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Christopher Schlick
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Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future

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Editors

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Advances in Human Factors and Ergonomics 2016

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Preface

Contemporary manufacturing enterprises aim to deliver a great number of consumer products and systems through friendly and satisfying working environments for people who are involved in manufacturing services. Human-centered design factors, which strongly affect manufacturing processes, as well as the potential end-users are crucial for achieving continuous progress in this respect. Researchers around the world attempt to improve the quality of consumer products and working environments. This book presents the results of their work. We believe that such findings can either inspire or support others in the field of manufacturing to advance their designs and implement them into practice. Therefore, this book is addressed to both researchers and practitioners.

The papers presented in this book have been arranged into four sections. The first section covers a variety of topics that refer to human-centered organizations. This section starts with a general viewpoint of socio-technical systems, including organizational innovativeness and enterprise agility, followed by issues related to designing human-centered production systems. Such systems take into consideration workforce diversity, high-wage countries, work-related occupational safety, work environment factors, ICT, and demographic features. The last thematic part of this section is focused on assembly planning and production inventories management. The second section of the book presents the effects of applied ergonomics in manufacturing and work studies concerning the improvement of human skills, as well as the quality and effectiveness of workforce. The presented chapters depict the influence of worker experience and the technology used to improve work effectiveness. Next, the comparison of non-expert and expert work is studied to find patterns that can be used to improve the technique of performing different tasks by less skilled employees. The third section deals with outcomes ergonomics have on industrial quality and safety, while the fourth and final section of this book is focused on ergonomic design of future production systems.

The contents of this book required the dedicated effort of many people. We would like to thank the authors, whose research and development efforts are published here. Finally, we also wish to thank the following Editorial Board members for their diligence and expertise in selecting and reviewing the presented papers:

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Part I
Human Aspects in Composite Manufacturing and Product Evaluation

Study on Light Diffusion of Creped Silk Inserted GFRP

Erika Suzuki, Tetsuo Kikuchi, Kiyoshi Fujiwara, Mamoru Saito, Yuka Takai and Yuqiu Yang

Abstract This research put the focus on fabricating the GFRP that inserted silk cloth (silk inserted GFRP) and developing the GFRP lighting materials. Now, the luminance diffusion of silk inserted GFRP is better than that of only GFRP have been reported. However, the light diffusion is not clear. In this study, the aim is to clear the light diffusion property of silk inserted GFRP by measuring haze. Furthermore, silk inserted GFRP's surface structure was measured to investigate relationship between the light diffusion and surface shape.

Keywords Haze measurement · Light diffusion · Silk insert molded · GFRP · Hand lay-up

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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. GFRP lighting materials has been said for appearance—a glass pattern appears—to be 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 and haze of silk inserted FRP samples were analyzed.

Previous researches on the embossed or grained GFRP 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 Experimental Methods

2.1 Materials

An unsaturated polyester resin with no additives was used as the matrix resin. Glass mats (#230, #450) were used as reinforcing material. Inserted silk cloth in GFRP layer is the cloth which generally used for *Kimono*. In this research, we used the cloth which has crape. This cloth is called *Yo-ryu*. Crape is an irregularity to emerge on the surface of the textile by twisting yarn. Inserted silk cloth is not dyed and solid white color. Figure 1 shows silk cloth which we used.

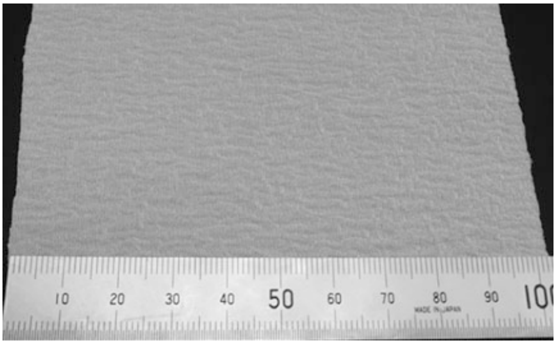

Fig. 1 Silk cloth

2.2 Fabrication

GFRP and Silk inserted GFRP samples were manufactured by skillful craftsman. The samples were molded by hand lay-up method. The size of the sample was 300 mm × 300 mm. GFRP samples which have three types thickness and silk inserted GFRP which have each one, two, three sheet are molded. Samples were cured at room temperature for an hour.

Table 1 shows GFRP layer thickness and the number of insert silk cloth of samples, Fig. 2 shows laminated configuration of samples and Fig. 3 shows picture of samples. Two types GFRP 1 mm samples were fabricated, one is laminated two #230 glass mat layers, the other is laminated a #450 glass mat layer. GFRP 4 mm sample is laminated four #450 glass mat layers, and GFRP 7 mm samples are laminated seven #450 glass mat layers. All silk inserted GFRP is laminated two #230 glass mat layers. Silk inserted GFRP which have a silk cloth laminated silk cloth in the third layer. Silk inserted GFRP which have two silk cloths laminated silk cloth in the first and fourth layer. Silk inserted FRP which have three silk cloths laminated silk cloth in the first, third and fifth layer.

Table 1 Thickness of FRP and the number of insert silk

Sample	FRP thickness [mm]	Number of insert silk cloth [sheet]
GFRP 1 mm (use #230 × 2)	1	0
GFRP 1 mm (use #450 × 1)	1	0
GFRP 4 mm (use #450)	4	0
GFRP 7 mm (use #450)	7	0
GFRP 1 mm + silk 1 sheet (use #230)	1	1
GFRP 1 mm + silk 2 sheets (use #230)	1	2
GFRP 1 mm + silk 3 sheets (use #230)	1	3

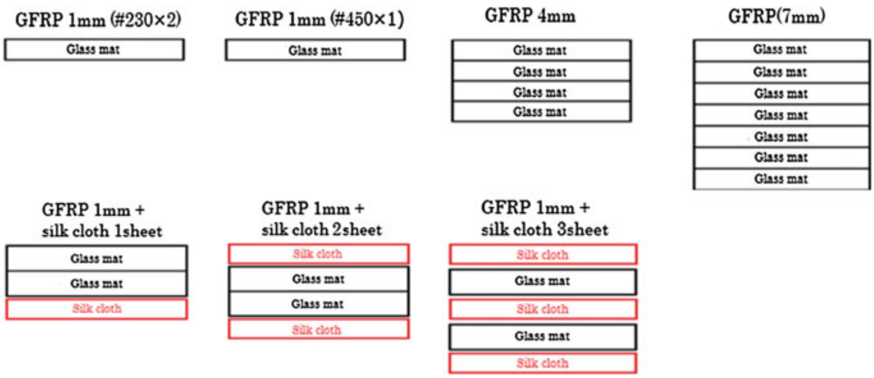

Fig. 2 Laminated configuration

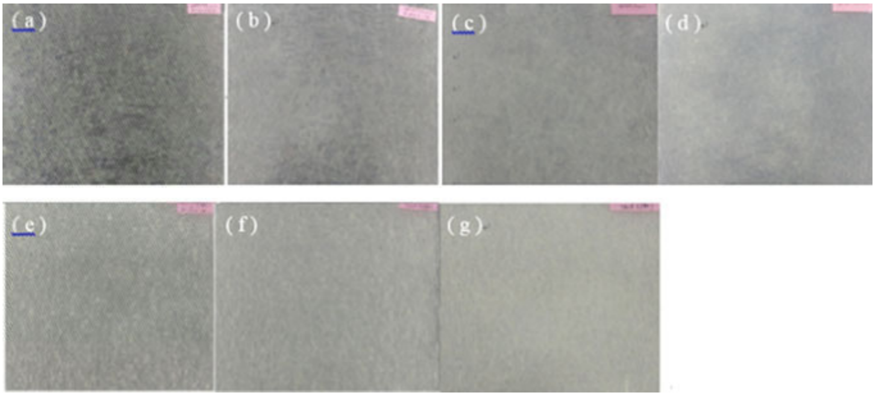

Fig. 3 Photo of samples. **a** GFRP 1 mm (#230 × 2), **b** FRP 1 mm (#450 × 1), **c** FRP 4 mm, **d** FRP 7 mm, **e** GFRP 1 mm +silk 1 sheet, **f** GFRP 1 mm + silk 2 sheets, **g** GFRP 1 mm + silk sheets

2.3 Measurements

Haze Measurement. In order to reveal light diffusion property of GFRP and silk inserted FRP, haze was measured. Haze measurement carried out according to JIS K 7136 and 7361-1. NDH400 (Nippon Denshoku Industries Co., LTD.) was used. From haze meter, parallel light transmittance and light diffusion can measure. By measuring these properties, total light transmittance and haze ware calculated by the following formula.

$$\text{Total light transmittance} = \text{parallel light transmittance} + \text{scattering transmittance} \tag{1}$$

$$\text{Haze} = \text{scattering transmittance/total light transmittance} \times 100 \quad (2)$$

Surface Structure. The surface structure of silk cloth was measured by using non-contact three-dimensional measuring device (VR-3100, KEYENCE Corporation). The surface structure of GFRP and silk inserted GFRP were measured by using contact three-dimensional measuring device (Form Talysurf PGI 1200, Taylor Hobson Ltd).

3 Results

3.1 Haze Measurements

Total light transmittance of GFRP is shown in Fig. 4. Total light transmittance of GFRP 4 and 7 mm is lower than GFRP 1 mm. The haze of GFRP is shown in Fig. 5. The haze of GFRP increases in order of GFRP 1, 4 and 7 mm, GFRP 4 and 7 mm show almost the same values. Furthermore total light transmittance and the haze of GFRP 1 mm change by laminating configuration.

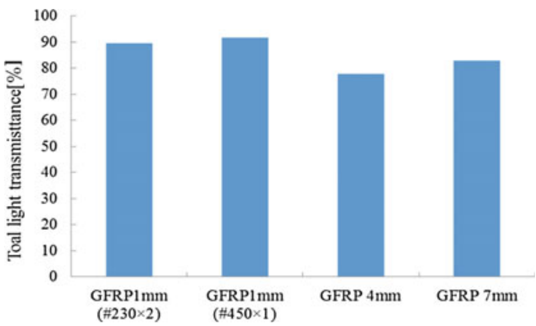

Fig. 4 Total light transmittance of GFRP

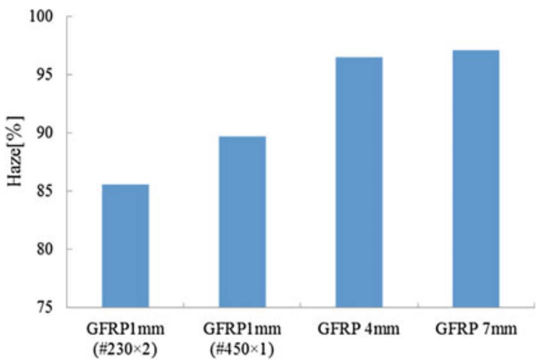

Fig. 5 Haze of GFRP

Total light transmittance of silk inserted GFRP is shown in Fig. 6. Total light transmittance of silk inserted GFRP decreases with the increase of the silk sheets. The haze of silk inserted GFRP is shown in Fig. 7. The haze of silk inserted GFRP which have 1 sheet have high haze value than GFRP. By increasing the number of silk cloth, the haze of silk inserted GFRP increase. However, in case of the number of inserting silk cloth is 2, and 3 sheets, the increment of the haze is small.

3.2 *Surface Structure*

Arithmetic average roughness (Pa) of samples are shown in Fig. 8. Arithmetic average roughness is the depth of mean value of the unevenness. Arithmetic average roughness of silk inserted GFRP is three times larger than that of GFRP. In addition, the number of insert silk cloth of silk inserted GFRP and surface irregularity structure do not have the association.

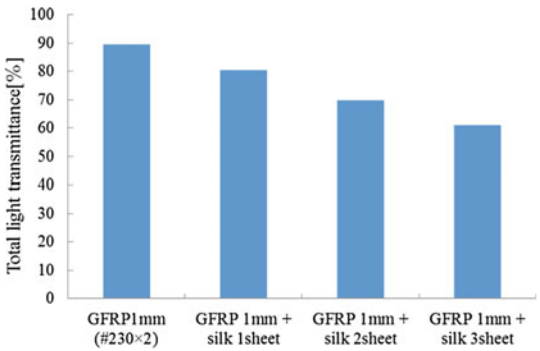

Fig. 6 Total light transmittance of silk inserted GFRP

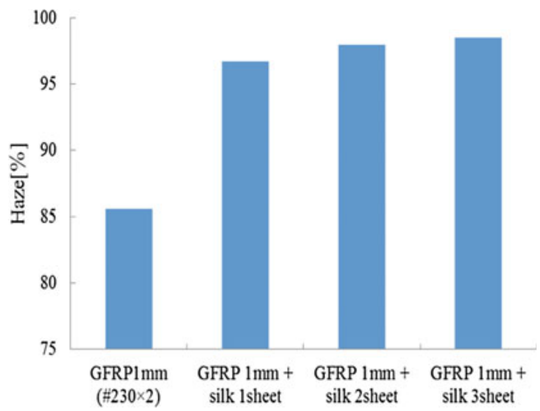

Fig. 7 Haze of silk inserted GFRP

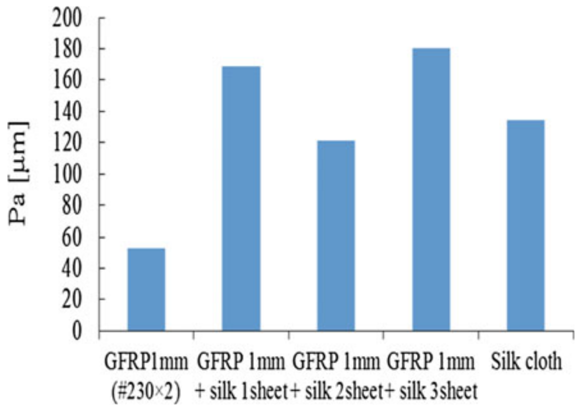

Fig. 8 Results of structure measurement (Pa)

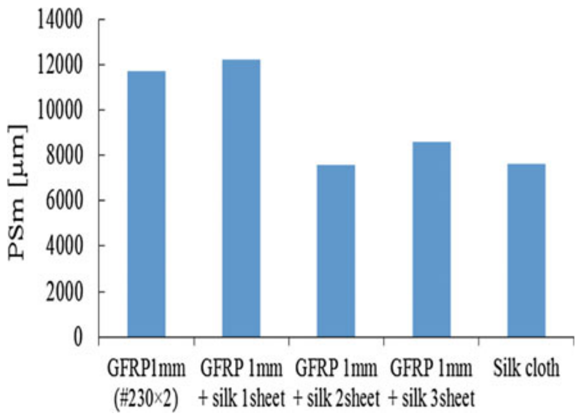

Fig. 9 Results of structure measurement (PSm)

Average length (PSm) of samples are shown in Fig. 9. Average length is an average value of the unevenness of the intervals. GFRP and silk inserted GFRP which have a silk sheet show the biggest average length of all. Silk inserted GFRP which have two and three silk sheets and silk cloth of average length is almost the same value.

4 Discussion

It is desirable that total light transmittance and haze have high value, because it is intended to creation of materials that produces soft light without reducing the amount of light in this research.

The relationship between total light transmittance and haze of GFRP and silk inserted GFRP are shown in Figs. 10 and 11.

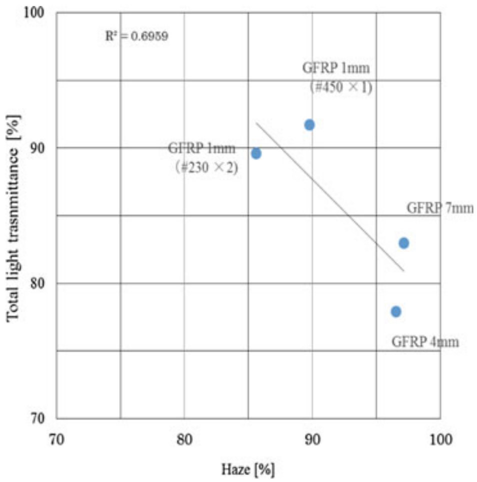

Fig. 10 Relationship between total light transmittance and haze (GFRP)

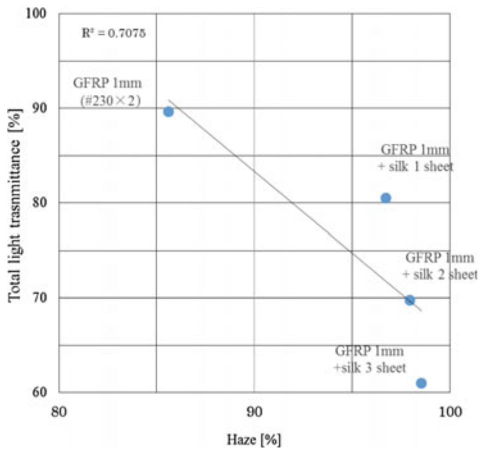

Fig. 11 Relationship between total light transmittance and haze (GFRP and GFRP + Silk)

From Fig. 10, Comparing GFRP 1 and 4 mm, GFRP thickness increase, it is seems that the total light transmittance is significantly reduced, and haze is increases greatly.

However, comparing GFRP 4 and 7 mm, GFRP thickness decrease, haze is almost no change. This is due to increase the thickness of the GFRP layer, the amount of glass fiber increases, therefore the percentage of incident light is reflected or absorbed increase by glass fiber. As a result, it is thought that total light transmittance decreased because transmittance light reduces by diffused reflection.

From Fig. 11, total light transmittance of silk inserted GFRP decreases with increasing the number of insert silk, haze increases. However, it is seemed that increase width of haze is small.

In addition, for increasing the number of insert silk, decline of total light transmittance is greater than the range of decrease of the total light transmittance for the thickness increase of the GFRP, therefore it is considered that silk fabric have an effect of reflecting or absorbing the source light than glass fiber.

From the above contents, factors relating to the transmittance and haze of the light include the following three points.

1. The number of insert silk cloth and increase the number of silk cloth.
2. Increase the number of glass mat layer.
3. Surface structure.

In addition, it is thought that there three points give an impact the light transmittance and haze, the influence degree is 1, 2, and 3 in descending order.

5 Conclusion

This research put the focus on light diffusion property of silk inserted GFRP, and measure haze and surface structure. Because the haze of silk inserted GFRP is higher than GFRP, it is clear that silk inserted GFRP have an effect of light diffusion. In addition, it is considered that factors relating to the transmittance and haze of the light are the number of insert silk cloth and increase the number of silk cloth, increase the number of glass mat layer, and surface structure in descending order of effect.

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Research and Development of Robots with Advanced Skills in Hand Lay-Up

Tetsuo Kikuchi and Erika Suzuki

Abstract Hand lay-up fabrication is a form of craftsmanship and an implicit skill supported by individual sense, and subjective implicit values deep-rooted in expertise and judgment by touch and from appearance based on "instinct" and "know-how" skills inherited from past generations for the evaluation of thickness and impregnation, removal of voids, etc. Typically, more than 20 years of experience is required for a person to become a skilled craftsman in hand lay-up fabrication. Challenges the need to be addressed are how to pass their skills onto future generations, foster artisans, and construct a sustainable manufacturing process. In this study, the development of HLU molding robots input with the knowledge of skilled engineers as an achievement of this research will help overcome the lack of skilled workers during the stage of training young personnel to replace their predecessors as generations change.

Keywords Hand lay-up · Tacit knowledge · Compressive pressure · Dimensional stability · Robotization

1 Introduction

Expectations on robot technology have been growing as a means to solve the lack of manpower due to the ageing population and declining birthrate, improve the labor environment, and enhance productivity. Within this context, this study aims to develop robots with advanced skills in hand lay-up (HLU) molding of composite materials and utilize them in the production of composite materials, to build a system for continuous supply of high quality composite material products.

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The HLU method has been used since long to fabricate composite materials. A simple mold, the skills, and raw materials are all you need in hand lay-up molding. The molds used for hand lay-up process is inexpensive and this method requires little equipment investment, allowing the manufacturer to flexibly respond to wide-ranging requirements in terms of production volume, size, and changes in product shapes. Meanwhile, there are disadvantages: as the HLU method depends on human skills, product quality differs by the worker who fabricated the product and even between different parts of the same product. For these reason, highly sophisticated control techniques and the succession of molding skills are required to constantly provide products with stable quality. In other words, HLU molding requires craftsmanship. The skills for removing air bubbles and smoothening material surface are based on "instinct" and "knack" passed down from predecessors, which are all tacit knowledge rooted in subjective senses such as touch, vision and bodily feelings obtained from repeated motions, supported by experience and individual sensitivity. Typically, an HLU molding worker would need more than 20 years to become fully experienced. Process analysis results suggest that the work time in the deaeration process and the method of using a roller characterize the HLU method. We therefore themed this study on the comparative review of the skills applied in the deaeration process and investigation on methods for converting tacit human skills to explicit knowledge and incorporating such knowledge into robots as explicit values.

While growing demand for housing and hotels is expected with Tokyo hosting the 2020 Olympics and Paralympic Games, the serious lack of labor skills and front-line workers is increasingly standing out.

Considering such circumstances, the development of HLU molding robots input with the knowledge of skilled engineers as an achievement of this research will help overcome the lack of skilled workers during the stage of training young personnel to replace their predecessors as generations change. In addition, it will enable a flexible response to the need for small lot production of diverse products, the reduction of manufacturing costs, high productivity, and other advantages of the HLU molding technique leveraging the low facility and operation costs involved. While applying such strengths, it should also realize the continuous and stable supply of high precision, high quality products originally expected of robots. Consequently, this may promote the further evolution of composite materials design and rapidly increase the opportunities of fabricating composite materials using HLU robots.

2 Methodology

2.1 Subjects

The subjects were four craftsmen consisting of an expert in HLU with 27 years of experience, and craftsmen with experience of 13, 3, and 0.5 years, respectively. Table 1 shows the biological data of the subjects.

Table 1 Biological data of subjects

Subject person	Age	Years of experience (year)	Height (cm)	Weight (kg)	Dominant-hand
Expert	50	27	171	52	Right
Intermediate-1	35	13	179	66	Right
Intermediate-2	31	3	164	52	Right
Non-expert	31	0.5	182	77	Right

2.2 Experimental Protocol

The subjects carried out FRP forming by HLU on the measuring device (Fig. 1). The roller used in this study was that used in normal work. Attached with 3 mm hog bristles throughout the whole circumference, the roller measured 14 mm in diameter and 70 mm in width (Fig. 2). Video was taken using one video camera. Figure 1 shows the measurements using a reaction force measuring device. As for the coordinates, the front-back direction in respect to the subject was taken to be the x axis, the left-right direction the y axis, and the up-down direction the z axis. Without specifying the roller work time, the subjects were asked to carry out finishing work using the roller until they were satisfied.

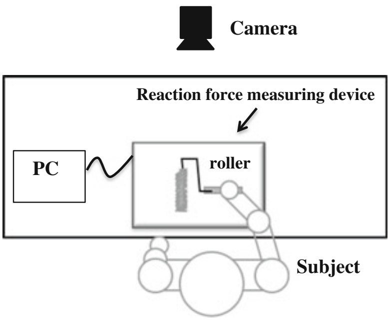

Fig. 1 Measurement environment of this study

Fig. 2 Defoaming roller

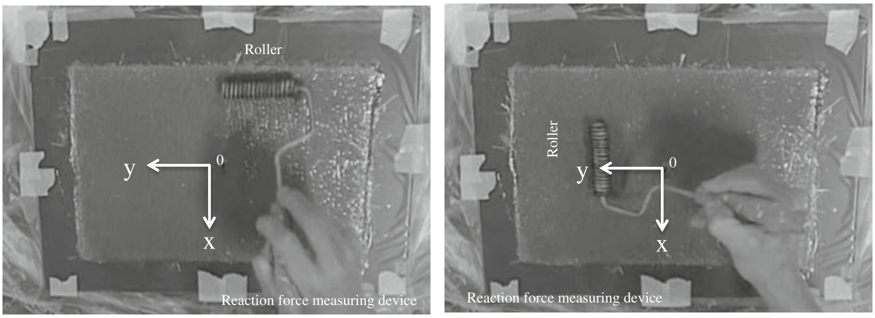

Fig. 3 Photo of reaction force measurement (*left* x-direction, *right* y-direction)

The requirements of the finishing roller work were the elimination of voids inside the FRP laminated layers and smoothness of the finished surface. Finishing is an important step in HLU fabrication and the step where difference in the level of experience appears most conspicuously. The unsaturated polyester resin used in this study changes to gel in 30 min because it is a photocurable resin, which means that the work time is restricted (Fig. 3).

2.3 Materials

Glass fiber chopped strand mat (450 g/m^2) was used as the reinforced substrate. For the matrix, unsaturated polyester resin made with isophthalic acid was used. A curing agent (MEKPO) was added to the resin at a ratio of 100:1.0. Three glass fiber chopped strand mats were laminated in the forming work. The size of the fabricated FRP sheet was horizontally 300 mm and vertically 200 mm (Fig. 4).

2.4 Measurement of Dimensional Stability

To compare the dimensional stability of the obtained samples, the thickness of the FRP sheets was measured every 20 mm using a micrometer (Fig. 4).

2.5 Measurement of Reaction Force

To measure the reaction force imposed by the finishing roller on the laminated layers using the HLU method, the reaction force measuring device was used