

Study on New Material of Grating which Used in Three-dimensional Printing

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Abstract

With the development of printing and related technology, three-dimensional printing advances increasingly. A kind of new material of grating was prepared on the basis of analyzing the principle of three-dimensional printing. It is proposed that UV curable varnish can be used as three-dimensional imaging materials of grating instead of plastic. Through testing and analysis the performance of new materials, a kind of new three-dimensional printing process suitable for the materials was discussed. The result indicates that UV curable varnish is a new material of grating, the print not only can overall stereo imagery, but also partial stereo imagery when using UV curable varnish as grating material.

Key words

Three-dimensional printing; grating; UV curable varnish

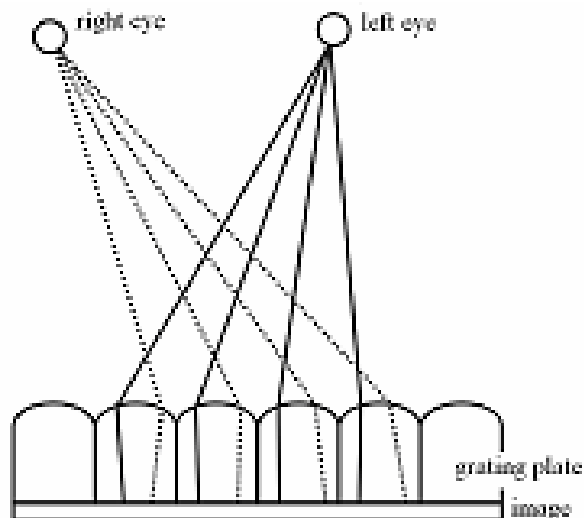
1 Introduction

Three-dimensional printing, also called printing with grating, is a kind of printing to make image features space impression with grating according to optical principle such as refractive. It includes technologies of physical, chemical, optical, aesthetic and visual of bionics fields, forms a complete and special printing technology. From the origin of three-dimensional photography to the development of three-dimensional printing, the history dates back 150 years. However, because of complex production techniques, high technical requirements, and high cost, the commercial production of three-dimensional printing is only for 50 years. Today, the development of digital image processing technology and software advances the three-dimensional printing technology. Three-dimensional printing adapts to the requirement of market, it has a very strong competitive ability, and is becoming a new topic concerned by printing businesses.

As a mature technology in Europe and America, three-dimensional printing is very popular. But, in China, this technology is still in exploration stage because of a late start. Almost all the three-dimensional printing businesses with scale depend on importing consumables from foreign countries. At present the main material of grating is plastic. The use of UV curable varnish has not been sported as a kind of material of grating. As an environmental friendly, high efficiency, energy-saving new material of grating, UV curable varnish breaks the limitations of traditional plastic grating that can only achieve overall three-dimensional printing, and makes the partial three-dimensional printing feasible.

2 Imaging principle of three-dimensional printing

Three-dimensional printing is based on the physiological characteristics that binocular parallax of human eyes forming space impression and the optical principle that refraction and spectroscopic imaging of grating plate, and can make two-dimensional images stereographic by using grating plate.^[1]



Therefore, if we can record a group of right and left visual image, and make the right and left eyes see the corresponding part of the image, through refraction and spectroscopic imaging of grating plate, the print will show stereographic effect. Imaging principle of grating plate is showed in figure1.

Figure1 Imaging principle of grating plate

Grating plate is composed of many small cylindrical lenses with identical structure parameters and performance. Each cylindrical lens is a convergent lens, it has the function of lights focusing to image. Therefore, the performance index of grating material can be got through analyzing the light path of the cylindrical lens. In three-dimensional printing, the image is in the focal plane ($f = d$), due to this characteristics, cylindrical lens which compose the grating plate has a special optical characteristics, that is the light from random point on the image becomes parallel beam after refracted by cylindrical lens. Light path of the cylindrical lens is showed in figure2^[2].

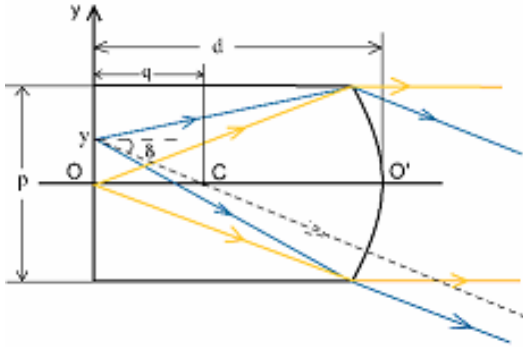


Figure2 Light path of the cylindrical lens

In figure2, point C is the node of cylindrical lens, the distance between the first optical plane and point C is q . Establish system coordinates Oy , and the origin O is on the optical axis. The light from random point y becomes parallel beam with corresponding information after refracted by cylindrical lens, the transmission direction angle is δ , analyzing the light path in figure2, the following formula is got.

$$\delta = -\arctan \frac{ny}{d} \quad (1)$$

“ n ” is refractive index in formula(1). So bounded to the optical axis OO' , the transmission direction of parallel beam from points above OO' is downward, the transmission direction of parallel beam from points below OO' is upward, optic beam width is P , so cylindrical lens has the function of spectroscopic imaging.

Formula (1) shows that the transmission direction angle of light is related to the thickness, refractive index of grating plate and the location of point y . If the right and left visual image was processed according to grating space, and arranged in focal plane of cylindrical lens grating plate in accordance with a certain order, then entered the human eye, and caused stereographic vision.

From the above analysis of imaging principle of three-dimensional printing, we can find that the transparency, specific refraction, thickness and grating space of grating material should be considered when designing the parameters of grating plate to get the best stereographic effect. In addition, three-dimensional printing demands high quality of image production, in order to ensure three-dimensional images with clear screen and sufficient brightness, grating material must has a very high degree of transparency.

3 New material of grating which used in three-dimensional printing

Currently, materials of grating are mainly polyethylene terephthalate (PET), polypropylene (PP) and polyvinyl chloride (PVC) in the market. These three materials have a very high quality of transparency, refractive index and flexibility, and can make print

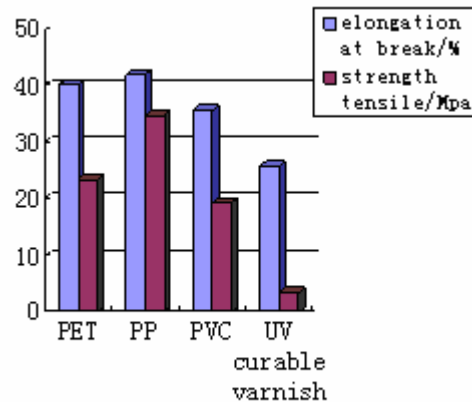
with high-quality in color and tone, and produce better stereographic effect. So, if a kind of material is to be used as grating in three-dimensional printing, it must be equal to these three plastics or superior to these three plastics firstly, what's more, it must be meet the efficiency requirements. Therefore, in order to introduce the main performance of UV curable varnish, one kind of PET、PP and PVC are selected as a comparison.

3.1 Curing rate of UV curable varnish

UV curing process is that photo-initiators absorb ultraviolet, then generate free radicals or cations which provoke reactions of monomers and pre-polymers polymerize and cross-linked, and result to form a kind of mesh structure of the film^[3], so UV curable varnish can be cured instantaneous. Different formulations of UV curable varnish are cured to be a film by a UV curing machine which manufactured by FUSION UV SYSTEMS, INC, the curing rate is 30~65 m/min in the power of 80W/cm. Comparing with plastic grating, UV curable varnish not only save energy source but also improve efficiency. Therefore, the characteristics of rapid curing of UV curable varnish can meet the need of three-dimensional printing automated production.

3.2 The transmission ratio of UV curable varnish

The transmission ratio is used to interpret the degree of transparency of grating plate, and is controlled by grating material and processing technology. The higher transmission ratio is, the better transparency is, so the transparency of grating plate will directly affect the performance of three-dimensional images. The higher transmission ratio is, the less information loss of image after refracted by grating plate is, and the higher lightness is. On the



contrary, the lower transmission ratio is, the more information loss of image after refracted by grating plate is, then affects the quality and lightness of reproduction image. Therefore the material with high transmission ratio should be chosen to produce grating plate. In order to introduce the transmission ratio of UV curable varnish, different materials of grating were tested by ultraviolet and visible spectrophotometer, results as shown in figure3.

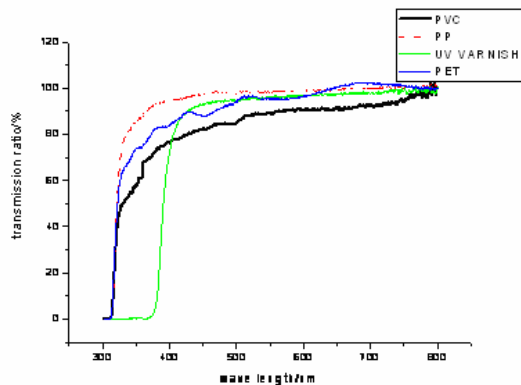


Figure3 The transmission ratio of different materials of grating

It can be seen from figure 3 that UV curable varnish has a high quality of transparency compared to the three plastics PET, PP and PVC. It's transmission ratio higher than 90% in the scope of visible light. Thus, UV curable varnish can meet the demand of three-dimensional printing in transparency.

3.3 The refractive index of UV curable varnish film

The refractive index is decided by the grating material itself. The higher refractive index of grating plate is, the bigger visual angle is, and the better spectroscopic imaging is. The refractive index of different materials of grating were tested by WAY-2W index machine, results as shown in table1.

Table1 The refractive index of different materials of grating

material	PET	PP	PVC	UV curable varnish
refractive index	1. 6078	1. 6740	1. 6294	1. 6330

The data in table1 indicates that the refractive index of UV curable varnish film is close to the three plastic, it has a good function of spectroscopic imaging, so it meet the need of refractive index of grating material in the three-dimensional printing.

3.4 The flexibility of UV curable varnish film

Three-dimensional printing technology is complex, especially the form process of grating, and has high requirements for the flexibility of grating material, the prepared film of UV curable varnish and the three kind of plastic grating materials are tested by WDW3020 micro-controlled electronic testing machine at the speed of 2mm/min. Elongation at break and tensile strength are measured, results as shown in figure4.

Figure4 The flexibility of different materials of grating

From figure4 we can see that the flexibility of UV curable varnish film is worse than plastic, it is difficult to meet the need of complex form process of current three-dimensional printing, therefore, new form process of grating should be studied to adapt to UV curable varnish.

In addition, In order to meet the actual needs of three-dimensional printing, the thickness of grating is usually controlled by the viscosity of UV curable varnish and coating conditions. Grating space and curvature radius can be controlled by different molds on request of production requirements.

4 Research on three-dimensional printing form process

The existing form technicality of plastic grating has been more mature. Most domestic grating is ordinary grating made by pressure from ordinary mold, but three-dimensional imaging effects are not ideal. Imports grating used precision mold perfuse by the way of arch-launch simultaneously cooling, and the grating deformation is reduced, thus the overlap accuracy between the process of printing and image was ensured. Three-dimensional imaging technicality of plastic grating is grating joint; therefore, it can only achieve the overall three-dimensional printing.

Since the poor flexibility of UV curable varnish film compared with plastics, form process of grating can not be much complex to cured film, therefore, a little much processes can be implemented before UV curable varnish curing processes. New process is as follows, coating the prepared UV curable varnish on the image that needs to be stereographic, then jointing the transparent grating negative model on the UV curable varnish to be cured in ultraviolet, finally, separating grating negative model and cured film to get raised cylindrical lens grating, therefore, the image has produced three-dimensional sense. This method can coat UV curable varnish on demand of image scale, but if using plastic as grating material, it can only joint the overall page. So we called it a break in three-dimensional printing.

5 Conclusions

(1) UV curable varnish has the main properties of grating materials, the lack of film flexibility can be compensated through improving the three-dimensional printing form process, and therefore, UV curable varnish can become a new kind of grating material.

(2) As a new grating material, UV curable varnish can be achieved partial three-dimensional printing, and breaks the situation that plastic grating material can only achieve the overall three-dimensional printing.

In addition, the urgent problem in three-dimensional printing is as follows. How to make the grating image match with grating perfectly, and improve the quality of three-dimensional image; how to choose the suitable parameters to produce three-dimensional images with better stereographic effects, their production costs will not increase at the same time.

References

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