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TESTING POWDER DISTRIBUTION METHODS FOR SELECTIVE LASER SINTERING

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Abstract: *Selective laser sintering technology can be used to create three dimensional objects out of various materials. This method uses a high-powered laser to solidify powdered material into thin layers which are produced sequentially on top of one another until the object is finished. The powder layer thickness and uniformity directly affects the resolution and quality of the object. The adjustability of the powder distribution apparatus allows the use of various materials and provides a method for system optimization. Modular construction of these components is a priority and will allow future modification with relative ease.*

Key words: 3D printing, polymer, powder

1. INTRODUCTION

Additive manufacturing (AM) is an umbrella term referring to a wide set of technologies that use the method of slicing a three-dimensional (3D) computer aided design (CAD) model to layers and then forming these layers one by one into a complete product. [1] A commonly used synonym for additive manufacturing is 3D printing, but because this term also refers to a specific additive manufacturing method, American Society of the International Association for Testing and Materials (ASTM) recommends using the term additive manufacturing instead [2].

The Selective Laser Sintering (SLS) technique can be described as follows. The workpiece is formed by distributing a thin layer of powdered material, typically 0.1mm onto a working platform. Material is then melted by a laser to form the geometry layer described by the CAD model. This cycle is repeated until the desired shape has been produced. The workpiece (or pieces, several parts can be formed simultaneously) is formed into a box of powdered material and this defines some of the fundamental properties of the technology. [1] Workpiece support, which is needed for fused deposition modeling (FDM), is not an issue as the unsintered powder supports the workpiece. [2]

The method is not without limitations however. For example, selecting SLS as the manufacturing method hinders the use of enclosed internal features, as unnecessary powder is trapped inside an enclosed structure. This largely eliminates one of the major upsides of additive manufacturing described by [2] as being the capability to include support structures inside a construction.

There are currently two major manufacturers of SLS machines: EOS Gmbh and 3D Systems Inc [5]. The manufacturers have some differences in their solutions, mainly in the feeding and preheating of the powder. The powder distribution is achieved either by using a counter-rotating roller or spread out by a blade. The powder is fed to the distribution system either by vertical moving feed chambers or a mixing station. The heating solutions differs mainly in where and what type of heaters are used.

The build capacities range from 200x250x300 mm to 550x550x750 mm, build rates from 7-48 mm/hour with layer thickness ranging from 0.06-0.18 mm. The materials that can be printed are DuraForm®, Polyamide, Polystyrene, Alumide and Carbonmide. The cost for commercial machines ranges from $250,000 to $1 million, making them hard to acquire [6].

To further research in this field, there is a need for a cost effective test rig to allow for materials research. The studies of the type presented in [3] for FDM are very important in the process of making additive manufacturing techniques more mainstream. This type of study presents ways of exploiting the properties of the material and manufacturing method to full extent, but creating such studies require the researchers to either purchase a commercial machine or build their own. The system described by this study provides the research unit with a solid basis to start materials studies from.

The system described by this study was designed with the idea of easily replacing a subcomponent with an enhanced one without requiring a complete redesign of the whole system. The experiment itself builds on the results of a study performed by another team on the same subject a year ago [4].

Providing an efficient and reliable system to distribute and collect the powdered material is the main research goal of this study.

2. METHODS

This study addressed the powder distribution method and apparatus. The focus was to develop a system that could operate without user interference for an extended period of time. Because the SLS process is time consuming, it is not feasible for the user to oversee the process continuously. Because the device would be used for research purposes, it would need to be constructed in a way that allows future developments to be implemented easily. The structure of the design can be seen in the schematics in Fig. 1 and Fig. 2.

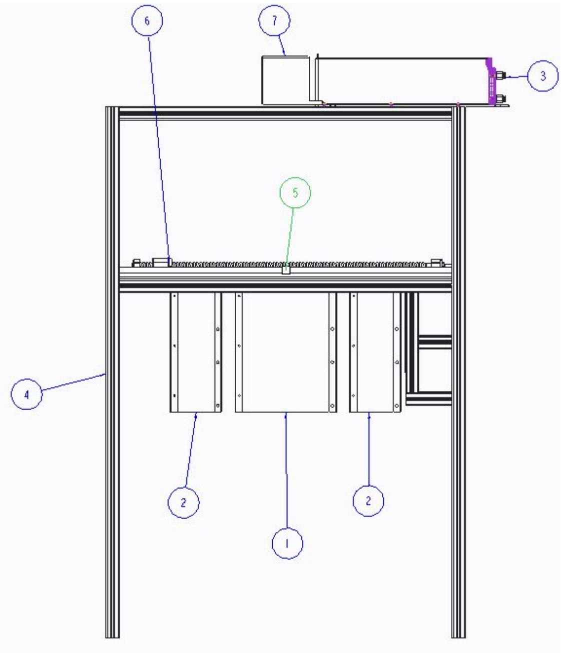

Fig. 1. Front view of the proposed apparatus.

The main components of the SLS apparatus have been denoted in table 1. The assembly is not limited to these components but these are the ones most interesting from the point of view of this study.

Part No	Description	Quantity
1	Main elevator and build platform	1
2	Feeder elevator	2
3	Laser	1
4	Frame	1
5	Guiderail	2
6	Blade	1
7	Flyer	1

Table 1. BOM for the SLS apparatus

The design can be roughly divided into following main functions.

2.1 Frame

Firstly, a frame is needed to hold the machine together and provide fixing points for the necessary attachments. The criteria for the frame solution would be to be rigid enough to provide enough stability for the printer to function correctly. The starting

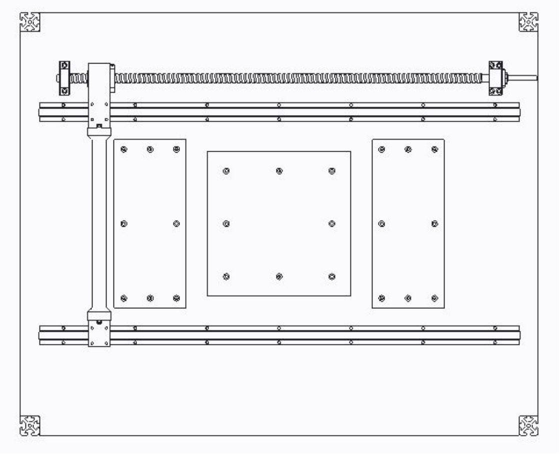

Fig. 2. The working area of the apparatus.

point was a modular frame combined with a sheet metal table top to provide fixings for the guide rails. This initial state was enhanced by providing additional rigidity to the working platform by the means of the extra elevators.

The design can be roughly divided into following main functions.

2.2 Feeder elevators

Secondly, a system to provide more powder into the process is needed. Again, simplicity was determined to bring most value. A simple solution was determined to be system of two feeding elevators deep enough to provide adequate amount of reserve powder to ensure autonomous function. The elevators can be seen in Fig. 3.

Being able to function without supervision was deemed to be of importance because of the possible long production cycles of an additive manufacturing machine. The solution was determined to be two feeder elevators are controlled via a ball screw and a stepper motor just as the build platform is. This allows for each elevator to alternate in a feeder elevator and overflow bin role. One will raise up and provide powder to the blade for spreading and the other will be lowered for collecting excess powder and allowing it to be recycled in the following iterations of the process.

Fig. 3. Feeder elevators

The most central function of the apparatus is naturally the main elevator, housing the build platform and its' actuators, shown in Fig. 4. The laser stays stationary and the build platform will move down after each layer is completed. This allows for very precise movement, 25 µm of each platform so the optimal layer thickness can be found. The layer thickness may need to change depending on the material that is being used. This study was completed using a nylon based powder.

Fig. 4. Main elevator

2.3 Powder distribution

After providing more material into the process, a system to add powder onto the working platform is needed. The simplest solution found was a horizontal blade moving along guiderails, actuated by a stepper motor. The blade would sweep the powder fed by the elevators to the working platform, evening the powder at the same time. The blade is designed to be easily replaceable if changes are needed. The blade design is shown in Fig. 5.

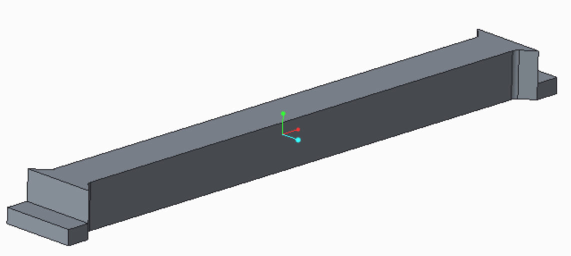

Fig. 5. Blade design

2.4 Laser

Once the material has been evened out on the working platform, the device uses a laser to sinter the powder into a solid form. The laser is a water-cooled version of Synrad Firestar Ti100 series with 100 W power, using a FH flyer head to control the x and y movements. The lens of the laser has a focal length from 591 millimeters to 614 micrometers. The software for controlling the laser is provided by the manufacturer. The build area for the machine is 300x300 mm, which is the size of the main elevator.

2.5 Electronics

Along with the mechanical components, a vital part of the design is the electronics needed to control the different functions. Each elevator and the powder distribution system is driven by a Nema 34 stepper motor with 4.5 Nm holding torque, controlled by CWD860 stepper drivers. The 32-bit Smoothieboard [7] microcontroller controls all of the physical movements as well as the laser output. The Smoothieboard is open source and is typically used in FDM devices.

A production machine would also require a heating system to keep the material heated as close to the melting temperature as possible to reduce the energy needed to sinter the powder using the laser. The development of the heating system was determined to be a future development and not in the scope of this research.

2.6 Powder material

The powder material chosen is Polyamide 12, also called Nylon 12. This multipurpose material produces a good resolution and surface roughness, comparable to the earlier standard material polycarbonate, while yielding good strength and durability as well and therefore chosen as a good reference material [8]. Several manufacturers supply this material and provide their own versions.

The average grain size is 56 μm with a printed part density of 0.93 g/cm^3 [9] Usage of other materials are limited to the surrounding print chambers temperature. Polyamide 12 has a melting point of 172-180°C.

3. RESULTS

As a result of this study, a testing rig for SLS related research was designed and built. This apparatus serves the purpose of a starting point to study different aspects of SLS manufacturing, including but not limited to studying effects of different process temperatures, different materials and different design approaches when choosing SLS as the manufacturing method.

The focus was on the powder distribution and achieving a user independent solution that is not highly dependent on process parameters or the material used. A simpler solution than commercially available was achieved, although further research needs to be done on the heating chamber.

The study shows that the proposed solution has a valid design principle and the device fulfills its' purpose well. The apparatus is able to function independently after the parameters are set and the different functions perform as intended. All of the components were either readily available or easy to manufacture.

The study established that stepper motors used in the apparatus proved to be correctly selected in terms of achieving intended speeds and torques. The electronics that had been selected proved to perform acceptably as well. The temperature of the shelf where the electronics were mounted remained at an acceptable level for the duration of a printing run.

4. DISCUSSION

The main contribution of this research was to provide a flexible and modular platform for further laser sintering research. The proposed solution is well suited for use in universities as the structure is very simple and all parts easily available online at a reasonable cost.

The overall cost of the apparatus of this type is naturally determined by the laser, since this kind of a laser sells for in the 20 000 – 30 000 € range. The structure proposed in this study provides for a cost-effective solution around the laser. Comparing to the prices referred to in the introduction of this paper, this would still mean a very cost-effective solution.

The structural parts were manufactured with equipment readily available for university and require only non-professional skill levels to manufacture to the level required by this design. Still the performance of the solution is good enough to suggest a suitable platform for future research project. This suggests that this type of a solution might be feasible for research units compared to commercial SLS machines.

An example of a further study topic would be the construction of a heat insulated working chamber to provide a more suitable temperature for the material to be printed in. This deficiency is currently patched with a very high powered laser compared to the commercial machines.

Another probable possibility of building on the results of this paper would be to analyze the capabilities of this machine and by examining the different layer thicknesses and distributions made by the blade, material analysis could be performed. The selection of process parameters to achieve desired material properties should be analyzed. Naturally, this could be expanded to other materials than the one used in this study.

To reduce the thermal differences in the powder and workpiece, using SLS requires the printing area to be heated to an appropriate level. The material is then close to its' melting point and thus requires only a small amount of energy to be delivered by the laser. [2]

Because of these factors, providing adequate heating and insulation is a critical step in SLS manufacturing machine design. This study provides a starting point for taking that step. Further investigations should be made into how the powder distribution system works with different temperatures.

The properties of the mechanical functions in higher temperatures should be analyzed in order to build an efficient heat insulated chamber. This type of study might also find ways to further enhance the functions proposed by this paper. Depending on the performance of the heating chamber, materials of higher melting temperatures could also be studied.

Other materials which could be tested include glass-filled polyamide, which has a much higher thermal resistance. Alumide is a combination of aluminum and polyamide powders, which enables easy machining and also tolerates high thermal loads. TPU 92A-1 is a material with flexibility, strength, as well as high abrasive resistance. [10]

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