
A New Technique Producing Double-sided Spherical Fresnel Lens Segments Assembled to Large Aperture Lenses

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Abstract

A new technique of molding of lens segments has been developed to produce a large, double-sided, curved Fresnel lenses for refractive telescopes. The molding process involves two steps of spherically curved plate formation and lens groove transfer onto the curved plate. These molding process have been carried out with two sides of the diamond-cut dies set in the hydraulic press machine at elevated temperatures to the lens material that is a transparent UV-acrylic of Mitsubishi. Ultra-precision dies were made of oxygen-free copper, which were cut by diamond tools to make Fresnel facets. A four-axis ultra-precision cutting machine has been developed first to manufacture ultra-precision mold dies. Double-sided, curved Fresnel lens segments will be used as circumference petals of lenses of 2500mm aperture surrounding a 1500mm diameter central lens.

1. Introduction

A mission proposed "Extreme Universe Space Observatory(EUSO)" [1] will detect the extreme energy cosmic rays ($E > 10^{19}$ eV) and the high energy cosmic neutrino flux looking at the streak of fluorescence light produced when the particles interact with the Earth's atmosphere from ~ 500 Km altitude under a 60° full field-of-view. The forgiven resolution requirements of EUSO suggest the use of Fresnel lenses. A two Fresnel lenses system has been designed to meet the EUSO specifications. Fig.1 illustrates this prototype optics design. Each lens is cut on a spherical substrate and has grooves in both sides. Table1 indicates the specifications of two lenses shown in Fig.1. Fig.2 shows one of four kind segments to be assembled as a circumferential petal into a double-sided Fresnel lens. A new technique producing these kinds of lens segments is described next.

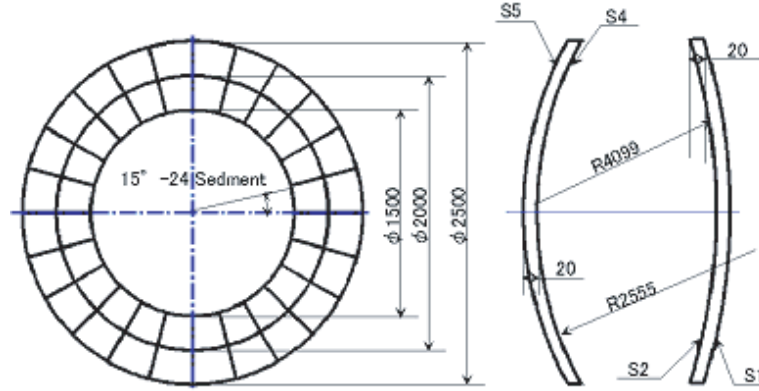


Fig. 1. The prototype design of a two Fresnel lenses system

Table 1. The specifications of two Fresnel lenses

	Lens1		Lens2	
	S1	S2	S4	S5
Material	PMMA		PMMA	
Base form	Sphere (SR4099mm)		Sphere (SR2555mm)	
Aperture [mm]	2500		2500	
Lens form	Aspheric	Aspheric	Aspheric	Aspheric
Angle [deg.]	-0.55 ~ 18.06	-0.25 ~ -24.9	-0.61 ~ -21.42	-1.09 ~ -17.33
Width [mm]	138.42 ~ 1.73	74.58 ~ 1.39	49.33 ~ 1.22	135.31 ~ 8.80

2. The process producing double-sided spherical Fresnel lens segments

The process includes two hot hydraulic pressing steps[2]. The first hot hydraulic pressing step is for curvature formation of planar acrylic substrates. In this stage a planar acrylic substrate is pressed to have curvatures on both sides and corresponding thickness. The pressing conditions are as follows; substrate preheating temperature 180°C, die temperature 70°C, press force 40tons and press time (simultaneously cooling down) 40min.. Then, hydraulic press machine, die-set (a frame for press motion with a pair of dies assembled into) and hot drying furnace are utilized. The dies and die-set are able to be commonly used in the Fresnel facets pressing, by covering dies surfaces with PTFE sheets. The second hot hydraulic pressing step is for Fresnel facets transfer from dies surfaces onto the curved acrylic substrates surfaces. In this stage hydraulic press machine, dies and die-set, and hot drying furnace are the same ones as in the first step. The pressing conditions are as follows; substrate preheating temperature 70°C, dies temperature 160°C, press force 40tons, press time 40min. and cooling time (in

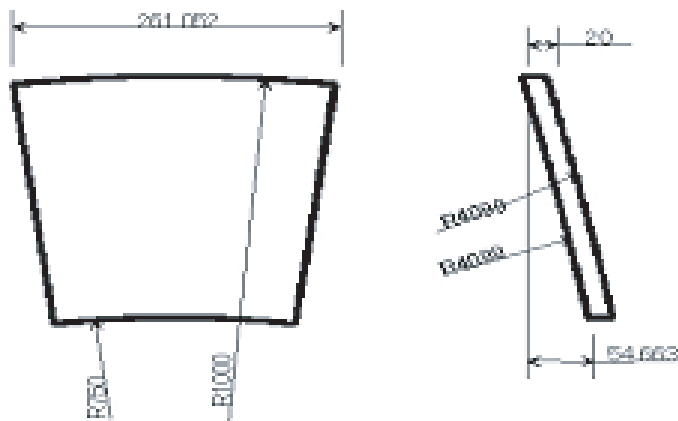


Fig. 2. One kind of the segment lenses

the die-set after pressing) 160min.. The acrylic molds are trimmed by cutting the peripheral remnant off, after hot hydraulic second pressing steps. Then, the Fresnel lens segments are completed. The die-set used was specially designed and fabricated. Fig.3 shows the die-set in pressing situation. The most important technique in the process above described is to make ultra-precision dies. Dies are key components. Then, ultra-precision mold dies have been developed first[3]. Dies made of oxygen free copper were cut with planer cutting by diamond tools on the ultra-precision 4-axis CNC machine. Dies were nickel-plated after diamond cutting. Both type of die surface were prepared. In one type Fresnel facets are engraved on convex spherical surface. In the other type Fresnel facets are engraved in concave spherical surface. Fresnel facets surfaces are mirror finished only by diamond tool cutting. Then, Fresnel facets engraved on die surface should be replicated to acrylic substrate surface with high fidelity by transferring pressing.

3. Result of the process application

The double-sided spherical Fresnel lens segments shown in Fig.2 were produced by applying the process above-mentioned. In these segments, curved shapes and Fresnel facets have been transferred with high fidelity. Small surface roughness of diamond-cut die surfaces has also contributed to maintaining a clear transparency of acrylic. In addition, it seems that UV-acrylic of Mitsubishi(PMMA) is appropriate for the process developed. Fig.4 demonstrates lens function of these segments, that is, person's image shifts by refraction from the situation as it is.

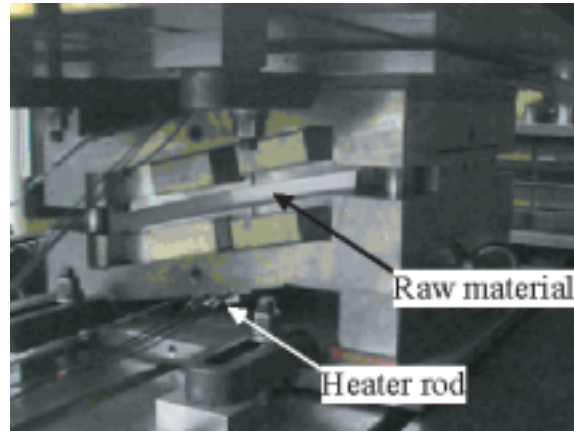


Fig. 3. The pressing situation with die-set



Fig. 4. The lens function of the segment produced

4. Conclusion

The new technique developed to produce double-sided, curved Fresnel lens segments will enable to fabricate very large assembled type Fresnel lenses that cannot be hitherto manufactured by a single diamond-turning machine.

1. L.Scarsi et al. 2000, Proposal for the ESA F2/F3 Mission
2. Y.Uehara et al. ULTRAPRECISION FORMING OF 2500mm DOUBLE-SIDED FRESNEL LENSES APPLYING HOT HYDRAULIC PRESS TECHNIQUE, 6th International Conference on Progress of Machining Technology, 420-425
3. T.Suzuki et al. ULTRAPRECISION DIAMOND CUTTING OF MOULD DIE FOR 2500mm DOUBLE-SIDED FRESNEL LENSES, 6th International Conference on Progress of Machining Technology, 265-268