

Development of Freeform Master I - a desktop RP machine based on a new sheet lamination process

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Abstract

A novel process was developed for building Rapid Prototyping(RP) parts using a sheet lamination technique. The building process of existing sheet lamination RP machines consist of the following steps : feeding, lamination and cutting. In this process, the laminated part of an object is often scratched by a cutter or damaged by a laser beam due to the cutting operation after the lamination step. In addition, decubing of the unused portion from the laminated block is difficult. In the new process, however, cutting is performed before lamination. The cutting operation takes place while a paper sheet is firmly attached, using electrostatic force on the plate. Then liquid glue is applied only to the calculated region of the given contour for lamination. This new process aims to manufacture a \$2k RP machine, what we call the Freeform Master I and can use A4 size or letter size sheets of paper. A prototyping machine that demonstrates the concept design was built and further research issues are discussed

Introduction

The rapid prototyping(RP) process is a well known technique that build materials in layers and manufactures some designed form with the cross-sectional data in three-dimensions. This kind of equipment based on RP technique have many merits, such as they can manufacture various forms or shapes. Such machines and the materials they use, however, are very expensive. Therefore, the need for an inexpensive RP machine has increased recently. According to this need, we tried to develop an inexpensive RP machine that uses cheaper materials. Therefore the sheet lamination RP process was chosen to this aim.

In a general RP process, we get information of the cross sections from the corresponding 3D CAD model, the practical model is made through various RP processes and then the unnecessary parts are removed. This research is focused on the process of making a practical RP model.

The current sheet lamination RP process

The existing sheet lamination RP process is discussed in the following steps:

1) Feeding - There are generally two types of paper used in the sheet lamination RP process. Rolling paper is used in process 1 of Fig.1 and it is fed by a roller, and plain paper is used in process 2, and it is also fed by a roller,

2) Gluing & Lamination – The gluing & lamination methods between the two processes are different in accordance with the method of feeding the paper. In process 1, the heat-melted glue is pasted on one side of the paper and the paper is pressed by a heated roller. In process 2, the glue is printed on a piece of plain paper in a laser printer and the papers are pressed with a heated plate.

3) Cutting - In process 1, a laser beam is used and in process 2, a knife is used for cutting.

The sheet lamination RP process can be summarized in brief; feeding - gluing & lamination - cutting.

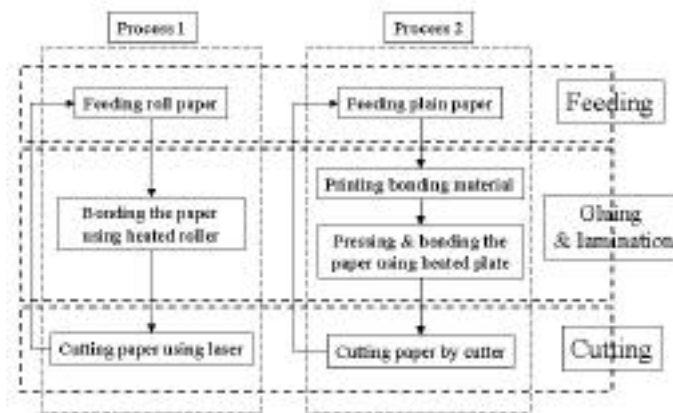


Fig. 1 Two types of sheet lamination process

The problems of the current sheet lamination RP process and solutions

The problems of the current sheet lamination RP process are summarized as follows:

1) Gluing of the unnecessary part - The fact the cutting step is after the gluing & lamination step mean that gluing the unnecessary part, regardless of the need.(process 1)

_ Perform the gluing & lamination step after the cutting step.

2) The damage of existing layers - The layers which have already been made can be damaged by cutting after the gluing & lamination step.(process 1, process 2)

_ Perform cutting before the gluing & lamination step.

3) Fixing the first layer of materials and removing them - There are some problems in fixing the first layer of materials and detaching it from the plate since cutting is done after gluing & laminating in the current sheet lamination RP process.(process 1, process 2)

_ Fix and detach the first layer of materials by using an electrostatic force.

The requirements of the new sheet lamination RP process

To solve the problems of building the unnecessary part and damaging the existing layers, we changed the working process from a 'cutting step after the gluing & lamination step' to 'the gluing & lamination step after cutting'. To solve the problem of fixing the first materials we fix and detach the first layer of materials using an electrostatic force. Overall, we changed the existing sheet lamination RP process from 'feeding _ gluing & lamination _ cutting' to 'feeding _ cutting _ gluing & lamination' and defined the basic functions as followings.

- Feeding - feed A4 size paper.
- Cutting - cut the paper or materials.
- Gluing & lamination - glue and press the paper or materials after spraying the glue only on the necessary part.

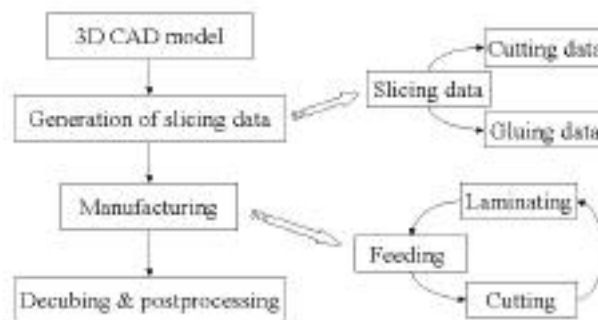


Fig. 2 Overview of the proposed process

To develop this new process, we arranged the necessary conditions as follows:

1) Feeding.

- Sheets of paper must be fed one after another.
- Transportation to the place of manufacturing must be easy.

2) Cutting

- A place for cutting is necessary.
- We must fix the paper so that it can be firmly attached to the plate while cutting.

3) Gluing & lamination

- The glue must be sprayed only to the necessary part selectively.
- The materials must be pressed for safety adhesion.
- A plate to fix the first layer is needed.

The process and device for the new sheet lamination RP

The detailed process based on the preconditions is as follows:

- 1) Feed the materials - feeding device
- 2) Carry the materials to the place of cutting and glue spraying - conveying device
- 3) Cut the materials - cutting device
- 4) Spray the glue selectively only to the necessary region which is already built - spraying device

5) Build the materials - lamination device

We modularized all the devices after we organized all the necessary steps. The cutting device(3) and the spraying selectively device(4) are similar in their functions, because they are operated along the cross sections from a 3D CAD model. So we united the two devices. Therefore, all the process is operated through 4 modules; feeding device, conveying device, cutting/spraying device and lamination device.

(1) Feeding device

The feeding device is used to feed the materials into the unit. If the user of this machine feeds materials in preparation of the whole process, then this device will help by feeding the papers one sheet after another to the cutter. This feeding device makes the shaked papers move up and down so that it can carry one sheet of paper after another by the electrostatic panel.

(2) Conveying device

This device carries papers from the feeding device to the lamination device. It carries each sheet of paper after it has been fixed to the electrostatic plate by the electrostatic force.

(3) Cutting/spraying device

This device cuts the piece according to the cutting information the user inputs after the paper has been fixed tightly on the plate by the electrostatic force. After cutting, the glue is selectively sprayed on only the necessary region according to the information the user inputs. Cutting is performed with knife, and spraying of the glue is performed through a nozzle using the vapor pressure.

(4) Lamination device

After the cutting and spraying step is finished, the lamination device moves up and down, and press the cut materials on the part where the glue have sprayed. The electrostatic force is used to fix the first layer and laminated papers until the whole building process is finished.

A rapid prototyping equipment applying the electrostatic force(Freeform Master I¹)

The real size of the Freeform Master I which was made based on these functions, is 1070 mm _ 760 mm _ 720 mm and its working space is 247 mm _ 160 mm _ 150 mm. The prototype machine developed is shown in Fig. 3.

¹ The proposed RP machine based on the new sheet lamination process is named as the Freeform Master I.

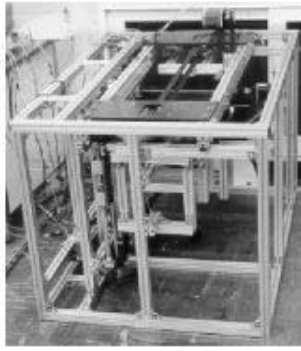


Fig. 3 The Freeform Master I(left) and the CAD model of Freeform Master I (right)



Fig. 4 The CAD model (left) and manufactured parts(right) by Freeform Master I

The time required to build parts with this machine differs according to the shape and complexity of the part. It took 120 seconds to finish one cycle of the process in making simple shaped part as shown in Fig.4.

Conclusion

In our prototype machine, we simplified the RP process and reduced the cost and the complexity of the system using an open-loop control. The new process proceeded using a 'lamination step after cutting', while any materials can be used if they are nonconductive materials, because they need to be fixed by an electrostatic force. Moreover, we can use any used papers in this machine, if they are not damaged in their size and shape. Therefore, we are sure that this machine can contribute in the reduction of the expense as well as it can contribute for reusing of resources.

We are going to further develop this machine to make it more convenient and reliable so that it can be used in daily life and as a teaching aid in schools. Moreover, if the bulk of it is reduced, we can use it as a peripheral, too.

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