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Application of Compressive Wood to the Activity of Making-Things

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This is a case study on the application of compressive wood by harnessing its hydrothermal characteristic to the activity of making-things (*monozukuli*) which could be organized in schools. Sugi (*Cryptomeria japonica* D. Don) sapwood was used to produce the samples of compressive wood. The density of sugi sapwood after oven-drying was 0.480 g/cm^3, and the compression ratio in the radial direction was set as two-thirds of its initial dimmension. To ascertain the effectiveness of the application of compressive wood to making-things, three trial examples were made to display the entropy elastisity of wood utilized in commpressive processing to the students in an elementary school of Kumamoto City. The students' interest and concern about compressive processing of wood by using its hydrothermal characteristics were investigated by conducting a questionnaire survey among 27 sixth graders. Based upon the feedback received from the students, it is revealed that they could understood the entropy elasticity of wood, the key mechanism of compressive processing, through displaying samples combined with an explanation by using a model of wood cells. Consequently, a very higher valuation and a keen interest in such an advanced technology of wood processing were acknowledged. Almost all of the students expressed their wills to be eager to enjoy this kind of making-things.

Key words : wood processing, compressive wood, hydrothermal characteristics, making-things, *monozukuli*.

1. Introduction

Lately the effective use of forest resources from thinning trees which harmonized with global environment has become of general interest. Trimming plantation trees properly has been recognized to be indispensable to activation of forest and establishment of the ideal forest circulatory system which is radically distinguished from forest destruction. In addition, wood has been known as the one of the renewable materials which is superior to the other materials in many respects such as sensory characteristics in vision, hearing, smelling, and touching, as well as emotion related characteristic. It is also an easy material to be processed by machining, and gluing in particular. As the increased emphasis on environmental performance and sustainability of forest resource, wood is considered to be a most suitable material for the activity of making-things (*monodukuri*) in schools. Even though wood is frequently used in the art-and-craft class of elementary school and the technology course of junior high school, the wood processing available in schools currently is still restricted to some regular methods such as cutting, drilling, gluing or assembling.

Nowadays, a lot of advanced technologies in wood processing field have been developed. One of those is compressive wood. The most distinctive feature of compressive wood is to harness its hydrothermal characteristic itself to get a large compressive deformation in the radial direction of wood. This technology has already been applied to improve the properties of soft wood surface, such as hardness, abrasion resistance, etc. As a result, the practical density of a softwood surface could be altered to exceed its original density through compressing the surface layer, followed by permanent fixation by certain treatments[1~2]. This technology therefore allows lower grade round logs to be converted into high grade rectangular structural columns through compressing by special dies[3]. Different from the regular and traditional wood machining, these processing technologies are regarded on exhibiting fully the mechanical properties of wood itself by utilizing or reducing the residues from machining.

This is a case study on the introduction of wood compression as an advanced wood processing technology into the activity of making-things in schools. It is

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necessity to view if the compressive wood is a useful content to attract students' interest and arouse their volition to enjoy the activity of making-things. It is also to be thought as a part of the trail to promote the utilization of wood from thinning trees in education.

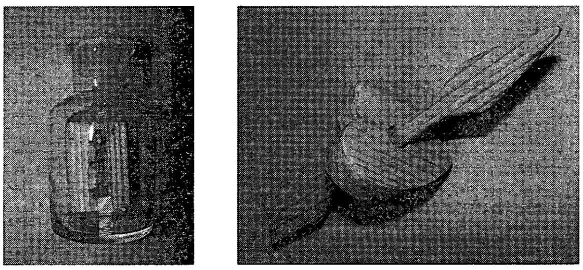
To improve the understanding of compressive behavior of wood, three compressive wood samples were used to demonstrate clearly the entropy elasticity of wood to 27 sixth graders in an elementary school of Kumamoto City. The intensity of the students' interest will be addressed based on the feedback received via questionnaire survey.

2. Compressive Wood Samples Processing

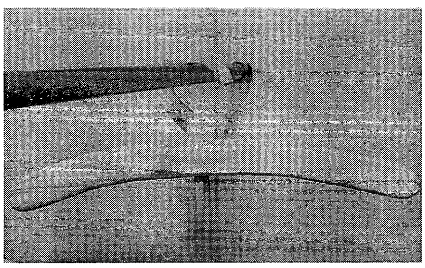
Wood is quite a stiff material along the fiber direction while very light. It is attributed to its micro structural characteristic described as parallel arrangement of hollow tube-liked fiber cells with "reinforced-concrete" structural cell wall. In general, wood is known as an orthotropic and elastic material, while it behaves visco-elastically when both moisture and heat act on it (hydrothermal action). Hence, if wood, especially coniferous sapwood, is softened in hydrothermal condition, a great transverse compression could be obtained easily under hydrothermal action without any visual failures; so wood is a material to be able to endure a very large compression deformation in the perpendicular direction of the grain. The deformed wood could be fixed through drying while being held in its restrained deformation. This is termed "drying set". "Drying set" is an unstable state, as almost all of the deformation will disappear when hydrothermal action is imposed on it again.[4] Therefore, as an engineering material, compressive wood must be treated to fix its deformation permanently. However, considering that such a unique phenomenon of "drying set" would be a useful teaching material to help students to understand the entropy elasticity of wood, as well as to arouse their work volition in such kind of making-things by harnessing the hydrothermal characteristics of wood, a case study on compressive wood was carried out in an elementary school of Kumamoto City.

Three samples of compressive wood as shown in Fig. 1 were processed by using sugi sapwood from the thinning trees in Kikuchi District of Kumamoto Prefecture. Its average annual ring width and moisture content were 2.4 mm and 12.5%, respectively, while its density after oven drying (ρ_o) was 0.480 g/cm^3.

Fig. 2 shows the drawing for producing the one of the three samples, a wooden hanger. The hook's end of hanger was processed by compressive method. Its processing procedure is as shown in Fig. 3 and described briefly as follows:



(a) A piece of wood in the bottle (b) A wooden Cupid's arrow



(c) A wooden hanger

Fig. 1 Three samples of compressive wood

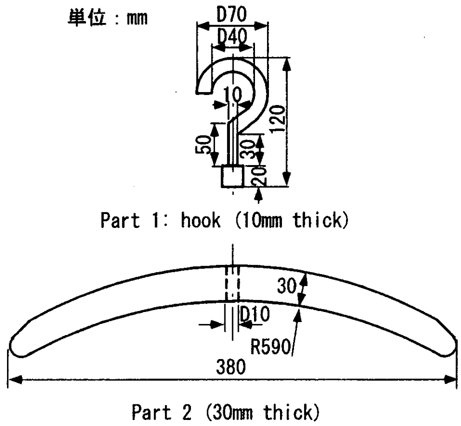


Fig. 2 A drawing of a wooden hanger

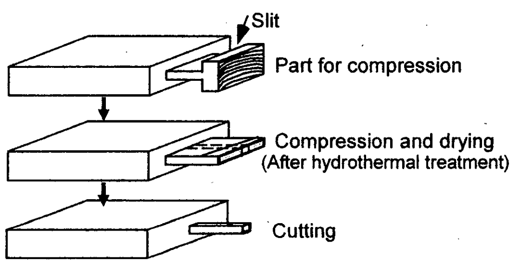


Fig. 3 Processing procedure of hook's end of wooden hanger

The part for processing the hook's end of hanger was prepared in dimensions of 20 mm × 30 mm × 60 mm (longitudinal by radial by tangential direction). Its tangential dimension was set as two times that of the radial one so as to avoid buckling in the perpendicular loading direction (radial) during the compression process.

The part of hook's end to be compressed later was separated from the others by two cutting slits of 30 mm wide prior to soaking in hot water. The hydrothermal treatment was continued until the hook's end was considered to have reached the water saturated state, and then compressed it in the radial direction to two-thirds of its initial dimension by means of a vise. The compression load was maintained for one week until its moisture content has become lower than the equilibrium value (15%). Upon removal from the vise, the hook's end was cut into 10 mm wide in the tangential direction, and processed into a round rod with a radius of 5 mm, which is slightly smaller than that of the hole on the hanger. Once threaded the hook's end through the hanger's hole, the hook's end was soaked in hot water again to recover it from compressive deformation. As a consequence, it was attained that the hook's end with a greater dimension than that of the hanger's hole. In appearance, it is not possible to remove the hook through the hanger's hole at all.

However, the maximum value of compression ratio in wood's radial direction, termed compressibility C, could be calculated easily using the following formula[5], which greatly depends on the density of wood after oven drying, ρ_o.

$$C = (1 - \rho_o / \rho_s) \times 100 = (l_o - l_c) / l_o \times 100\ (\%) \quad (1)$$

Where, ρ_s, is the density of the actual wood cell wall substance, which remains constant irrespective of wood species and cellular structure with a value of approximately 1.5 g/cm^3 [6]; l_o, the initial thickness of specimen (before compression); l_c, the final thickness of specimen (after compression). In the case of sugi sapwood with a density (ρ_o) of 0.480 g/cm^3 after oven drying, its maximum compression ratio could be 68%. However, the compression ratio in samples processing was set as two-thirds (66.7%) in this study.

3. A Case Study in an Elementary School

In order to make sure if compressive wood is a useful content for the activity of making-things, a case study was carried out in an elementary school of Kumamoto City cooperated with 27 sixth graders after normal school hours. Three samples (Fig. 1) were first displayed to the students, including a piece of wood in a glass bottle, a wooden Cupid's arrow and a wooden hanger. Then they were surveyed by the questions of that how the big wood could be put into a bottle with a small neck, the wide arrow could pass through the narrow hole; and the big hook could be threaded through the small hole of the hanger. To stimulate students' thinking by themselves, their own opinions were sought immediately. Then group discussions combined with some hints giving were conducted. Finally, the entropy elasticity of wood harnessing its hydrothermal characteristic was disclosed by a demonstration using a model of wood cells made of a bundle of drinking straws.

Continuously, the following questionnaire survey was carried out to investigate their interest and concern about the application of such compressive wood to the activity of making-things. However, questionnaire items 1, 2, 3 and 5 were in optional choice, question 4 was in free comments style for them to describe the reason why to choose the answer for question 3.

Question 1. Do you know how the big wood could be put into a bottle with a small neck?

I know.
I know some about it.
I don't know.

Question 2. Do you understand the entropy elasticity of wood after the explanation?

I understand.
I understand a little.
I don't understand at all.

Question 3. Do you think such kind of making-things is interesting?

I think so very much.
I think so.
I do not think so very much
I do not think so at all.

Question 4. Why do you think it is interesting?

Question 5. Do you want to enjoy such kind of making-things?

I am eager to enjoy it.

I want.

I do not want to do it so much

I do not want to do it at all.

4. Results and Discussion

Fig. 4 shows the results of questionnaire survey. In question 1, we asked if the students know how the big wood could be put into a bottle with a small neck. There was no correct answer obtained immediately. After group discussions combined with some hints giving, the positive answers have reached up to 78 % of the respondents. However, almost all students said they understood it after an explanation by a demonstration using a model of wood cells made of a bundle of drinking straws. The students showed a great interest over this kind of making-things. Their responses to questions 3 and 4 represented that they would like to enjoy such kind of making-things in school. It seems that such observation of some phenomena which are beyond their imaginations would arouse students' interests, and give them much food for thought.

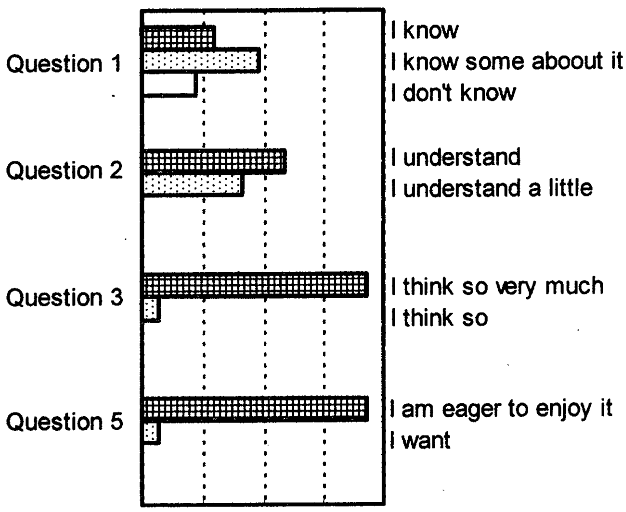


Fig. 4 Questionnaire results

The followings are some responses to question 5 as the comments to describe the reasons why this kind of making-things is considered to be interesting.

"It is the first time for me to know that the compressive wood can be recovered from its deformation when hydrothermal action imposed on it. That is interesting", 24 % of the respondents commented. It seems that the students came in contact with such an advanced technology of wood processing which is so different from general one that it made them feel interesting.

"These interested me very much. I will try to do so since I never have such a wonderful idea", said by 36 % of the respondents. It was obviously that they had great interest in such kind of making-things and showed their strong will in enjoying these activities. It could be expected that such things are so impossible in appearance that they were attracted and eager to take part in it.

"The big wood can become small while fully recover again when hydrothermal action imposed on it. It's really like a magic performance", 40 % of the respondents were fascinated with this application of wood's entropy elasticity.

"Since it is different from the general wood processing such as cutting or assembling, it is out of our imagination". Such advanced technology of wood processing impressed some students dramatically.

Therefore, it could be concluded that this kind of making-things by harnessing the hydrothermal characteristics of wood has a strong attraction to the students in evoking their interest and concern, which gives them an incentive to take part in it. Furthermore, as an available content of making-things for students to enjoy in schools, the necessity is to develop a series of samples to match the making volitions of students in various developmental stages.

5. Conclusion

As a case study on the application of compressive wood to the activity of making-things which could be organized in schools, three samples by harnessing the hydrothermal characteristic of wood were processed and used in a demonstration to the students in an elementary school of Kumamoto City. Based upon the feedback received from 27 sixth graders via questionnaire survey, it is revealed that compressive wood attracted students' attention greatly, and a significant effectiveness exhibited in arousing students' interest and volition. In addition to its simple process and available equipment, compressive wood is expected to be a meaningful application to the activity of making-things which could be organized in schools.

However, since a duration of one week is preferable for realizing “drying set”, a temporary fixation of the compressive set of wood in an air-dry condition; such kind of making-things requires to schedule at least a two weeks period plan.

References

1) M. Inoue et al., Surface Compression of Coniferous Wood Lumber II, Permanent Set of Compression Wood by Lower Molecular Weight Phenolic Resin and Some Physical Properties of the Products (in Japanese), Mokuzai Gakkaishi, Vol.37, No.3, 227-233 (1991).
2) M. Inoue et al., Surface Compression of Coniferous Wood Lumber III, Permanent Set of the Surface Compressed Layer by a Water Solution of Lower Molecular Weight Phenolic Resin (in Japanese), Mokuzai Gakkaishi, Vol.37, No.3, 234-240 (1991).
3) M. Tanahashi et al., Compressive molding of Wood by Steam Treatment (in Japanese), Abstracts of the 44th Annu. Meet. of Japan Wood Res. Soc., 537(1994).
4) Wood Research Institute, Kyoto University, The Secrets of Wood (in Japanese), 129 (1994), Tokyo Books.
5) Kansai Branch of Japan Wood Processing Technologies Society, Basic Wood Science (in Japanese), 40(1992), Kaiseisha.
6) J. M. Dinwoodie, Timber: Its Nature and Behaviour, 46(2000), E&FN Spon.