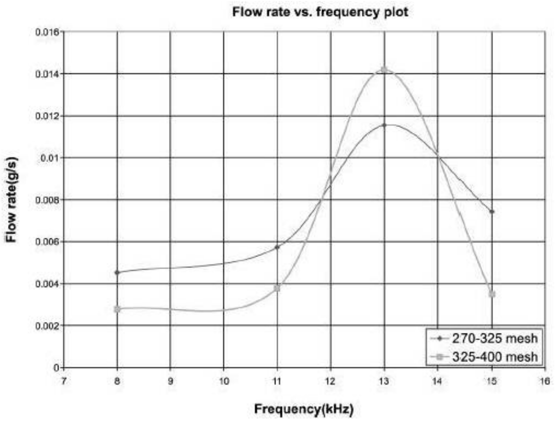

Figure 1. Plot of Flow rate vs frequency on high frequency vibration method [3]

In this research we developed a powder deposition method which used a frequency range up to 200 Hz with the amplitude of 150 µm . With this method, we can use a simple and inexpensive actuator which is vibrated by a magnetic pulse generator. The goal of this research is to determine an optimal parameter of powder flow-ability for controlling line width of pattern deposition.

2. Methods

The wall of hopper and nozzle uses PVC material and nylon respectively. Diameter of nozzle orifice is 0.8 mm which is made by drilling process. The dimension of hopper is shown in Figure 2.

In pattern deposition experiment, a hopper nozzle is handled by double-cantilever beam which is made by metal sheet of carbon steel material. The cantilever dimensions are 50 x 12 x 1.5mm. As vibrator system of double cantilever beam is used an electromagnetic pulse generator which bound on up side of it. In this experiment, the location of pulse generator is selected in the end of cantilever beam construction (near of hopper nozzle position).

The experiments used a frequency range of up to 200 Hz with 150 µm amplitude. The parameters of flow-ability examinations consist of: particle size, uniformly particle size and particle shape. Powder flow-ability was measured by measuring the weight of powder per second (flow-rate).

Pattern deposition experiments are conducted by 2 axis plotter, and its parameters are deposition gap and feed-rate of hopper nozzle displacement. The dimension of line width was measured by millimeter block that was placed under glass plate.

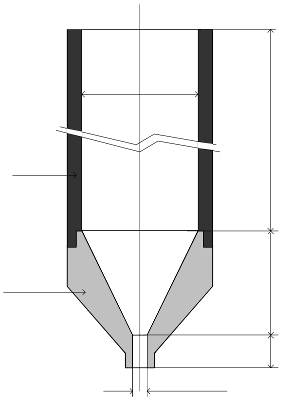

Figure 2. Hopper nozzle

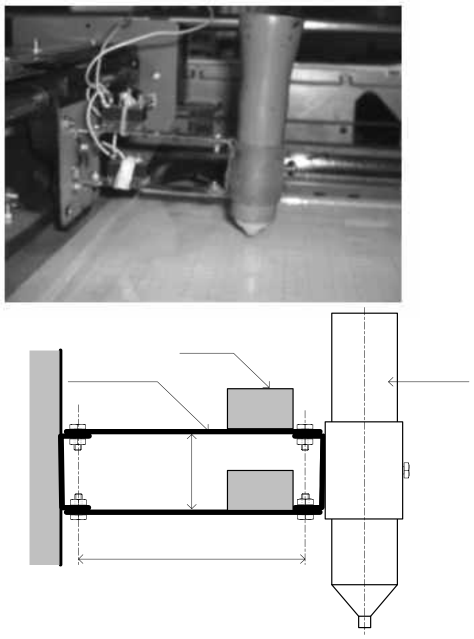

Figure 3. Double Cantilever beam and the location of pulse generator

3. Result and Discussion

Results of the research consist of powder flow-ability and line deposition. In the flow-ability experiments, correlation between the particle size and flow-ability can be shown in Figure 4. According to Figure 4, the dimension of particle size influenced the frequency range and powder flow- ability. The smaller of particle size tends to narrow the frequency range. Powder Flow-ability is increased by decreasing of particle size.

While the correlation between uniformity particle size and flow-ability is shown in Figure 5. Based on Figure 5, the flow-ability frequency range of 75 - 150 µm stainless steel particle is longer than the one of mixing of 38-75 µm and 75-150 µm stainless steel particle.

Powder flow-ability also depended on particle shape. Based on Figure 6, flow-ability of spherical particle shape (stainless steel powder) is higher than the one of irregular particle shape (aluminum powder).

The results of pattern deposition experiments show that the line width depends on particle size, deposition gap (the distance between nozzle orifice and the surface of glass plate) and feed-rate of hopper displacement.

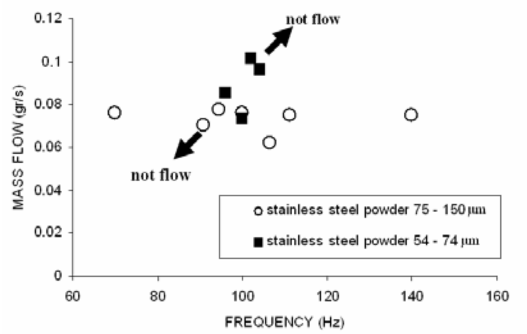

Figure 4. **Correlation between uniformity particle size and flow-ability**

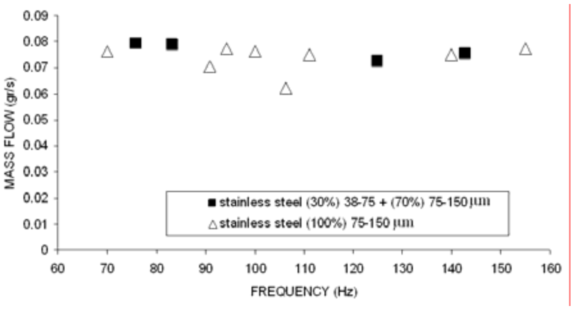

Figure 5. **Correlation the uniformity particle size and flow-ability**

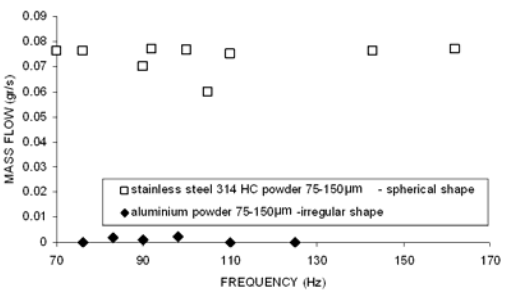

Figure 6. **Mass flow of stainless steel and aluminum powder which depend on their particle shapes**

4. Conclusion

In low frequency vibration system of hopper nozzle, the uniformity of particle size determines the frequency range of flow-ability. In particle size range of 38-150µm, powder of 75-150µm in diameter has a largest frequency range. Powder Flow-ability is influenced by the particle shape. The flow-ability of spherical particle shape is higher than irregular particle shape. The dimension of line width deposition depends on particle size, deposition gap and feed-rate of hopper nozzle displacement. Increasing of deposition gap and particle size would be widening the line width, while increasing of feed-rate would be narrowing the line width.

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