Method for Rapid Prototyping by Using Linear Light as Sources

S Y Lee, M R Wang, C Y Chen, C L Chen, S J Hwang, H Chen, W H Lai, L T Shyng and C C Wang
Mechanical Technology Research & Development Center, NCKU, Taiwan, China
1 Professor of Mechanical Engineering Department, NCKU, Taiwan, China
Director of Mechanical Technology Research & Development Center, NCKU, Taiwan, China

Abstract. A new method for rapid prototyping by using linear light as sources is present. The material experienced two times of physical and chemical changes so as to have stronger mechanical features. The material with weaker feature is supported by the material having stronger features and the two types of materials can be separated by proper methods. Therefore, the 3-D object can be obtained within a short period of time.

1. Introduction
Typically, a complete process for developing a new product from design, making a prototype, management of production processes, mass production to introducing the product to the market, there always need a prototype for evaluation and examination. Thus, a prototype that is easily manufactured and amended is an important factor for a successful product. How to manufacture the prototype that meets needs is crucial for not spending too much manufacturing cost.

There are numerous methods available for prototype production such as the conventional manual production, CNC milling and carving machine. As for the conventional manual model production, except for experiences, it lacks precision. The CNC milling or carving machine is also confined to the types of chucks, bits or the size of the machine.

With the improvement in technologies, the quick growth of CAD package software has distinguishably shortened the development cycle for new products. For the past few years, the industry of Rapid Prototyping has well integrated with the CAD and production technologies and remarkably improves the efficiency for product design. The methods of quick formation can be classified as Layer Manufacturing, Automated Fabrication, Freeform Fabrication and Solid Imaging, etc. For the continuous development of past decades, there are ten more types of RP models available in the current markets. The methods of rapid formation can, according to the use of energy resources, be classified as Light Illuminating Processing, Stick-Formation processing and Complex Formation Processing. According to the documentary records, we classify the production process for rapid prototype making in terms of work piece properties, energy resources types, and stacking types.

Some conventional production processes are as follows:
(1) SLA (Stereo-Lithography) [1]:
It is currently the most widely applied processing method with the formation by means of Stereo-Lithography Formation. This production process is designed with He-Cd or Ar+ ultraviolet laser galvanometer-mirror to scan and illuminate the fluid polymers (light hardening resins). The resin required for formation becomes a thin film (around 0.15mm–0.05mm). Then, with the descending of
Z-axis, the work piece zone is coated with a layer of liquid polymers. By using a scraper to destroy the surface tension of the liquid polymers, one obtains a flat surface. The liquid polymer is then scanned by laser beams so that the layers are combined firmly. A -D solid work piece is obtained by repeating the previous steps.

A U.S. Patent owned by 3D Systems, USA, filed on August 8, 1984, issued on March 11, 1986. The patent application dominates most of the market.

The shortcomings of the SLA are:
- Establishing support is required;
- Because of liquid resins, the material buckets must be completely filled so that the material cost will be high.

(2) SLS (Solid Laser Diode Plotter System) [2]:
Illuminating the hi-molecule resin powders by hi-power laser to sinter and the resins are melted and affix to the work pieces to form a thin layer. After that, the Z-axis of the machine descends and a new layer of powder is spread on the work piece by using a scraper. The outer layer is then sintered by the laser beams. By repeating the procedures, an overall 3-D solid work piece is obtained.

The typical problems of the SLS are:
- The powder cannot be spread evenly by using rollers or scrapers;
- The powder needs a long period of time to be warmed which prolongs the working hours;
- The powder easily causes flaying dust and potentially harmful to human health.
- The powder is difficult to be heated evenly;
- Unavailable for the production of large work pieces.

(3) FDM (Fused Deposition Modeling) [3]:
The powder of work piece is pre-mixed with binder to form elongate stripes, the stripes are heated and melted and using nozzles to feed for production. The main defect of this method is that the surface of work pieces is rough and requires for support.

(4) 3DP (Three-Dimensional Ink Jet Printer) [4]:
It is also known as 3-D printing. This method establish a thin layer of powder and selectively sprays adhesive on the surface of powder by method of jetting such that the powder is affixed and form a thin layer on solid work pieces. By repeating the procedures, we can finish the production of 3-D solid work piece.

The shortcomings of the method are:
- Due to the formation is fully depended upon nozzles, the precision of nozzles is high.
- It will come with inferior precision.
- The materials of work pieces can only be porous items.
- The powder cannot be spread with uniform densities.

(5) OBJet [5]:
OBJet is also a type of 3-D printing process. The OBJet is designed with 2 different types of materials. One type of the materials is the material to create the 3-D solid work pieces and the other type of material is used as support for the models of work pieces. With the OBJet method, the nozzles are filled with two different types of materials and then use the ultraviolet radiation to make maturity of the materials of work pieces and the strength will be also enhanced. The materials used as support finally becomes gel type substance. By repeating the foresaid procedures, we can finish the 3-D solid work piece.

The OBJet production process is featured with the advantages like high quality, high precision, cleansing and speedy operation. However, within the production process, the most important component is the nozzle. If the nozzle control is inferior, the precision of finished products will be much more defective. The nozzle of high precision is quite expensive but results in frequent congestion and this situation will significantly affect to cause much production cost.

(6) DLP (Digital Light Processor) [6]:
DLP is also a type of stereo lithography process and the differences compared with SLA are that the SLA is meant to harden the resin by laser. Because the laser beams are thin and linear laser beams, thus, it will prolong the production process. Also, the cost for using laser as ignition resource is high. DLP (Radiation Hardening Formation) is radiated with the light radiated from halides and it is further controlled by DMD Digital Micro mirror Device) for the hardening radiation directly onto the resins. Because the light source of DLP is able to illuminate a certain zone, it can significantly shorten the working hours. The DLP production process is controlled by DMD for precise processing. Currently, the resolution can reach 1280*1024; namely, the common difference can be reduced within +/- 0.005 inch.

The DLP uses a single material. When the product is formed by means of DLP, the material is hardened by light illuminating. As the working platform is descended, the hardened materials are covered by a layer of unhardened materials. By repeating the foresaid procedures, we can finish a 3-D solid work piece.

The major problems happening to DLP are:
- Because of the preparation for fluid materials, the material bucket for work piece must be completely filled. Thus, it causes high material consumption and cost.
- The precision is entirely controlled by DMD. Thus, the high precision of DMD is extremely required so that it will directly cause higher production cost.
- The process is thoroughly triggered by light sources so that light isolation becomes critically important. Also, the DMD is available for provision of low density light and it is quite sensitive to the ambient light sources. Thus, the material buckets are also vulnerable for light reaction to cause the increasing difficulty for material storage.
- When creating some work pieces, it is required for additional supports.
- Due to the large illumination area, if the intensity of light sources is not high enough, the material cannot react as desired.

2. Description of the new Method

Referring to Figure 1, a new method for rapid prototyping of the present invention comprises the following steps:

1. Preparing raw material onto a defined zone by using rolling, nozzles spreading, or by spreading the raw material and then rolling to obtain an even and thin layer of material with flat surface;
2. Illuminating the raw materials by light source, electronic beams, or heating to cause a first time of physical or chemical changes;
3. Using more powerful linear light source with cooperation of portable Digital Micro-mirror Device (DMD) to scan the selected zones of the material to cause a second time of physical or chemical changes;
4. Repeating pre-set times of the step (1) to (3) and removing the material without the second time of change by proper methods so as to obtain a solid work piece.

The proposed method has the following advantages:
- It is a new kind of method.
- The raw material is prepared onto a defined zone only, instead of the entire domain. Fewer raw materials are required.
- In this method, no any supports are required. The material with weaker feature is supported by the material having stronger features and the two types of materials can be separated by proper methods.
- The 3-D object can be obtained within a shorter period of time.

3. Conclusion

A new method for rapid prototyping by using linear light as sources is proposed. The method is not restricted by the existing patients. It requires fewer raw material and no any supports are required. In addition, the 3-D object can be obtained within a shorter period of time.
Figure 1. Procedures for rapid prototyping of the present invention.

1. Preparing raw material onto a defined zone by rolling or nozzles spreading

2. Raw material with 1st change

Illumination or electronic beams

Temperature of heating board increased

Temperature of platform increased

3. Raw material with 2nd change due to more powerful plane light source

4. Repeating to obtain solid work pieces

References
[1] http://www.3dsystems.com/
[2] http://rpc.msoe.edu/machines.php
[3] http://www.stratasys.com/Global/index.html
[4] http://rpc.msoe.edu/machines.php
[5] http://www.2objet.com/Tech/index.html
[6] http://pguerit.sri.com/SriWeb/current/DPS.html