Light Transmission Properties of Insert Molded GFRPs with Different Crape Structure of Silk Fabrics

Kiyoshi Fujiwara[1], Erika Suzuki[2], Tetsuo Kikuchi[2], Takashi Furukawa[3], Atsushi Endo[4], Yuka Takai[5](✉), and Yuqiu Yang[6]

[1] Mazda Motor Corporation, Hiroshima, Japan
fujiwara.k@mazda.co.jp
[2] Toyugiken Co. Ltd, Kanagawa, Japan
{erika-suzuki,tetuo-kikuchi}@toyugiken.co.jp
[3] HISHIKEN Co. Ltd., Kyoto, Japan
t-furukawa@hishiken.co.jp
[4] Kyoto Institute of Technology, Kyoto, Japan
shootingstarofhope30@gmail.com
[5] Osaka Sangyo University, Osaka, Japan
takai@ise.osaka-sandai.ac.jp
[6] Donghua University, Shanghai, China
amy_yuqiu_yang@hotmail.com

Abstract. In this research, the hand lay-up method was focused as one of the decoration molding techniques for the GFRP lighting materials. The hand lay-up method can be more developed in the market of the GFRP lighting material because type of form and reinforced material are free to be selected in this method. Therefore, this research aimed to clearly the light transmission property of the GFRP inserted the Kyo Yu-zen fabric with crape. The cross section structure, light transmission property and luminance distribution of the GFRP samples were analyzed. As the results of this research, it was confirmed that the structure of the GFRP inserted the silk fabric with crape was different in each sample according to a laid direction of the yarn and use of the laid yarn, the GFRP inserted the silk fabric with crape had more profound effect on a dispersion of the light with the luminous intensity and the luminance than the GFRP with only glass mat, and a degree of the dispersion of the light was changed by the structure of the crape, and it was the highest in the Silk4 showed the highest Ra value.

Keywords: GFRP · Hand lay-up · Silk fabric · Crape structure · Light transmission property · Luminance distribution

1 Introduction

Use of glass fiber reinforced plastics (GFRP) as lighting materials has spread. For example, exterior as the roof material of the housing terrace or the carport, interior material as the bathroom door and the indoor partition window as shown in Fig. 1. GFRP lighting materials has been said for appearance – a glass pattern appears – to be

V.G. Duffy (Ed.): DHM 2015, Part I, LNCS 9184, pp. 267–276, 2015.
DOI: 10.1007/978-3-319-21073-5_27

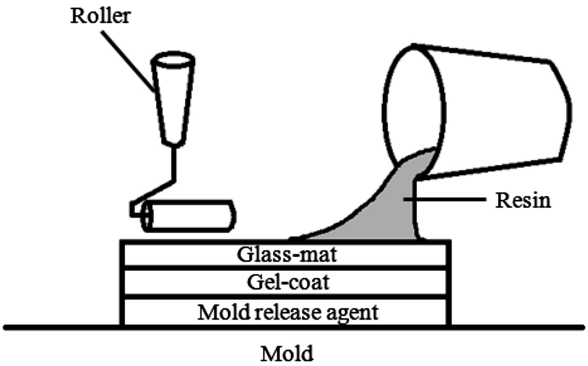

Fig. 1. Hand lay-up method

bad although physical properties, such as mechanical strength, are good. This problem was solved in pattern printing to the surface of the GFRP board with transcriptional molding technique. The ratio of the parallel light/diffusion light of the transmitted light of the GFRP board was shifted to the diffusion light side. From this technique, the glass pattern disappeared by the difference in the refractive index of resin and glass. As a result, the panel which does not have visibility at the same time it lets light pass was realized. On the other hand, LED lighting has the high directivity of light and it is difficult to illuminate all the directions like a filament lamp. As one of the solution for this problem, it is thought that GFRP lighting materials with high light diffusion can be diverted to the housing of LED lighting.

In this research, the hand lay-up method was focused as one of the decoration molding techniques for the GFRP lighting materials. The hand lay-up method can be more developed in the market of the GFRP lighting material because type of form and reinforced material are free to be selected in this method. Therefore, this research aimed to clearly the light transmission property of the GFRP inserted the Kyo Yu-zen fabric with crape. The cross section structure, light transmission property and luminance distribution of the GFRP samples were analyzed.

Previous researches on the embossed or grained FRP can be referred for GFRP inserted the Kyo Yu-zen fabric with crape [1, 2]. Light transmission property and luminance of the FRP have been analyzed [3–5], there are less researches aimed to develop the GFRP lighting materials. Whereat, this research is significant for the development of the GFRP lighting materials.

2 Method

2.1 Materials and Fabrication

The samples were molded by hand lay-up method as shown in Fig. 1. Hand lay-up method has been used for molding composite structures from long ago. It can be performed by only a mold, skill and material. Reinforcing fiber is impregnated with liquid resin and it is laminated on the mold with roller by hand.

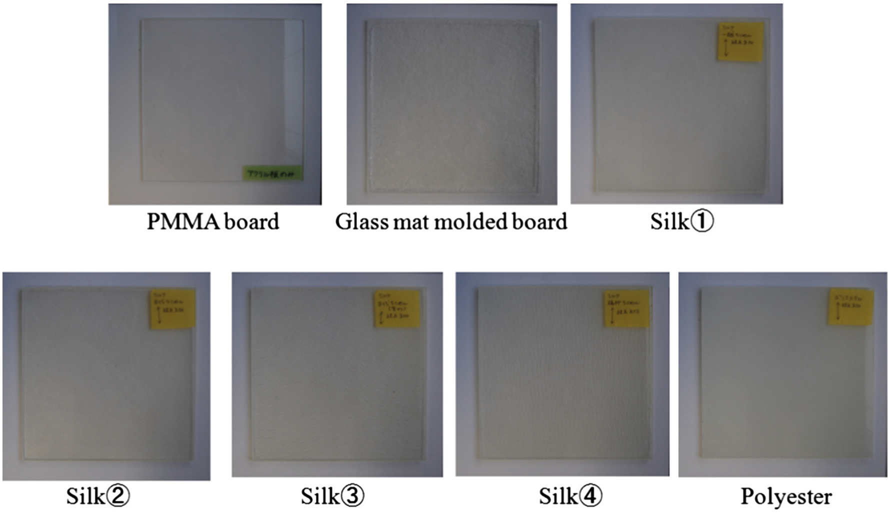

Fig. 2. Photos of insert molded GFRPs with Silk Fabrics

An unsaturated polyester resin (2035P, U-PICA Company. Ltd.) was used as the matrix resin. A glass mat (#230, Central Glass Co., Ltd.) was used as reinforcing material. The crape fabric was used as decorative material. Figure 2 shows photos of samples. A size of the sample was 200 mm×200 mm. The crape fabric was called “Silk1”, “Silk2”, “Silk3”, “Silk4” and “Polyester crape” based on a difference in crape structure or fiber. Each silk fabric structure is as follows;

- Silk1: Fabric woven left-laid and right-laid woofs alternately one by one.
- Silk2: Fabric woven left-laid and right-laid woofs alternately two by two.
- Silk3: Fabric woven left-laid and right-laid woofs alternately two by two.

A number of the warp is larger than the Silk2.

- Silk4: Fabric woven right-laid woof.

The laminated constitution of samples was shown in Fig. 3. First, glass mat was laminated two layers on the PMMA (Polymethylmethacrylate) board, and it was cured at room temperature for three hours. Then crape fabric was laminated on the glass mat layer, and it was cured at room temperature for twenty-four hours.

2.2 Measurement

In order to reveal influence of lamination of crape on the light transmission property of the sample, the light transmission property and the luminance distribution of the sample were measured.

Cross Section Structure. The cross section structure of the sample was measured by using non-contact three-dimensional measuring device (NH-3SP, Mitaka Kohki Co., Ltd.).

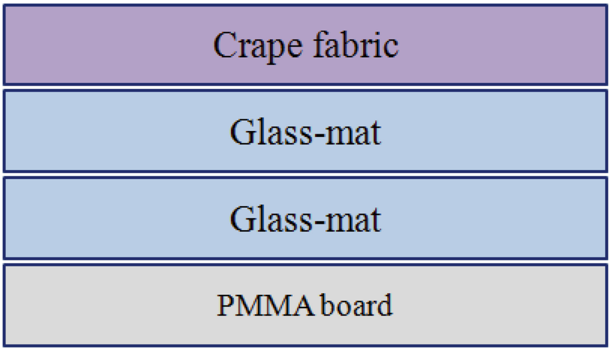

Fig. 3. Laminated constitution of sample

In the case of the sample with silk fabric, a center of the sample in warp direction and woof direction was measured. In the case of the glass mat sample, the canter of sample in any direction was measured because an orientation of glass fiber in the glass mat was random. Measurement range was 50 mm in all samples.

Light Transmission Property. The light transmission property was measured by the light distribution measurement bench as shown in Fig. 4. This instrument consists of biaxial goniometer, douser and spectroscope. The optical path length was 1 m. The light source is a LED light reflector bulb (equivalent to 40 W, white daylight, total luminous flux 280 lm). Sample was placed at a distance of 25 mm from the light source, the transmitted light of the sample was measured.

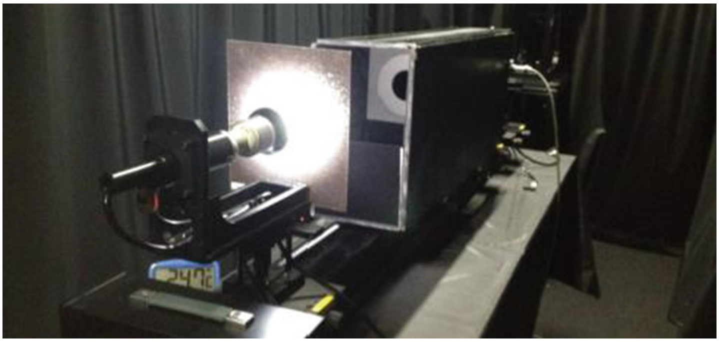

Fig. 4. Light distribution measurement bench

Luminance Distribution. The luminance distribution was measured by two-dimensional luminance colorimeter (CA-2000; Konica Minolta, Inc.) as shown in Fig. 5. Light source was a LED light bulb (equivalent to 40 W, white daylight, total luminous flux 485 lm). Sample was placed at a distance of 500 mm from the light source. The optical path length was 750 mm. Measurement image was divided into 960400 area based on x direction 900 and y direction 980, and 960400 luminance distribution data per one measurement were got in this instrument.

Fig. 5. Two-dimensional luminance colorimeter

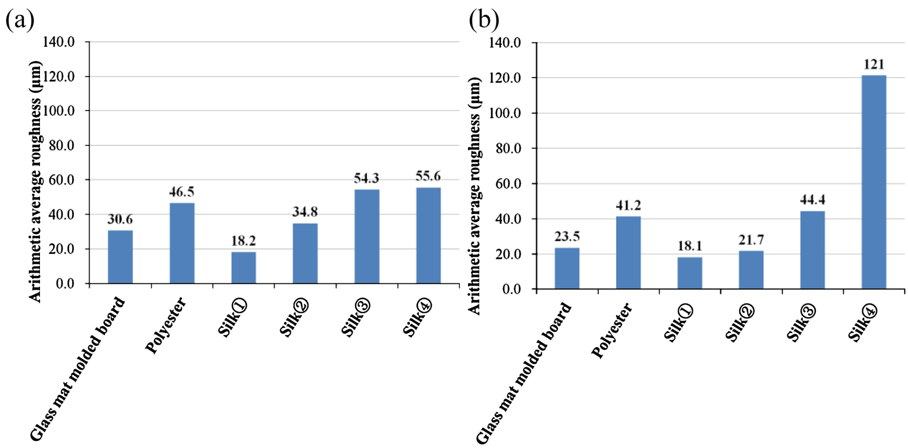

Fig. 6. Arithmetic average roughness; (a) Warp direction, (b) Woof direction

3 Results and Discussions

3.1 Cross Section Structure

Figure 6 shows arithmetic average roughness (Ra) of the sample. Arithmetic average roughness is the depth of mean value of the unevenness. Silk4 in the warp and woof direction showed the highest value in all samples. There wasn't so much of a difference between the value in the warp direction and the woof direction in each sample except for Silk4. It seems that the arithmetic average roughness of Silk4 was large because the fabric was woven by using only right-laid woof.

Figure 7 shows average length (RSm) of the sample. Average length is an average value of the unevenness of the intervals. Silk3 in the warp and woof direction showed the highest value in all samples. It seems that this result was caused by the crape with large width because 4 woofs were woven in Silk3. It is found that the space of the crape in all of the silk fabrics with crape in the woof direction was larger than it in the warp direction.

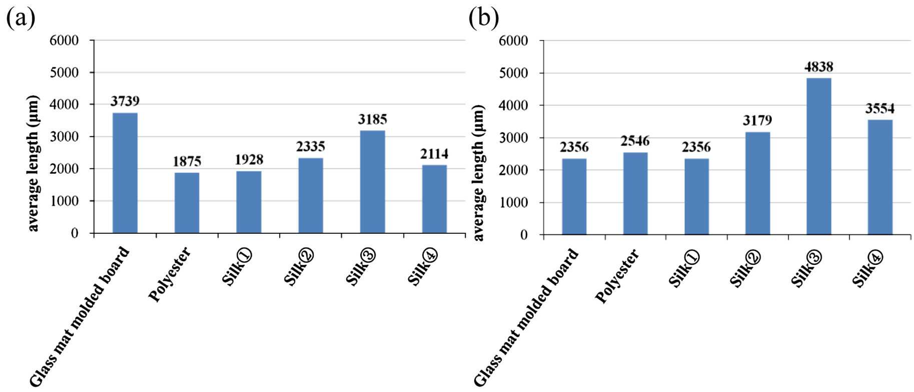

Fig. 7. Average length; (a) Warp direction, (b) Woof direction

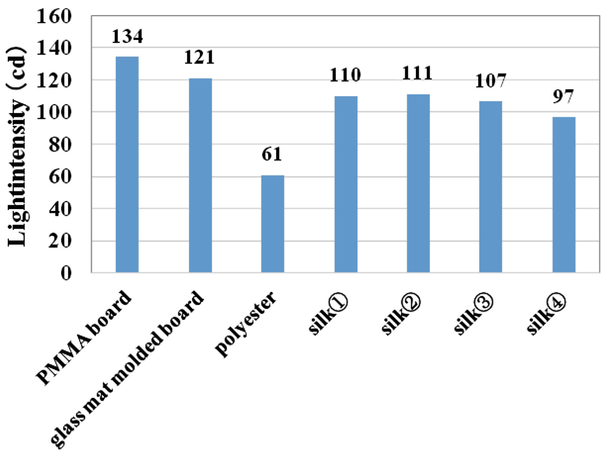

Fig. 8. Results of luminous intensity of the transmitted light

3.2 Light Transmission Property

Figure 8 shows results of luminous intensity of the transmitted light. The luminous intensity of the sample with laminated crape fabric was lower than the sample with only glass mat. In the case of the sample with crape fabric, it was revealed that luminous intensity changed because of the difference of thickness, structure and fiber.

Figure 9 shows results of general color rendering index (Ra). Color rendering index is a value which means the difference between the color under the light source evaluating the color rendering properties and the color under the stated base light source when the color under the stated base light source with respect to each correlated color temperature was regarded as 100. In general, the higher color rendering index is, a light source is similar to the natural light, Ra value of incandescent and halogen bulb is 100. Ra value reduced by laminating crape fabric, but a color shift did not occur. It is found

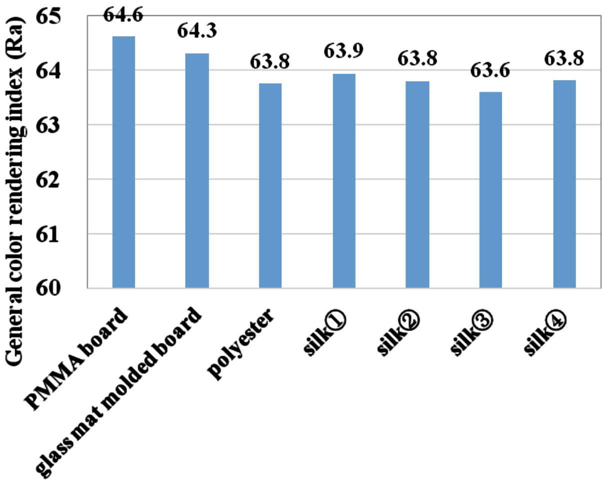

Fig. 9. Results of general color rendering index

that a thickness, structure and fiber of crape fabric didn't significantly affect the Ra value in this research.

3.3 Luminance Distribution

Figure 10 shows luminance distribution of LED bulb, PMMA board, glass mat molded board, and Silk2. Luminance distribution of LED bulb was similar to the one of the PMMA board. Luminance distribution of the glass mat molded board was showed in a wide range, but a luminance value was high in a part range. Luminance distribution of

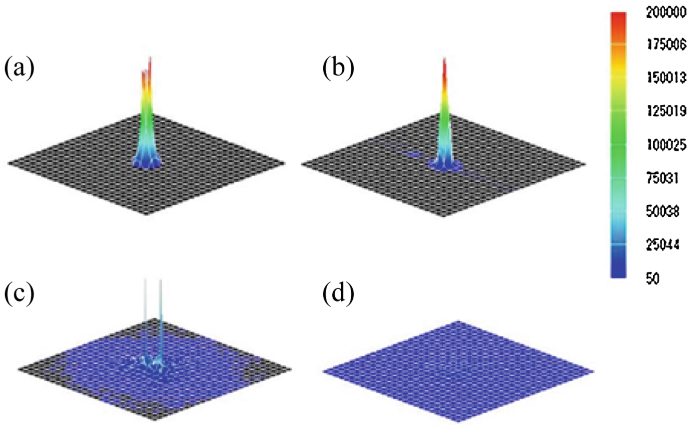

Fig. 10. Luminance distribution of (a) LED bulb, (b) PMMA board, (c) Glass mat molded board, (d) Silk2.

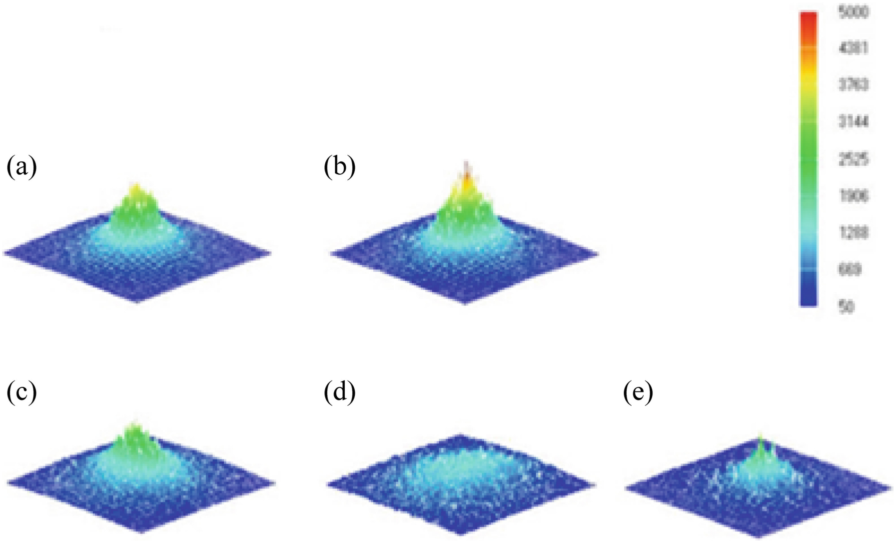

Fig. 11. Luminance distribution of (a) Silk1, (b) Silk2, (c) Silk3, (d) Silk4, (e) Polyester crape

Silk2 was showed in a whole range. In order to know the detail luminance distribution of the laminated crape fabric molding board, a display scale of the luminance distribution figure was changed. Figure 11 showed the luminance distribution of each sample with enlarged display scale. Luminance distributions of Silk1, Silk2, Silk3, Silk4 and Polyester crape was showed in a whole range, the luminance value was high near the light source. The luminance of Silk4 did not increase rapidly near the light source. Figure 12 showed an average luminance. The average luminance of silk crape fabric molded board was decreased by about 40%, and the average luminance of the polyester crape fabric molded board was decreased by about 70% compared with the glass mat molded board.

As these results, it is found that the silk crape fabric molded board has a profound effect on a dispersion of the light with the luminous intensity and the luminance, and it was the highest in the Silk4. It seems that more light was reflected diffusely, and it was transmitted over a wide range when it was transmitted through the silk crape fabric because a cross section of a silk fiber is triangle, and it has the property that it is easy to reflect the light.

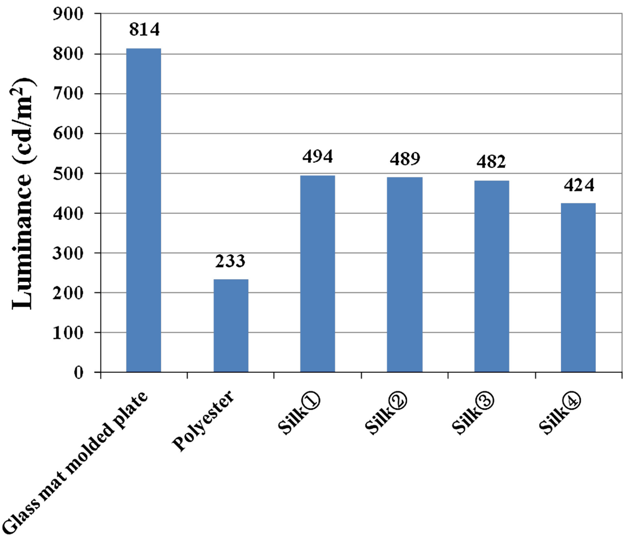

Fig. 12. Average luminance

4 Conclusions

In this research, the hand lay-up method was focused as one of the decoration molding techniques for the GFRP lighting materials. This research aimed to clearly the light transmission property of the GFRP inserted the Kyo Yu-zen fabric with crape. The cross section structure, light transmission property and luminance distribution of the GFRP samples were analyzed.

As the results of this research, it was confirmed that;

- The structure of the GFRP inserted the silk fabric with crape was different in each sample according to a laid direction of the yarn and use of the laid yarn.
- The GFRP inserted the silk fabric with crape had more profound effect on a dispersion of the light with the luminous intensity and the luminance than the GFRP with only glass mat.
- A degree of the dispersion of the light was changed by the structure of the crape, and it was the highest in the Silk4 showed the highest Ra value.

In the case of the GFRP inserted the silk fabric with crape, there is a good possibility that the dispersion of the light is free to be controlled by its structure. Therefore, it seems that the GFRP inserted the silk fabric with crape is expected to be used as a lighting equipment, and it makes the environment more comfortable.

References

1. Minamiji, H., Suzuki, H., Kamibata, J., Ohtake, Y.: Synthesizing leather textures for digital SHIBO design. Proc. Des. Syst. Conf. Jpn. Soc. Mech. Eng. **2010**(20), 3305-1–3305-6 (2010)
2. Noguchi, H., Wei, J., Nakagawa, T., Miyamoto, K., Yanagisawa, A., Imamura, M.: Development of plastic mold with fine surface pattern for polymer forming. J. Surf. Finish. Soc. Jpn. **41**(6), 624–629 (1990)
3. Hana, N., Todoroki, A.: Optical transparency change method for cure monitoring of GFRP. J. Soc. Mater. Sci. Jpn. **56**(8), 771–776 (2007)
4. Fujii, T., Mizikawa, K., Zako, M.: The Measurement with respect to statically characteristics, of fiberglass reinforced plastics (FRP) by the light transmission method. J. Soc. Mater. Sci. Jpn. **19**(204), 803–808 (1970)
5. Murakami, O., Yamada, K., Kotaki, M., Hamada, H.: Effects of injection molding conditions on replication, birefringence and optical property of microscopic V-groove structures for polycarbonate. J. Jpn. Soc. Polym. Process. **20**(10), 762–768 (2008)