The Load Measurement of the Beating Brush in the Second Lining Procedure

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Abstract. Hanging scroll is a traditional Japanese ornamental art, which includes paintings and calligraphy. Scrolls are unrolled and hung on a wall or in an alcove when displayed and are rolled up and stored in a box. They should hang straight without rippling or warping when unrolled, and be rolled up smoothly and tightly from the bottom when stored. To enable rolling out and hanging scrolls smoothly, the paintings and calligraphy referred to as "main works" are generally backed with traditional Japanese paper and adhered using a paste made from wheat starch. Especially in order to guarantee this flexibility function that enables rolling up smoothly, a type of glue that does not harden after it dries is employed as the adhesive agent for the lining process. But since this glue does not have sufficient adhesive effect, craftsmen employ a traditional technique of pounding the paper with a special "pounding brush" to enhance its adhesive effect. In this study, using pressure measurement films, we considered differences in the techniques of an expert and a non-expert by measuring the pounded area by a brush and the pressure to be applied by pounding with a brush. Through the quantification of the differences of these two subjects, we aim to understand the characteristics of proper pounding technique, to help new craftsmen learn more quickly.

Keywords: Pressure measurement films · Hanging scrolls · Pounding brush

1 Introduction

Hanging scroll is a traditional Japanese ornamental art, which includes paintings and calligraphy. This art works binding method has been playing an important role in decorating the space, with the development of Japanese cultures such as tea ceremony and flower arrangement. Scrolls are unrolled and hung on a wall or in an alcove when displayed as shown in the Fig. 1, and are rolled up and stored in a box as shown in the Fig. 2. Storing the scrolls rolled up protects the artwork inside from exposure to light and air, this method has been recognized as a superior way to preserve paintings and calligraphy from other eras. The preservation method is extremely important for the paintings or calligraphies with high cultural values. In case of repairing the high cultural valued art works bound in scrolls and passed down from ancient or Middle Ages to the present, it usually remove a art work from a scroll and repair the damaged

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parts and rebind it again. This binding technique is essential method to hand down the precious cultural assets to the next generations. They should hang straight without rippling or warping when unrolled, and be rolled up smoothly and tightly from the bottom when stored. To enable rolling out and rolling up functions smoothly, the paintings and calligraphy referred to as "main works" are generally backed with traditional Japanese paper and adhered using a paste made from wheat starch.

Fig. 1. A Hanging scroll displayed in an alcove with flower arrangement

In order to back-line main works, four layers of paper, called "lining papers," are generally adhered with starch paste. These layers are known as the first, second, third, and final lining papers, in order of proximity to the artwork. *Nakauragami*, or the third lining paper is the name of the layer to be back-lined before adhering the final lining paper, after the work called "*Tsukemawashi*", which applies brocades and silk around the edges of the main work for the purpose of protecting it, as well as for decorations. Depending on quality and size of the base material of the main work, more linings may be applied. In this case, the second and the third lining layers are applied without "*Tsukemawashi*". And the third layer applied in this case is also called "second lining"instead of "third lining". Or sometimes, the final lining paper is applied after "*Tsukemawashi*", without applying the third layer. The Fig. 3 shows the most common type of laminated constitution of binding work, where four layers backing papers were attached to the back side of the main work. Types of Japanese papers and glue, and concentrations of diluted glue used are different for each layer. To enable rolling out and rolling up functions smoothly, it is said that it takes long time to acquire the lining technique.

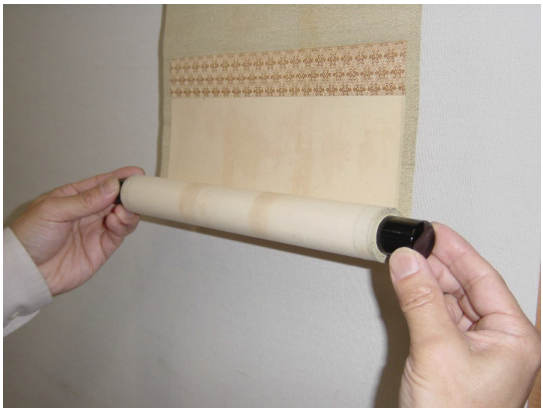

Fig. 2. Rolling up a Hanging scroll

For adhering the first lining layer directly to the back side of the main work, the glue called as "Shin-nori (fresh paste) with strong adhesive properties is used. This glue is made from wheat starch that has been heated and allowed to gelatinize, and then cooled naturally overnight. The purpose of applying the first lining layer is to reinforce the main works from the back side. And in order to prevent ripping and warping, the first lining paper should be adhered firmly with fresh paste. However, since fresh paste has strong adhesive properties, if it is used for the second and later layers, there is a concern that it may spoil the necessary flexibility to be required for a scroll when rolled up and down. Thus, aged paste is used for adhering the second and later layers. The aged paste is made by putting newly made paste during the coldest season in Japan into a pot and sealing it. It is then aged for ten years in a cool, dark place to allow it to ferment. During the fermentation process in the pot, biodegradation advances and the molecular weight of the starch paste decreases, severely weakening its adhesive properties. This weaker aged paste does not stiffen like new paste, even after it has dried. Due to this function, the aged paste is applied for the adhesion of the second and later lining layers, which allows the scrolls to be smoothly rolled up for storage.

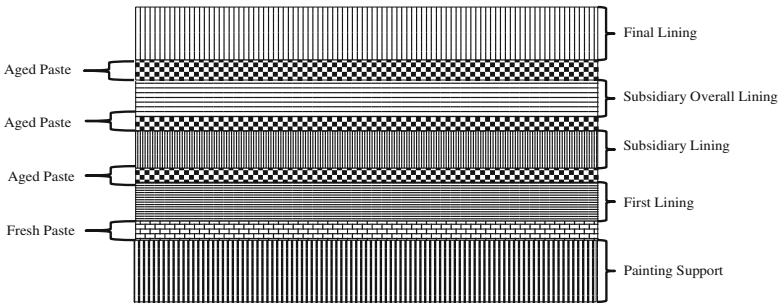

Fig. 3. The Outline of laminated constitution of binding work

For adhering the first lining layer directly to the back side of the main work, the glue called as "Shin-nori (fresh paste) with strong adhesive properties is used. This glue is made from wheat starch that has been heated and allowed to gelatinize, and then cooled naturally overnight. The purpose of applying the first lining layer is to reinforce the main works from the back side. And in order to prevent ripping and warping, the first lining paper should be adhered firmly with fresh paste. However, since fresh paste has strong adhesive properties, if it is used for the second and later layers, there is a concern that it may spoil the necessary flexibility to be required for a scroll when rolled up and down. Thus, aged paste is used for adhering the second and later layers. The aged paste is made by putting newly made paste during the coldest season in Japan into a pot and sealing it. It is then aged for ten years in a cool, dark place to allow it to ferment. During the fermentation process in the pot, biodegradation advances and the molecular weight of the starch paste decreases, severely weakening its adhesive properties. This weaker aged paste does not stiffen like new paste, even after it has dried. Due to this function, the aged paste is applied for the adhesion of the second and later lining layers, which allows the scrolls to be smoothly rolled up for storage.

The aged paste is diluted with water when it is used. Therefore, its adhesive strength is insufficient, and because of that, scroll makers use a traditional technique of pounding the surface of each lining paper with a special "pounding brush," to provide better adhesion. The process of applying glue on the second and later lining papers and pounding on their surface is called "pounding work". When pounding lining papers with a brush, it damages the paper if pounding is too strong, but if it is too weak, it cannot enhance the adhesion property. Moreover, if the entire adhesion surface is not pounded evenly with the consistent strength, it will result in an uneven adhesion state

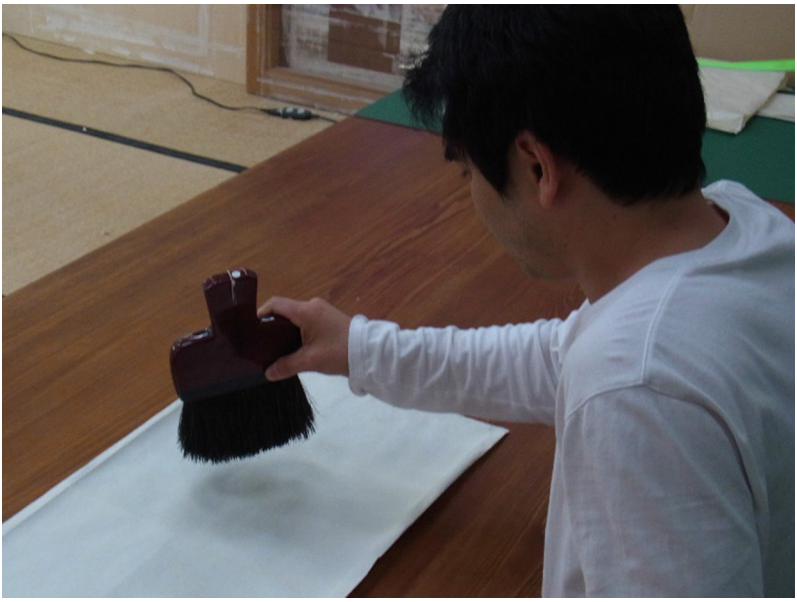

Fig. 4. Pounding work

of the entire surface. And it will eventually cause warping when binding work of a scroll is completed. Same as other traditional techniques, non-experts watch and learn this technique from the movement of experts, so it takes a long time to acquire this pounding technique (Fig. 4).

In this study, using pressure measurement films, we considered differences in the techniques of an expert and a non-expert by measuring the pounded area by a brush and the pressure to be applied by the brush, and the average pressure. The expert and the non-expert were instructed to pound the surface of the pressure measurement films, assuming that the film was a lining paper surface to be adhered. The color of the pressure measurement film changed only on the locations where pressure was applied. From the spots where the color changed, it allowed us to ascertain the differences between the expert and the non-expert, and comparatively analyzed the test results. Through the quantification of the differences of these two subjects, we aim to understand the characteristics of proper pounding technique, to help new craftspeople learn more quickly.

2 Experiment with Pressure Measurement Film

2.1 Subjects

In this study using pressure measurement films, we assigned one expert and one non-expert respectively and instructed them to do the "pounding work". The information of the subjects is stated in the Fig. 1.

The non-expert has been acquiring training of pounding work. But according to the expert, his work is not stable and the unevenness of his finish is frequently pointed out. He is not yet in the stage where he can perform the pounding work in the real work situation (Table 1).

Table 1. Data about the subjects

Subject (age)	Years of Experience	Height (cm)	Weight (kg)	Gender	Dominant Hand
Expert (40)	22	171	72	M	R
Non-expert (27)	6	170	54	M	R

2.2 Pressure Measurement Film

In this study, the pressure measurement film "Prescale" for ultra low pressure LLLW made by Fujifilm Corporation was used. The possible measurement range is from 0.2 MPa to 0.6 MPa. This film consists of two kinds of films, film A and C. Film A, which had a coupler layer, and film C, which had a layer of color developer, were placed together and used for measurement. The mechanism of this film is; when the micro-capsule in the coupler layer is destroyed by pressure, the coupler adheres to the color developer, and then turns to red by chemical reaction (extracted from the instruction manual of "Prescale"). The film was 270 mm in length and 200 mm in width.

2.3 Experiment Method

Both the expert and non-expert were instructed to conduct the "pounding work" on their workbenches in their usual manners. We measured how much pressure was applied by one pounding, and the size of the area of the pounding brush that is used for pounding. In order to obtain the result per each pounding, we asked the subjects to pound the same spot on the workbench repeatedly. During the motion, we inserted a film between the pounding brush and the workbench to take the marks brought by one pounding motion, which was then pulled out after 1 pounding.

Next, the subjects were instructed to pound the entire surface evenly. Based on the standard process of second lining, both subjects started pounding from the right side front, gradually moving the brush in the way shown in the Fig. 5. After the pounded films were scanned and digitalized, they were analyzed by the pressure analysis system FPD-8010 J. The area applied with pressure, pressure load and the average pressure were digitalized according to each pounding. In case the entire surface of a film was pounded, we detected the existence of unevenness visually, and then calculated the pressure load and the average pressure.

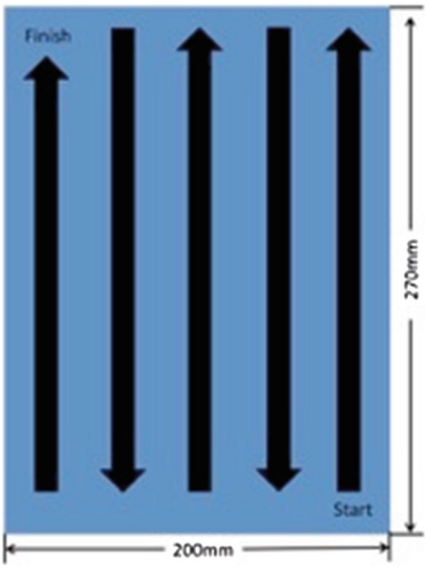

Fig. 5. The outline of motion of brush when pounding entire surface of pressure measurement film.

3 Result and Discussion

3.1 Analysis of One Pounding

The Fig. 6 shows the pressure measurement film pounded by the expert and the Fig. 7 shows that of the non-expert. As shown in these two figures, the expert pounded larger

area than the non-expert. Moreover, the area applied with pressure, and pressure load and average pressure obtained by the image analysis are indicated in the Table 2.

Table 2. Comparative analysis between expert and Non-expert about area applied with pressure, pressure load and average pressure by one pounding.

	Pressurized area (mm^2)	Load (N)	Mean pressure (MPa)
Expert	4997	1174	0.23
Non-expert	4101	914	0.22

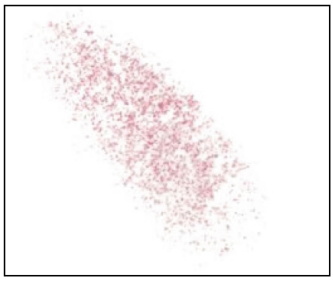

Fig. 6. Trace of Pounded Area by Expert

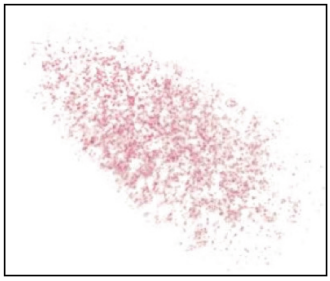

Fig. 7. Trace of pounded area by Non-expert

These results shows that the area the expert could apply the pressure by one pounding for enhancing the adhesive properties is 1.22 times larger than it of the non-expert. Though the difference in the pressures applied by one pounding between the expert and the non-expert is 260 N, no difference in the average pressure between the two subjects was detected. As the result shows, the expert pounded larger area and applied more pressure by one pounding than the non-expert, which enabled him to enhance the adhesive properties efficiently.

3.2 Pounding the Entire Pressure Measurement Film

The Figs. 8 and 9 show the image analysis results for the expert and non-expert respectively. The numbers of poundings of both subjects, and the pressure load and average pressure obtained by the film image analysis are shown in the Table 3.

Although the non-expert showed the higher values in the pressure load and average pressure, the cause of this result was presumed by observing the pounded films shown in the Fig. 8. Generally, the non-expert could not pound evenly; there were some parts where the films remained white, especially in the lower central parts. On the other hand, he pounded the same part repeatedly, which caused that part to turn red. While

the image analysis in the Fig. 9 shows that the red spots showing 0.25 N to 0.60 N pressures are distributed evenly in the work done by the expert, the yellow spots showing 0.60 N or more pressures are unevenly distributed in the non-expert's work, especially in the right side of the films as shown in the Fig. 10. And when comparing the number of poundings, while the expert pounded 52 times to complete the pounding on the entire surface, the non-expert needed 88 time to complete his work.

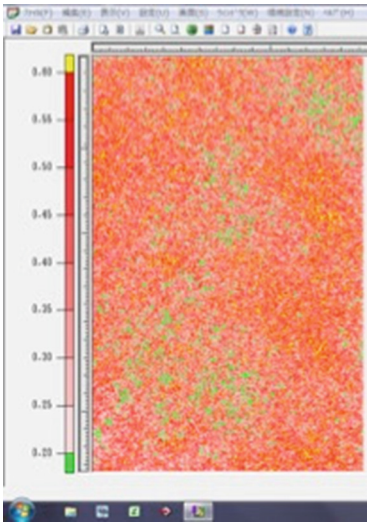

Fig. 8. Analysis after pounded by Expert

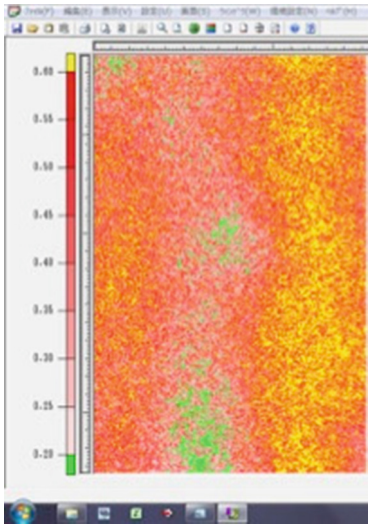

Fig. 9. Analysis after pounded by Non-expert

3.3 Comparison by the Range Where the Pressure Was Applied

The Fig. 10 shows the pressure distribution chart prepared based on the analysis result.

The differences in the pressures applied on the surfaces of films were observed between the expert and non-expert. While the expert pounded the most of the area with the pressure range from 0.30 MPa to 0.35 Mpa, the non-expert pounded the most of the area with 0.60 MPa or more.

Table 3. Comparison of the number of poundings, pressure load, and average pressure between expert and non-expert.

	Pounding times	Load (N)	Mean of pressure (MPa)
Expert	53	14214	0.40
Non-expert	88	16699	0.47

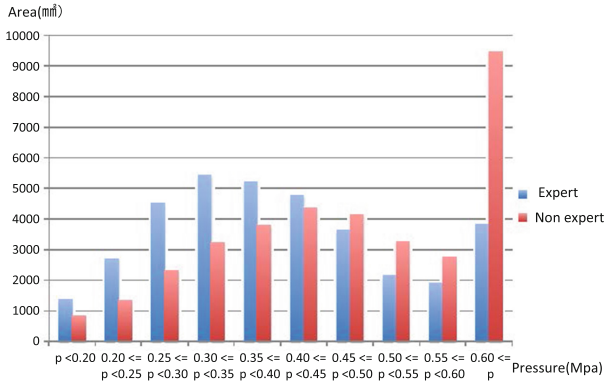

Fig. 10. Pressure distribution chart

4 Conclusion

In this study using pressure measurement films, we verified the differences in the techniques of pounding done by an expert and a non-expert for the purpose of adhesion enhancement, by measuring the pounded area and the pressure applied by pounding. The results showed that the expert was able to enhance the adhesion of larger area and apply more pressure load by one pounding than the non-expert. Thus, in case of enhancing the adhesion in large area, the expert could complete the pounding work more evenly than the non-expert. And the number of poundings done by the expert was less than that of the non-expert. It revealed that the non-expert pounded the same spots repeatedly, while he left some other parts not pounded. Through such unevenness in the adhesion enhancement process, there is a concern that the original function of hanging scrolls which is to hang straight might be impaired.

Also, after pounding works, we interviewed the expert and the non-expert how to grip a pounding brush. While the expert griped the brush with an angle, holding it with upward diagonal angle from fingers to wrist,, the non-expert tended to grip it from side horizontally. Moreover, when asked which part of the bottom of the brush was used, the expert clearly answered that he intentionally used the right side half of the brush when holding it with his right hand. However, the non-expert did not pay attention to which part of the bottom side of the brush he was using during pounding. These differences are presumed to influence the differences in the techniques between the expert and non-expert, so that more discussion is necessary.

The measurement with pressure measurement films is an effective method to evaluate the technique for pounding the adhesion surface evenly. Since this method can visualize the acquired level of technique easily, it is thought to be the effective way to utilize in the instruction manual for new craftspeople in the future.

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