Study on a New Method of Manufacturing Aspheric Mirror

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Abstract. A simple method for manufacturing aspheric mirror. Pour the polymer liquid into a rotating mold. The mold rotates at a constant angular velocity, Stop heating after a period of rotation. The surface of the liquid is parabolic after solidification. This method is suitable for producing embryos of large size aspherical mirror. It can reduce the processing difficulty and reduce the grinding consumption. Relative to existing manufacturing methods, centrifugal molding can greatly reduce processing costs.

Introduction
Because aspherical mirror has excellent optical properties, The design of aspherical mirror in optical system has become a common method of modern optical system. The optical system with aspherical mirror is not only widely used in the civilian industry, It also has been widely used in national defense, space science, nuclear energy and other important industrial fields. The manufacture of optical components by grinding and polishing techniques has evolved over the decades. Large telescopes require a large number of aspherical mirrors. As large telescopes are increasingly demanding in size, and optical components in accordance with traditional manufacturing methods cost is very high, meanwhile grinding polishing also takes a lot of time. Therefore, it is urgent to study a new manufacturing method which can reduce the cost and shorten the processing time.

This paper presents a centrifugal casting technology to manufacture the surface of aspheric mirror paraboloid, avoids the expensive and time-consuming grinding process, this method has low production cost, short production cycle, which is very suitable for the manufacture of large and medium-sized aspheric mirror.

Theory of Manufacturing Aspheric Mirror
Pour some liquid into a round container, after the rotation of the container, the liquid surface will become concave [1], as shown in Figure 1. The same principle, Add the liquid in the round mold, after a period of rotation, the surface shape of the liquid material[2] will stabilize. As the temperature decreases the liquid is gradually solidified so that the surface can form a paraboloid after rotating cooling. According to Darren Bell principle, the mass forces acting on liquid particles include gravity and centrifugal force. As shown in figure 1, the components of the mass force acting on the liquid mass of the mass are [3]:

![Figure 1. Principle of centrifugal casting method.](image-url)

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\[ f_x = \omega^2 r \cos \alpha = \omega^2 x \quad (1) \]

\[ f_y = \omega^2 r \sin \alpha = \omega^2 y \quad (2) \]

\[ f_z = -g \quad (3) \]

g represents gravity acceleration
\( \omega \) represents rotating speed of mold

The mass force and fluid balance differential equations can be obtained:

\[ dp = \rho (f_x dx + f_y dy + f_z dz) \quad (4) \]

Integral get:

\[ p = \rho \left( \frac{\partial^2 x^2}{2} + \frac{\partial^2 y^2}{2} - g3 + C \right) \quad (5) \]

At the origin point, \( x=r=0 \), Pressure is atmospheric pressure, \( p=0 \), Integral constant \( C=0 \), get:

\[ p = r(\frac{\omega^2 r^2}{2g} - z) \quad (6) \]

We can get the isobaric equation:

\[ \frac{\omega^2 r^2}{2g} - z = \frac{p}{r} = \text{constant} \quad (7) \]

For free surface, \( P=0 \), so:

\[ z = \frac{\omega^2 r^2}{2g} \quad (8) \]

In this equation when \( z=0 \), the lowest point of the curve is at the coordinate origin. From the equation can be seen in any of the isobaric surface free surface is a paraboloid, the free surface shape is only related to rotational speed and gravity.

The calculation formula of parabolic focal length can be obtained by the following formula:

\[ f = \frac{g}{2\omega^2} \quad (9) \]

Because of the gravity acceleration \( g=980\text{cm/sec}^2 \), the formula for calculating the focal length above can be rewritten as [4]:

\[ f = \frac{490}{\omega^2} \quad (10) \]

**Material Characteristics**

Epoxy resin [4] are organic compounds a molecule containing two or more than two epoxy group. In addition to a special exception, epoxy resin relative molecular mass is not big. Because of the active epoxy groups in the molecular structure, they can cross react with various types of curing agent to form insoluble polymer with three direction network structure. When the molecular structure containing epoxy groups of high molecular compounds collectively referred to as epoxy resin. Cured epoxy resin has good physical and chemical properties. It has excellent bonding strength to the surface of metal and non-metal material, dielectric properties is good, deformation
shrinkage rate is small, product dimensional stability, high hardness, good flexibility. Because the material is stable in alkali and most of the solvents, the material is chosen for the experiment. Obtaining the most suitable polymer becomes the most difficult problem, at the same time we have carried out many experiments which are not very successful to find the ideal polymer. In general, the ideal polymeric polymer [5] capable of generating a paraboloid should have the following characteristics:

1. No shrinkage or deformation during curing;
2. The viscosity of polymer in liquid state should be in 0.1-1Pas (100-1000cP);
3. After curing, the polymer surface should be absolutely smooth;
4. The cured polymer should be durable;

Finally we find a kind of polymer which can obtain satisfactory results. This polymer is composed of phenol and epoxy acetylene (DGEBA), The viscosity of the cured polymer is about 0.95Pas (950cP).The curing process is a slow process which takes several hours. The characteristics of curing process can guarantee the deformation of the parabolic surface[6-8].

3- chloro -2,6- two ethyl aniline (MCDEA) as curing agent, diluent is 2-methanol-2-glycidyl ether (ED757),This composition can be mixed and solidified at a lower rotational speed.

Experimental Process

Experimental structure and device diagram are shown in Figure 2. The device consists of two parts: the heating part and the rotating part. The heating function is realized by the resistance wire, and the mold is surrounded by thermal insulation material, so as to ensure the constant temperature in the mold, The rotating mechanism consists of gearbox and motor,. The cast iron mold is located above the rotating mechanism, material is placed in the mold, the rotating mechanism drives the grinding tool to rotate, and the temperature and speed are controlled by the control cabinet.

First, apply a mold release agent on the mold surface, which is convenient to take out the castings we need after the test, and then mix the epoxy resin and hardening agent. They must be fully mixed, and mixing time cannot be too long, it takes about 10 minutes to mix at about 80℃, the mass ratio of resin and hardener is about 5:2. We can use the rotary vacuum pump to remove the mixed bubbles. In the injection process, we need to pay attention to avoiding the generation of bubbles and do not let dust fall into mold,. At the same time we should ensure the stability of rotation speed. The resin which has just hardened could not be touched directly. On the surface of the film coated with a layer of aluminum film, it becomes a real telescope mirror.
Optical Testing of Products

Ronchi is a method of testing by a grating (or a single slit). The principle of the Ronchi test device is shown in Figure 3. Place a Ronchi grating near the curvature center of the inspected mirror, the light source is reflected by the examined mirror after grating, and the image of the grating falls back on the grating to produce the moire fringe. The shape of these fringes depends on the aberration of the reflected mirror. Thus, the surface shape error of the detected mirror can be calculated according to the deformation of the fringe.

![Figure 3. Diagram of Ronchi test device.](image)

The test results are shown in Figure 4. The left graph is the result of an early experimental aspheric mirror test, the stripes are very irregular. The image on the right shows the improved results of the aspheric mirror, which is more in line with the requirement, although some surface defects due to dust can be seen. The results show that the centrifugal method is feasible, but some improvements are needed to improve the quality of the lens.

It can be concluded from the above experiments that there are some defects on the surface:

1. The slight vibration of the experimental equipment in the rotation process leads to surface defects and the equipment still needs to be improved.
2. The regional surface damage is due to the injection speed of aluminum process caused by too fast, the surface shape of epoxy resin is damaged.
3. In the course of the experiment, the dust into the equipment leads to the uneven surface of the casting defects

Conclusion

It is a new machining method to make parabolic optical element by centrifugal forming. Many aspects still need to be improved. In this paper, it is it is proved theoretically and experimentally that it is feasible to manufacture optical components by centrifugal molding. Although this does not meet the high accuracy of optical component requirements, but In consideration of the manufacturing cycle and efficiency, this method of manufacturing optical components by centrifugal molding has the incomparable superiority compared with other manufacturing methods. Especially for large size optical lenses, other methods often have strict limits on size, this method is not so strict on the size constraints. The research of this method has important practical significance for the development of large size optical lens.

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