Researching Sounds Generated During the Second Lining Pounding Process

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Abstract. Japanese calligraphy and works of art, which are written and painted on paper and silk, are often lined with Japanese *washi* paper and strengthened from the reverse side. They are then treated with various binding methods based on the purpose of the item and how it is intended to be viewed. The hanging scroll, which is a perfect example of a binding format, is only displayed when it is meant to be viewed and is hung on an alcove or beam. When it is finished being used, it is rolled up tightly from the bottom and stored in a box. In order to repeatedly roll up and open a hanging scroll smoothly, the hanging scroll is lined with several layers of Japanese *washi* paper, which are pasted onto the reverse side of the scroll. A paste with a low adhesive strength which has been further diluted is used to prevent the adhesive from hardening after it has dried. The joined surfaces are then pounded with a brush to enhance the adhesion. The level of expertise of this technique is determined by the sound that is generated when pounded using the traditional method. This research measures the sound generated when the joined surfaces are pounded by an expert and a non-expert with the purpose of evaluating the specific features of both sets of sounds.

Keywords: Amplitude · Hanging scroll · Pounding brush

1 Introduction

In the 6th Century, around the time when Buddhism was introduced from the continent of Asia, various cultural works were brought to Japan. New cultures were introduced from overseas and Japan's own cultures gradually continued to flourish. Works of art from various fields depicted religious subjects, sceneries and genres, and calligraphy that depicted genuine records, sublimated to express beautifully, are known to be among those cultures. These works of art and calligraphies were prepared on paper and silk. Needless to say, paper and silk, which are organic materials, deteriorate and are easily deformed when exposed to air and light for long periods of time. Nevertheless, many works of art and calligraphies which are believed to have been created in Japan after the turn of the 8th Century are still being handed down to this very day. The strong determination that many people have to pass on these valuable works of art and calligraphies to the next generation is considered an achievement. However, at the

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same time, it is also believed that the method for binding works of art and calligraphy developed by Japan is the reason that many of these cultural works have been able to be passed on. The hanging scroll is a perfect example of this. Figure 1 shows an arrangement consisting of a hanging scroll which has been hung on an alcove with flowers placed in front of it to welcome guests. This hanging scroll is bound in a way so that it is only hung on an alcove or beam when it is meant to be viewed. Once it has finished being used, the hanging scroll is rolled up tightly from the bottom with the side that contains the work of art or calligraphy rolled up on the inside. It is then stored in a box. Figure 2 shows a hanging scroll being rolled up. In other words, the work of art or calligraphy which has been bound to the hanging scroll can be exposed to air and light, causes of deterioration, for a minimal duration, making it an excellent binding method.

They are unfurled and hung up on a wall for viewing but rolled up and stored in a box. The scroll needs to hang straight without causing any warps or undulations during display, but it also has to be able to be rolled up smoothly without creasing for storage. It is lined with Japanese *washi* paper in order to make these two functions possible. About four layers of Japanese *washi* paper is attached using starch paste for the purpose of lining. The adhesion needs to be supplied sufficiently when attaching the Japanese *washi* paper to withstand being rolled and unrolled, but if a starch paste with a high

Fig. 1. An arrangement consisting of a hanging scroll which has been hung on an alcove with flowers placed in front of it

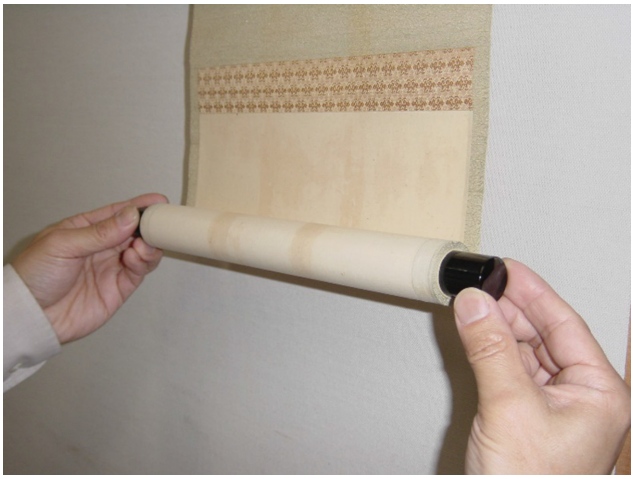

Fig. 2. Rolling up a hanging scroll

adhesive strength is used, the glued layers will become hard and the scroll will crease when it is rolled and unrolled. Thus, starch paste with a low adhesive strength is chosen for the lining adhesion from the second layer in particular. The paste is then heavily diluted with water so that it does not become hard after drying, allowing the scroll to be smoothly rolled and unrolled.

However, a paste with low adhesive strength is not able to sufficiently stick to Japanese washi paper. For this reason, the joined surfaces are pounded with a brush, a special skill that enhances the adhesion and has been handed down through hanging scroll craftsmen for several hundred years. In this research, this action of striking the scroll with a brush is referred to as "pounding". Figure 3 shows someone pounding. If the pounding is too strong, the lining paper can be damaged. On the other hand, if it is too weak, then the adhesion cannot be properly facilitated.

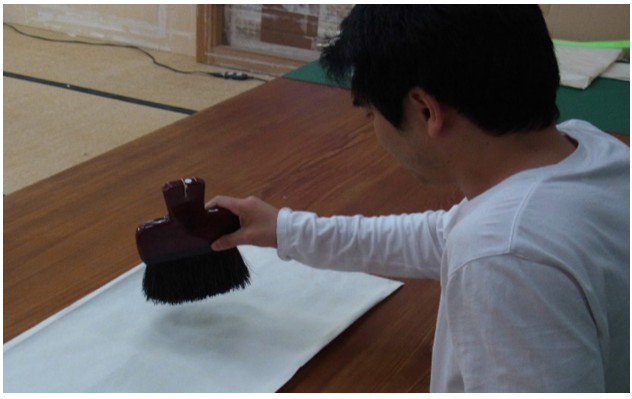

Fig. 3. Pounding

Similar to Japan's many traditional crafts which have a high degree of difficulty, watching and learning the skills of an expert is the primary method in which this skill has been passed down, making pounding difficult for non-experts to learn.

The level of expertise in this skill is sometimes measured in hanging scroll crafting workshops where this skill is put into practice every day primarily when experts use a brush on the joined surfaces, or more specifically, through the sound that is generated when the joined surfaces are pounded.

The subjects used in this research were an expert and a non-expert. This research analyzes the sounds generated by pounding, which has never been quantified until now. We expect this information to be of large assistance in learning how to pound.

2 Materials and Structure Used to Craft Hanging Scrolls

Usually, four layers of Japanese *washi* paper are stuck onto the back of where the work of art or calligraphy have been written or painted. Japanese *washi* paper called "*usu-mino* paper" is used for the first lining and glued directly to the back of the work of art or calligraphy. This Japanese *washi* paper, made from the plant fiber of a mulberry tree, is sturdy despite being so thin, and is resistant to water and other liquids. This properly supports the work of art or calligraphy from the reverse side and exists as what would be the "foundation" if using a building as a metaphorical example. It is manufactured in the Mino area in Gifu Prefecture. A wheat starch paste is used for the first lining adhesive. The wheat starch is gelatinized by stirring it in water for approximately one hour while applying heat to it, then it is left to gradually cool overnight before it is used. The starch paste has high adhesive strength.

For the second lining and all subsequent linings, this sturdy usu-mino paper and adhesively strong wheat starch paste cannot be used, and the lining cannot be layered. This is because using any more of these materials than is necessary causes the lining to harden after drying, preventing the scroll from being able to be neatly rolled and unrolled. Thus, misu paper, a Japanese washi paper which is even thinner and softer than usu-mino paper, is used for the second and third linings, and a Japanese washi paper called uda is used for the final lining. Misu paper and uda paper are made from mulberry tree, the same material used in usu-mino paper. Aged paste is added to misu paper, and white clay is added to uda paper.

A paste with a low adhesive strength called "aged paste" is used for the Japanese *washi* adhesive in the second lining and all subsequent linings. Aged paste is acquired by heating and gelatinizing wheat starch paste, sealing it in a pot and storing it in a cold, dark place for approximately ten years where it is left to mature. The starch is aged by storing it for a long period of time, and the molecular weight is considerably reduced due to enzymes which regenerate the microbes, giving aged paste a lower adhesive strength than normal starch pastes. Aged paste is normally diluted to about 3 % before it is used. It does not harden when it dries and does not crease, making it an essential material in allowing hanging scrolls to be repeatedly rolled and unrolled smoothly. Figure 4 shows Japanese *washi* paper and paste which have been layered and glued on the back of works of art and calligraphy.

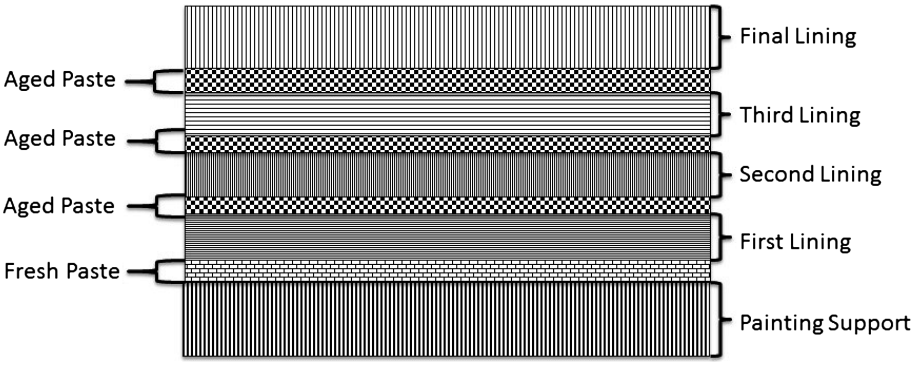

Fig. 4. A cross-section view of a hanging scroll with pasted layers of Japanese *Washi* paper

3 Adhesion Technique

The diluted aged paste, which is used for the second and all subsequent linings, hardly feels viscous when touched with a finger. As was previously mentioned, it has the advantage of not hardening after it dries, but on the other hand, it is not able to achieve adequate adhesive strength. Thus, the joined surfaces are pounded with a large brush called a pounding brush to facilitate adhesion. A worker continuously pounds with the pounding brush, starting from the front right and pounding in a forwards motion. Once the worker has reached the edge of the side furthest away from himself, he moves the pounding brush slightly to the left while continuing to pound. He then brings the pounding brush back towards himself. He pounds the joined surfaces which need to have their adhesion facilitated while repeating this forwards and backwards action. Figure 5 shows a diagram of the pounding brush's movements.

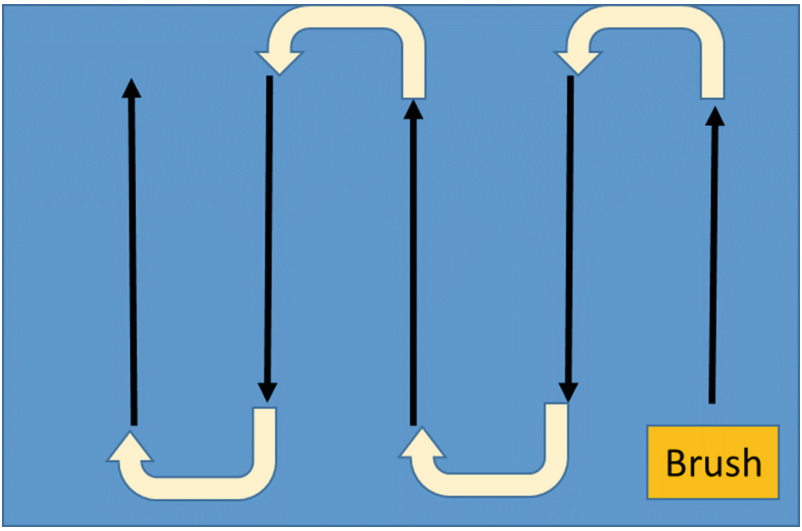

Fig. 5. Path of a pounding brush used to facilitate adhesion viewed from above

Fig. 6. Underside of the pounding brush which comes into direct contact with the joined surfaces

By repeatedly pounding as wide an area as possible on the joined surfaces with the underside of the pounding brush, shown in Fig. 6, adhesion can be facilitated without any unevenness. A non-expert, who needs to master the skill, is made aware that primarily, the wide area on the underside of the brush is supposed to strike the joined surfaces evenly. With each forwards and backwards action, the worker also changes which hand is holding the brush in order to prevent his arm from tiring and to allow continuous and stable pounding. The worker needs to be able to expertly use the underside of the brush the same way in both hands and pound the joined surfaces without any unevenness.

4 Measuring the Sounds Generated When Pounding

4.1 Purpose of Measuring

The level of expertise of the pounding technique is often determined by the sound that is generated when pounding. We instructed both an expert and a non-expert in the usual way of pounding. The sounds that were generated when they pounded were recorded by contact microphones, which were installed on the workbench. The difference in the level of expertise in performing this skill was investigated by measuring the amplitude of the sounds.

4.2 Test Subjects

The test subjects were an expert who has 22 years of experience in pounding, and a non-expert who only has 9 years of experience in pounding. The non-expert, with only 9 years of experience, is still learning the pounding technique, and is deemed to not yet be at a level where he is able to perform the task properly because he has not finished acquiring the skill. The details of each of the subjects are shown in Table 1.

Table 1. Subject information

Subject	Years of experience	Gender	Height	Weight	Dominant hand
Expert	22	Male	171 cm	72 kg	Right
Non-expert	9	Male	181 cm	60 kg	Right

4.3 Experimental Method

A sample was prepared for each of the subjects, which had a completed even-weave silk first lining and had been properly dried before placing the second lining. The subjects were instructed to pound the samples the usual way to facilitate adhesion. The samples were 35 cm in height and 60 cm in width. This was in reference to the size of the cloth lining which is selected when crafting hanging scrolls used in general events such as tea ceremonies.

In order to make the subjects work the same way they would when usually pounding, they were instructed to continue pounding until it was clear that the adhesion had been successfully facilitated.

Four contact microphones were installed on the workbench in order to measure the amplitude of the sounds that were generated when pounding. Figure 7 shows a diagram of the method used to measure the sounds. The sampling frequency was 48 kHz.

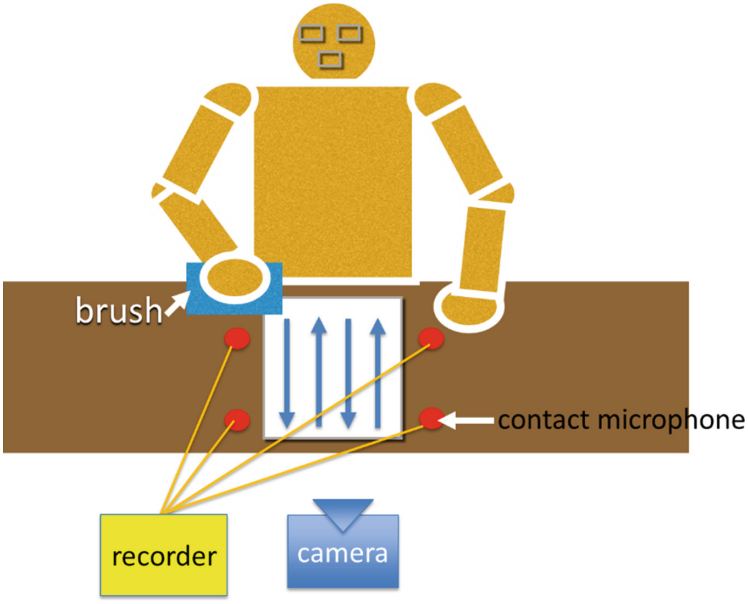

Fig. 7. Diagram of measuring method

5 Experimental Results

The number of times and the speed that the two subjects pounded were different. Both of the subjects began pounding from in front of themselves and proceeded to pound while switching the hand that was holding the brush each time it returned to the edge closest to them.

As is shown in the diagram in Fig. 8, both subjects started pounding just in front of themselves on the right hand side, continued pounding until they reached the left edge of the sample, and then returned while pounding from the left, all the way back to where they started in front of themselves on the right hand side. Once the brush had returned back in front of them on the right hand side, they then pounded until they reached the left edge, just like the first time. In other words, the brush moves 1.5 circuits around the surface when pounding. The expert pounded at total of 650 times, and the non-expert pounded a total of 591 times.

First, we compared the waveforms of the sounds recorded by the contact microphones that were generated when pounding. Some of the waveforms from the sounds collected from the expert's pounding are shown in Fig. 9, and some of the waveforms from the sounds collected from the non-expert's pounding are shown in Fig. 10.

When comparing both of the subjects' waveforms, it is evident that the amplitude of the sounds generated by the expert's pounding are larger than those of the non-expert's pounding, and that the amplitude of the expert's sounds were repeated with near-perfect consistency. We believe that, in contrast to the non-expert, the expert was able to use the pounding brush on a wide surface and pound effectively every time, achieving repeatedly large amplitude.

The amplitude of the non-expert's sounds were extremely low numerous times, sometimes achieving a waveform similar to that of the expert and sometimes not. This means that the non-expert was not always able to facilitate adhesion evenly and without irregularities on the joined surfaces, and indicates that the non-expert has not sufficiently mastered the pounding technique.

Figure 11 shows two smoothed waveforms – one from the expert's pounding that displayed consistent amplitude, and one which was observed numerous times in the

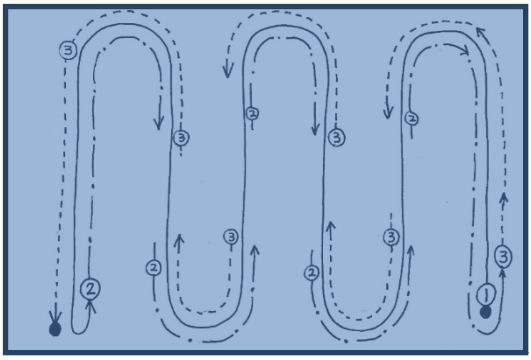

Fig. 8. Diagram showing the brush moving 1.5 circuits around the surface

Fig. 9. Expert's waveforms

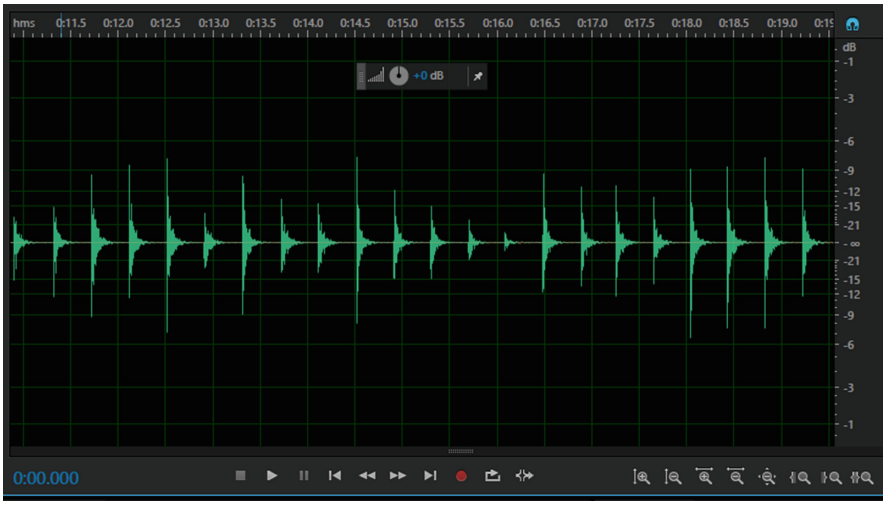

Fig. 10. Non-expert's waveforms

non-expert's pounding and that displayed a small amplitude. From this information, we were able to confirm that the expert achieved the largest amplitude directly after pounding the joined surfaces, and that the non-expert had a small peak in the second half of the pounding action.

When observing the subjects pounding, the non-expert's arm movements when pounding were small when compared to the expert, and his brush showed a tendency to

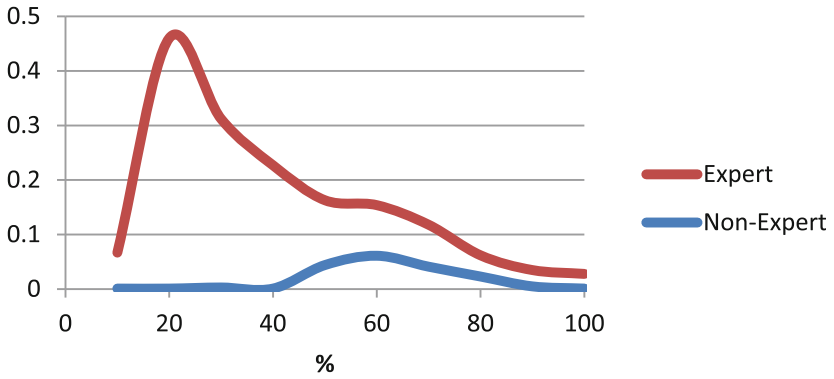

Fig. 11. Comparison of an expert and non-expert's waveforms

not pull back quickly from the joined surfaces directly after pounding. This is believed to be a factor that indicates that his waveforms were extremely small and different to those of the expert.

6 Conclusion

As stated earlier, the proficiency level of pounding with a pounding brush is often checked in workshops by the sound generated when pounding. Through this research, we have confirmed that the amplitude of the sounds generated by an expert's pounding are larger than those of a non-expert's pounding. We also confirmed that the sounds generated by a non-expert's pounding in one complete procedure of facilitating adhesion are not consistent and are both large and small in comparison to an expert. Within pounding, the ability to facilitate adhesion evenly over a wide area is strongly sought after. However, these results indicate that a non-expert's facilitation of adhesion is uneven when compared to an expert. This information is in agreement with the experimental results in the action analysis used to analyze similar pounding, which indicated that the expert's pounding action was able to be consistently reproduced in contrast to the non-expert's pounding action. Furthermore, this information is also in agreement with the peeling load results of samples that had actually been pounded in the peeling test. In the peeling test, by calculating the standard deviation of the peeling load from samples created by an expert and non-expert, it was revealed that the expert's sample had less dispersion than the non-expert's sample.

From this experiment, we have been able to quantify proficiency level in pounding for the first time by measuring the difference in sounds generated when pounding, indicating the accuracy of the method for evaluating proficiency level currently used in workshops.

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References

1. Hayakawa, N., Kigawa, R., Kawanobe, W., Higuchi, H., Oka, Y., Oka, I.: Basic research of the physical properties and chemical compositions of aged paste. Conserv. Sci. **41**, 15–28 (2002)
2. Hayakawa, N., Kimijima, T., Kusunoki, K., Oka, Y.: Effects of the pounding brush as an adhesive. Conserv. Sci. **43**, 9–16 (2004)
3. Nishiura, T.: Adhesive effects of pounding by brush. Sci. Picture Framing 99–107 (1997)
4. Hayakawa, N., Kigawa, R., Nishimoto, T., Sakamoto, K., Fukuda, S., Kimishima, T., Oka, Y., Kawanobe, W.: Characterization of Furunori (aged paste) and preparation of a polysaccharide similar to Furunori. Stud. Conserv. **52**(3), 221–232 (2007)