PROCEEDINGS OF SCIENCE

Development of aluminum honeycomb reflector in LACT

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As an important observation equipment for gamma rays, the Large Array of imaging atmospheric Cherenkov Telescopes(LACT) usually focuses and reflects cosmic rays to the telescope probe based on a large-area single reflector. Because of its large diameter, a single reflector is assembled by dozens of reflectors to form a complete single focusing reflector. The development of its reflector is still based on the traditional grinding technology in China. Although the optical performance of the processed reflector can meet the requirements of use, the reflector is heavy, the risk of filming is high, and the cost of bulk purchase is extremely high, so it is difficult to mass produce. This paper provides a new processing method of spherical reflector: the glass substrate, aluminum honeycomb sandwich and aluminum back plate are bonded and cured by structural adhesive under the force of vacuum negative pressure to form a regular hexagonal composite reflector blank. Preform the glass substrate before bonding, which can basically adapt to the spherical surface and reduce the subsequent grinding workload of the reflector blank; After bonding, the reflector blank is ground, measured and coated to form the composite spherical reflector. The method improves the production efficiency and reduces the production cost. The composite spherical reflecting reflector with this processing method has the advantages of light weight and large specific stiffness, which is beneficial to subsequent installation and splicing, and reduces the processing difficulty and cost of the mounting bracket.

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1. Introduction

In order to find evidence of cosmic ray acceleration with higher energy, gamma ray observation needs to be extended to higher energy, especially ultra-high energy gamma ray observation above 100 TeV will play a vital role. The "Large High Altitude Air Shower Observatory" (LHAASO) located in Daocheng, Sichuan Province is a major project in the Twelfth Five-Year Plan. The experiment adopts the mode of construction and operation, and half of its arrays will start scientific operation at the end of 2019. It is expected that LHAASO will realize full array operation in mid-2021. The design sensitivity of LHAASO gamma rays above 100 TeV is about one order of magnitude higher than that of HAWC experiment and CTA experiment. Up to now, nearly 30 ultra-high energy gamma ray sources have been observed, among which more than a dozen sources radiate more than 100 TeV[1]. In particular, LHAASO has detected a number of photons with energy greater than 1 PeV, creating a new record for human photon detection. The scales of these sources detected by LHAASO are mostly greater than 0.5 degrees. For example, the scales of the three brightest sources, LHAASO J1825-1326, LHAASO J1908+0621 and LHAASO J2226+6057, are all above 1 degree in the 100TeV energy band, and there are usually many TeV candidate objects in this scale (for example, LHAASO J1908+0627) However, the spatial resolution of LHAASO is greater than 0.25 degrees (for example, the PSF of the source LHAASO J1908+0621 is 0.45 degrees (68% confidence)), so it is impossible to clearly distinguish the contribution of each celestial body to gamma radiation, and it is also impossible to determine the origin celestial body corresponding to these radiations. Therefore, although the super sensitivity of LHAASO provides a strong guarantee for finding 100TeV sources, its weak spatial resolution makes it impossible to accurately distinguish the spatial structure of celestial bodies, and it is also difficult to determine PeVatron celestial bodies. The existing atmospheric Cherenkov imaging telescopes have high spatial resolution, but their sensitivity in the 100TeV energy band is relatively low. Under this background, it is urgent to develop a new large array of Cherenkov telescopes (LACT), improve the detection sensitivity of 100TeV energy band (see Figure 1), and carry out accurate spatial shape measurement of ultra-high energy gamma ray sources including LHAASO or other international sky surveys, so as to identify and distinguish these celestial bodies.

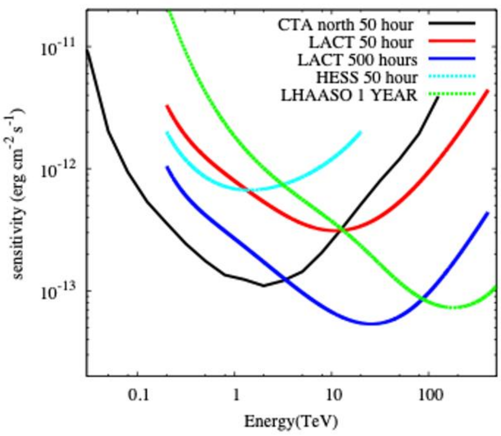

Figure 1: Comparison of Sensitivity of Large Array of imaging atmospheric Cherenkov Telescop (LACT) with Other Instruments

The core imaging component of Cherenkov telescope is a mirror. At present, many regular hexagons are used in large Cherenkov telescopes.The main problems are as follows:

1) The reflector is relatively heavy, so it is not easy to be hoisted, fixed and adjusted;

2) The specific rigidity of the mirror is not good, and its surface will be partially deformed when the telescope attitude changes, which will affect the imaging accuracy;

3) Due to the heavy reflector, the assembled whole reflector is heavy, which puts forward higher requirements for its pedestal and supporting structure, resulting in the increase of overall volume and cost.

In this paper, a processing method of glass reflector based on sandwich composite material is proposed, which can increase the specific stiffness and reduce its weight, improve production efficiency, control processing cost and realize engineering application.

2. Technical proposal and process

The basic scheme of the invention is that the three-layer structure of aluminum back plate, aluminum honeycomb and glass is heated and solidified into a three-layer sandwich-like composite structure under the action of vacuum negative pressure, and the spherical mirror with reflection function is made by grinding and coating. The composition of the mirror is shown in Figure 2.

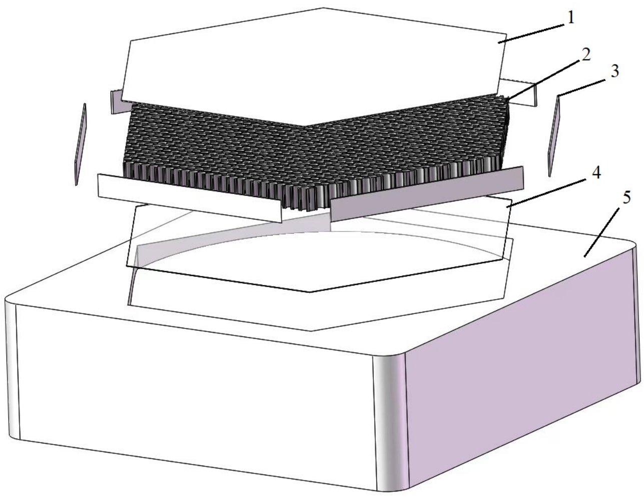

Figure 2: Mirror forming composition: 1-Aluminum backboard,2-Aluminum honeycomb,3-Edge sealing block,4-Float glass,5-Mould

The main forming process is as follows:

a. Glass hot bending forming

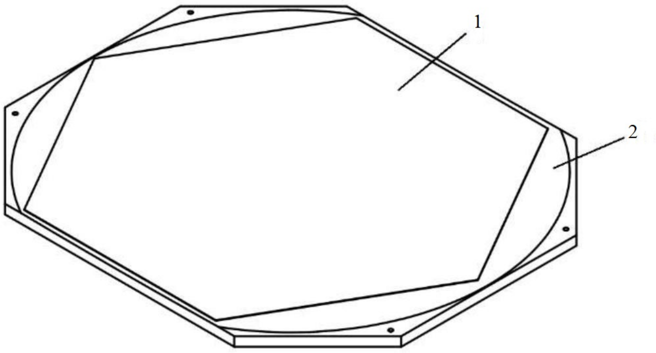

Figure 3: Hot bending glass: 1-Float glass,2-Hot bending mould

Glass hot bending belongs to glass preforming, which can reduce the grinding amount of glass grinding and polishing. The hot bending of glass is carried out in a heating furnace. The hot bending die 11 is a concave die with a concave spherical radius of 16 meters, made of ductile iron, and the lowest point in the middle has an exhaust hole. Glass 1 is made of glass with a thickness of 2 mm to 5 mm and cut into hexagons. The mold 2 is placed in a heating furnace, and the glass 1 is placed on it. The heating furnace is electrified and heated. When the temperature is 600°C, the glass 1 begins to soften, and the softened glass 1 adheres to the mold 11 under the action of its own weight. After half an hour, it slowly and linearly cools down, and the cooling process lasts for 4 hours. At this time, the glass 1 is shaped into a spherical glass which has been annealed and basically has no internal stress. In order to improve the two-component adhesive force of epoxy resin, the convex surface of glass 1 which has been shaped into a spherical surface is sandblasted and roughened.

b. Negative pressure bonding forming

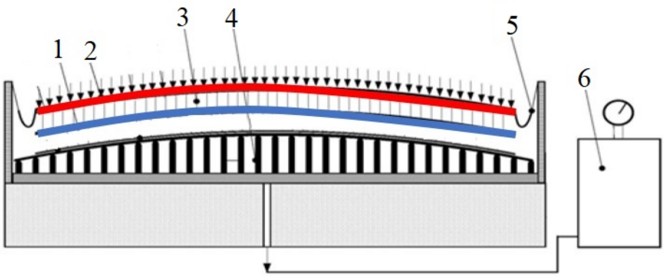

Figure 4: Forming: 1-Float glass,2-Aluminum backboard,3-Aluminum honeycombHot,4-Mould,5-Vacuum bag,6-Vacuum pump

The design of negative pressure die mainly considers the surface size and tooling design, and it is made of high-strength ball-milled cast iron, which has relatively little impact on the environment such as temperature and humidity. The precision of the finished face is required to be within RMS0.01 mm and the surface finish Ra0.8 mm The mold is provided with a vacuum pump 23 connection interface and a reflector tooling interface.

The negative pressure mold is placed in a warm room as a whole. Place the glass formed by hot bending (textured surface facing upward), epoxy resin prepreg, aluminum honeycomb, epoxy

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resin prepreg and aluminum back plate on the mold layer by layer, locate the tooling, place the edge sealing block, cover the sealing cover, start the vacuum pump, control the pressure to 0.02MPa, and keep the temperature of the warm room at 150°C for 8 hours. Under the pressure of atmospheric pressure, the aluminum back plate and aluminum honeycomb are stretched and attached to the mold together with the glass, and the epoxy resin prepreg is cured at high temperature, and finally the mirror blank is integrally formed.

c. Grinding and polishing

It is necessary to edge the mirror blank before grinding and polishing. Because the mirror blank is formed on a high-precision mold, the mirror surface on the mirror blank has high precision, but there will be local distortion on the glass surface, so grinding and polishing are needed to eliminate the distortion, so as to meet the requirements of smoothness and surface shape. Grinding and polishing are carried out on a single spindle machine. The diameter of the grinding tool can be 600mm, the upper hanging point can rotate freely, and the lower grinding surface is self-contained Because it is placed on the reflector, the reflector rotates with the turntable, and there is sand on the mirror surface of the reflector. When the reflector rotates, it will rotate with the grinding tool, so that the reflector and the sand generate relative friction motion, and the purpose of grinding and polishing is achieved. In the process of grinding and polishing, it is necessary to change the sand with different precision, and the sand is gradually changed from coarse sand to fine sand and then to final sand. Polishing sand. Precision measurement is carried out by using a ball diameter meter in grinding and polishing.

d. Coating

The mirror after grinding and polishing can be directly coated with aluminum film by evaporation, and the vacuum degree of the coating room is about 10-3Pa. Coating can be carried out at room temperature.

3. Machining result

Figure 5: The mirror

As shown in the above figure, according to the above processing technology, we made a mirror sample and coated it. The preliminary results show that the radius of curvature and surface shape of the mirror have basically met the requirements, and the reflectivity also meets the requirements.

4. Summary

At present, the traditional optical reflector processing is realized by grinding, slicing and coating. In the process of lens production, it is found that the process of grinding the lens to the corresponding radius of curvature is very slow, the production efficiency is low and the yield is not high, so the cost is high. Moreover, in order to maintain the mechanical strength, the weight of a single lens is about 15kg, which increases the burden of the supporting structure and the budget of the telescope supporting transmission system. After long-term technical accumulation and development, China has a certain technical reserve, and the development technology of new reflector has reached a certain maturity, and has been trial-produced. LACT plans to complete the technical research of the new reflector and use it in an all-round way.

References

[1] Zhen Cao and et al. Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 gamma-ray galactic sources, 2021.