

Difference in Polishing Process of FRP Between Expert and Non-expert

Takuya Sugimoto^{1(✉)}, Daiki Ichikawa¹, Hiroyuki Nishimoto²,
Yoshiaki Yamato³, and Akihiko Goto⁴

¹ Kyoto Institute of Technology, Kyoto, Japan
t-sugi@koyo-kinzoku.com, daikiichikawa0113@yahoo.co.jp

² Takeda Pharmaceutical Company Limited, Tokyo, Japan
hiroyuki.nishimoto@outlook.com

³ Kure National Collage of Technology, Hiroshima, Japan
yamato@kure-nct.ac.jp

⁴ Osaka Sangyo University, Osaka, Japan
gotoh@ise.osaka-sandai.ac.jp

Abstract. One of the quality assurance methods for steel and composite materials is to verify material constitutes and structures of polished specimens by microscope. We prepared a sample used for microscope analysis in the following method: first, cut a sample from the cross-section, and mount with the epoxy resin, and then grind it. This process requires long craftsmen's experience to grind a sample properly for microscope test. In this research, we comparably evaluated the differences in grinding sound and comprehension skills between the expert and the non-expert. As a result, we found that the expert was more sensitive to the difference in the sounds generated during grinding process. He comprehended the state of a grinding sample by the sound generated during grinding and adjusted his grinding force in a wider range.

Keywords: Polish · CFRP · Expert · Microscopic analysis

1 Introduction

The steel and composite materials are essential in the production of automobiles, construction machinery, transport equipment such as airplanes, and construction structures [1–9]. These materials are selectively used according to necessary strength and application purpose. However, the strength and mechanical properties of steel and composite materials can't be determined by appearance. In addition to the tensile and strength tests, it is necessary to verify the metallographic and laminate structures for making sure if material constitutes and structures are suitable for desired applications. And when verifying the metallographic and laminated structures, ground specimens are used for microscope tests [10]. This method enables us to comprehend the phase states of metal structures, the depth of grain boundary oxidations, austenite residue amount measurements, and the dispersion states of cementite [11–12]. Moreover, the microscope test of composite materials can verify the resin impregnation states, the existence of voids, and fiber bundle states [13].

As for the preparation method of a sample used for microscope analysis, first cut a sample from the cross-section, mount with the epoxy resin, and then grind it. The sample preparation method is specified by ASTM E3 [14]. Based on the fundamental theory for specimen preparation designed by Samuels et al. [15], Smith et al. suggested the comparative evaluation method of finishing qualities of thermal sprayed specimen made from different grinding materials [16]. However, there is no research about the necessary skills for the sample preparation. It required the high skills obtained through long years experiences for creating samples accurately for test use. The strengths and sizes of samples vary depending on characteristics of components, so that only skilled workers can comprehend the components' properties and adjust the grinding conditions properly. In this study, we analyzed the grinding process on the subjects with different proficiency. We also presume that the important information to grasp a grinding state properly is the sounds generated during grinding. We evaluated the sensitivity to the sounds generated during grinding works on the subjects. And also measured that the pressing forces of the subject's figures during grinding process. And then discussed how the difference in pressing forces of the figures and sensitivity to grinding sounds affect the grinding process and finishing quality.

2 Measurement Method

We adopted two craftsmen as the subjects for this study; one has 25 years grinding experience, who is referred as "expert." The other has only 2.5 years grinding experience and is referred to as "non-expert." The CFRP is laminated with a seven-layer made by a hand-lay-up method and was used as grinding samples. After cutting the CFRP specimen, it was heat mounted by epoxy resin with 31.7 mm thickness in the outer diameter (Durofast, Struers,).

2.1 Grinding Process Analysis

Using a grinding machine (by Refinotec, STO-228B) which the subjects daily used, the motion of a subject pressing a specimen on the grinding sheet was analyzed. The grinding was done by P120, P400, P800, and P1200 SiC grinding sheet and 5 μ , 0.3 μ m of alumina suspension.

Test Method. The motions that a subject gripped a specimen and pressed on a rotating grinding plate were recorded by a video camera for analysis. The test conditions such as the rotating speed of the grinding plate and water supply were the same for the both subjects. After the grinding process, we interviewed the subjects regarding the grinding process when necessary. The finished surfaces were evaluated by microscope (Eclipse MA-100, Nikon).

Results. The Total Grinding Time: Figure 1 shows the total grinding time of the subjects. The expert took 525 s and the non-expert took 637 s in the total grinding time respectively. The time that the expert spent for grinding was 112 s shorter. As for the total grinding time per each grinding particle size, the expert spent shorter time for all particle sizes, except the 0.3 μ m.

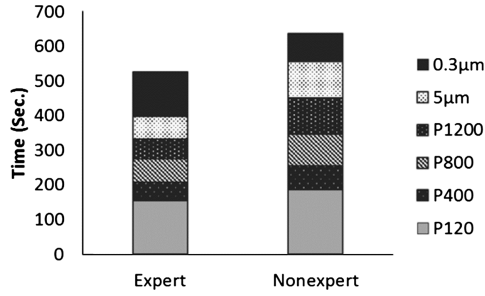


Fig. 1. The total grinding time of the subjects

The Average Grinding Time: During the grinding process, both subjects pressed the samples on the rotating grinding plate and they repeated this motion. Figure 2 shows the average time that the subject pressed the sample against the rotating plate. As the results shows, for all particle sizes of SiC and alumina grinding sheets, the expert showed greater variation in average time of pressing samples on the grinding sheets. When we interviewed the expert regarding this result, he remarked that he was doing this unconsciously. But he adjusted the pressing forces and time based on the feedback from the grinding sounds and the sense transmitted from the grinding sample.

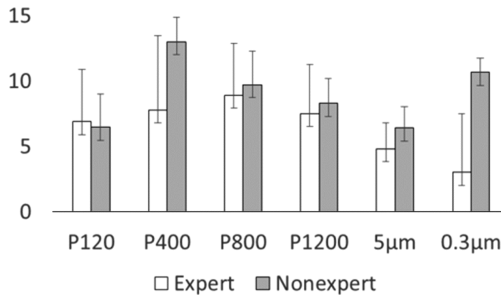


Fig. 2. The average time that the subject pressed the sample against the rotating plate between subjects.

Final Finished Surface: Figure 3 shows the final finished surface of the ground specimens done by the subjects respectively. Comparing the finished surface done by the non-expert, we found that warp and weft clearly appeared on the finished surface of the expert’s sample. This suggested that the expert ground the warp and weft, and resin in the uniform manner.

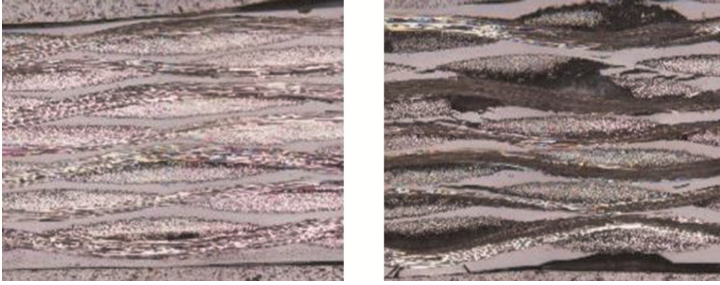


Fig. 3. The final finished surface of the ground specimens by each subject

2.2 Susceptibility Test of Grinding Sound

As the results of process analysis, we found that the expert comprehended the grinding conditions using the sound generated during grinding work. Thus, we tested the susceptibility of each subject to the sound generated by grinding. The grinding sounds were recorded beforehand and used for this test.

Test Method. We recording the grinding sound using a digital recorder, PCM (Pulse Code Modulation) recorder (R-26, Roland). The microphone was in-built in a linear PCM recorder. The sampling frequency was 44,100 Hz and the number of quantization bits was 16 bits. The grinding sound was recorded using an automatic grinding machine (IMT, Rana-3) with P120 grinding sheet, which both subjects had in daily use. The pressure range was 10–20 according to the usual levels to both subjects. While increasing the pressure with every 1, we recorded the grinding sound for 5 s on each pressure level, respectively. The Fig. 3 shows the location of the grinding machine and the recorder. Recording was conducted under the same environment where the subjects are usually working. Before the test, both subjects had time to make sure of the difference in the sound generated on each pressure level. We varied the pressure levels from 10–20. In the test, the subjects heard the standard grinding sound (10 N) once again. And then we increased the pressure level gradually from 10 N. The subjects answered the grinding sound corresponding to each pressure level from 10 N to 20 N, only with sound recognition.

Results. We examined the subjects' comprehension levels to the grinding sound with varying pressure levels by every 1 N from the standard grind sound (10 N) to 20 N. Figure 4 shows the results of each subject and the actual pressure levels. Regarding the difference between the actual pressure levels and the results, while the deviation range of the expert were within ± 1 N for all pressure levels, the non-expert selected the sound on the same pressure level (16 N) three times. This results suggested that the non-expert was less susceptible to the grinding sound compared to the expert. And the non-expert said that he sometimes judged sounds only with the volume. Also during the experiment, he no longer determined the standard grinding sound.

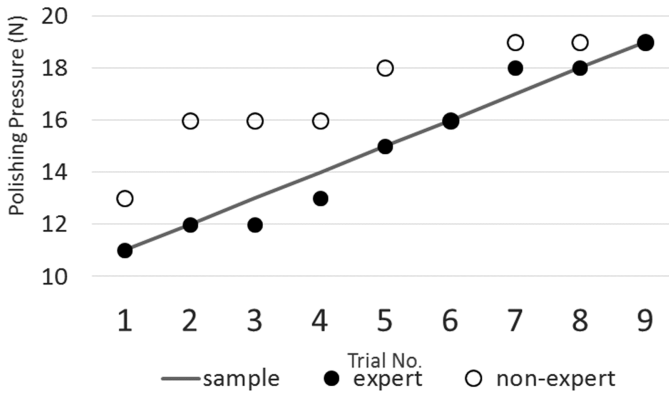


Fig. 4. The results of each subject and the actual pressure levels

2.3 Gripping Force During Grinding Process

According to the results of process analysis, the expert varied the force to press a sample on the grinding machine. We thus measured the gripping force of the specimen during the grinding process using a pressure sensor (Pressure Profile Systems Inc., Finger TPSII). The sensor thickness was at 2 mm and the sensitivity was 0.045 kg. We attached sensors on the thumb, index finger, middle figure and ring finger which the subjects usually use during grinding process. The data acquisition frequency was set at 40 Hz. Since the wet grinding was carried out with water, to avoid any effect to the sensors, the subjects wore very thin finger stalls during the experiment.

Test Method. Using a grinding machine (by Refinetec, STO-228B) which the subjects daily used, we analyzed the motions when the subjects pressed the gripped specimen on the grinding sheet. First, we asked the subjects to perform grinding with usual force for three times. Then, perform another three times with maximum pressure. Other grinding conditions such as rotating speed of grinding plate and water supply were in the same manner as usual.

Results. Figure 5 shows the average force that the each subject gripped a sample. The total amount of the average grip force of the expert was 7.15 kg, while the non-expert showed 3.18 kg. The result of the expert was more than two-fold of that of the non-expert. Moreover, regarding the total amount of the average grip force at the maximum pressure, the expert showed 186 %, which was much greater than 152 % of the non-expert.

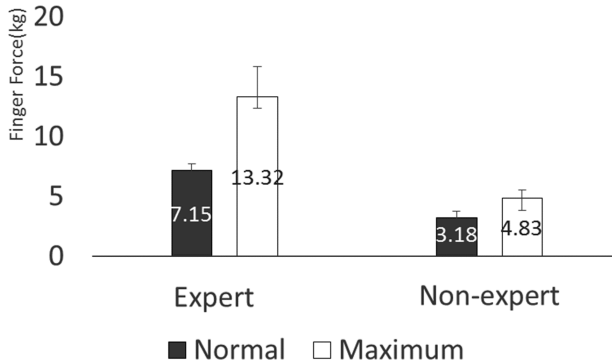


Fig. 5. The total amount of the average grip force between subjects

3 Discussion

As shown in Fig. 2, the standard deviation of the time while the expert pressed the specimen on the grinding sheet was greater than that of the non-expert. This suggested that the expert varied the grinding conditions more than the non-expert. In the interview with the expert, he perceived the grinding efficiency based on grinding sound. In order to verify the correlation between the grinding pressure and sound, we examined if the subject could identify the grinding sound corresponding to each pressure level. With this experiment, we found that the expert could identify the grinding sound within ± 1 N error range. This suggested that the expert could comprehend the grinding pressure level based on the skills cultivated through his long-term experience. Moreover, at the time of maximum pressure, the force gripping a sample of the expert increased with 86 % more than that in normal procedure. We assumed that the broad experience of the expert allowed him to relax, so that he could perform grinding works without overstrain. He therefore, was not overwhelmed by the disturbance occurred on the rotation plate by rotation force, and maintained stability in pressing the sample down on the rotating plate. On the other hand, the non-expert overstrained and couldn't perform well. Thus, the difference in the values between the normal and maximum rates was not as great as the expert. Furthermore, the expert enhanced the grinding pressure by utilizing the differences between the normal and maximum pressures levels. This enabled the grinding work efficiently, so that the total grinding time of the expert was shorter than that of the non-expert.

4 Conclusion

In this study, we compared the differences of the grinding process done by the expert and non-expert in the preparation of the specimens for CFRP microscope analysis. As the result, the standard deviation of the time when the expert had pressed the non-abrasive sample on the grinder was greater than that of the non-expert. It suggested that the

expert had changed the grinding conditions during the process. Regarding the force gripping the specimen during grinding, the expert showed a two-fold higher value than that of the non-expert. Also, as for the difference between the regular and maximum pressures when folding a sample down on the grinding machine, the expert also showed the greater value than the non-expert. We also found that warp and weft clearly appeared on the finished surface of the expert's sample.

Moreover, we verified the difference in the sensitivity to the grinding sound that is considered as factor to determine behaviors during grinding works. In the experiment, the expert could almost precisely determine the sound generated with varying pressure from low to high levels, while the non-expert chose the same sound generated by the same pressure level three times. It suggested that the sound sensitivity of the non-expert was lower than the expert. This result suggested that the expert comprehended the grinding states with the sound generated during grinding. He re-created the optimal grinding conditions with a wide range of pressure adjustments, which induced the finished surface with high-uniformity.

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