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https://doi.org/10.5109/16132

出版情報：九州大学大学院農学研究院紀要. 54 (2), pp.467-470, 2009-10-29. Faculty of Agriculture, Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **54** (2), 467–470 (2009)

Evaluation of Finger–jointed Laminae for Glulam Timber by Acoustic Emission I Development of Jig for Acoustic Emission Sensor Installed to Production Line and its Verification Test

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(*Received June 30, 2009 and accepted July 13, 2009*)

In end–jointing of laminae for the glulam timber, finger–joint is generally used. However, the strength properties of the glulam timber greatly decrease by slippage–off and destruction in starved joints of finger–jointed part when the laminae with starved joints in the finger–joint are located on the external layer of the glulam timber. Therefore, for the glulam timber with good strength properties, the evaluation of finger–joint properties after finger–jointing is important, and the method is hoped to be simple and non–destructive.

In this study, hinoki (*Chamaecyparis obtua*) finger–jointed laminae with starved joints (NH–laminae) and without starved joints (C–laminae) were prepared, respectively. The evaluation of finger–joint properties with a special attachment (jig) for installing the acoustic emission (AE) monitoring method into the production line of the laminae was conducted. That is, bending tests for these laminae with the jig were performed, and AE generated during the bending test was measured along with the load. Then, AE characteristics and bending strength properties of these laminae were examined. In addition, the verification test with the jig was performed. The main results are summarized as follows: AE signals of NH–laminae in the threshold of 20 mV were measured at the early stage in bending test as compared with C–laminae. The AE generation load of NH–laminae showed a small value and showed the smallest value in 20 mV. From these results, it became clear that AE technique with the jig in the threshold of 20 mV will be promising for the detection of the difference between C– and NH–laminae at the early stage during bending test. From the obtained result of the verification test with the jig under the conditions of the load: 4 kN and the threshold: 20 mV for the detection of the starved joints, it became clear that NH–laminae could be detected at the probability of about 70% under these conditions. Therefore, in the case of loading to the finger–jointed part of laminae in 4 kN as the detection load with the jig, the possibility of the detection of the starved joints by AE as a non–destructive method was suggested.

INTRODUCTION

In generally, the performance of wood–based materials is technologically guaranteed, and the difference of strength properties of wood–based materials is very small as compared with solid woods. The glulam timber used widely as a structural material of wooden house is the main kind of wood–based materials. The glulam timber has the characteristics which can be manufactured heavy section and large–scale by laminating the end–jointed laminae to secure the length needed as materials for large wooden buildings. In end–jointing of laminae, finger–joint is generally used. However, the strength properties of the glulam timber greatly decrease by slippage–off and destruction of fingers in starved joints of finger–jointed part when the laminae with starved joints in the finger–joint are located on the external layer. Therefore, for the glulam timbers with good strength properties, the evaluation of finger–joint properties after finger–jointing is important, and the method is hoped to be simple and non–destructive.

In our previous studies, we paid attention to acoustic emission (AE) as a non–destructive method, and bending test for finger–jointed laminae with starved joints has been performed. AE generated during bending test has also been investigated. From these obtained results, AE technique was promising for the detection of starved joints in the finger–joint at the early stage of the bending test (Ohuchi *et al.*, 2004). In addition, we clarified that the position of starved joints in finger–joint could be presumed by one–dimensional method of using AE signal (Yano *et al.*, 2007).

In consideration of installing AE monitoring method into the production line of finger–jointed laminae, the objective of this study was to obtain the basic information on evaluation of laminae in production line by AE. In this experiment, a special attachment (jig) for the AE sensor installed into the production line was developed. hinoki (*Chamaecyparis obtua*) finger–jointed laminae with starved joints in the finger–joint part were prepared, and the evaluation of finger–joint properties was conducted by AE with the jig as the non–destructive method. That is, bending tests for these laminae were performed, and AE generated during bending tests was measured along with the load. Then, AE characteristics and bending strength properties were examined. Moreover, from

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these obtained results, bending load for detecting finger–joint laminae with starved joints was examined, and the verification test with the jig was performed under the bending load.

MATERIALS AND METHODS

Specimens

Specimens used in this study were made from hinoki (*Chamaecyparis obtua*) laminae. The mean specific gravities and the mean moisture contents of specimens were 0.52 and 11.2%, respectively. These laminae were sorted not to have any knots or faults within 100 *mm* of the tip of finger–joint, and short–length laminae were made. The profile of the finger–joint was as shown in Fig. 1, where l=14.0 *mm*, p=3.9 *mm*, t1=0.7 *mm*, t2=0.6 *mm*, and θ=4 *in* 98. These laminae were finger–jointed using aqueous polymer solution–isocyanate adhesive for wood (API) and end pressed at 9.2 N/mm^2. The adhesive was spread on the laminae before pressing, and the specimens were cured under room temperature for more 48 hours after adhesion. In finger–jointing laminae, two types laminae were manufactured as follows; the laminae finger–jointed by using API combined curing agent (hardener) with base resin at weight ratio 100:10 was assumed as C–Laminae (control specimen). The other laminae finger–jointed by using API without hardener was assumed as NH–lamimae (with starved joint). The size of finger–joint laminae for bending test was 110 *mm* wide, 21.5 *mm* thick, and 450 *mm* long.

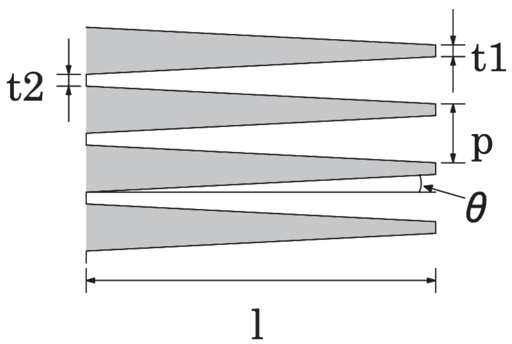

Fig. 1. Profile of the finger–joint.

AE monitoring method during bending test

Figure 2 shows a schematic diagram of the bending test and AE measurement. A static bending test for all specimens was conducted by three–point loading using the Instron mode strength test machine. The span was 330 *mm*, and the crosshead speed was set at 5.0 *mm/min*. The modulus of elasticity (MOE) and modulus of rupture (MOR) were measured and recorded for each specimen. In addition, the AE generations during the bending test were measured along with load. In consideration of installing AE monitoring method into the production line, a special attachment (jig) for AE–sensor installed to the production line was developed as shown in Fig. 3. Two AE–sensors were mounted on each side of the jig using electron wax as a couplant. This jig was set up in the test machine as an emphasis of bending test. Thus, it was possible to evaluate the finger–jointed laminae continuously without replacing AE sensors by using this jig. The AE signals received by AE sensors of the jig during bending tests was amplified to 40 *dB* by a preamplifier and additionally amplified to 40 *dB* by a main amplifier. The threshold level was set to 20, 40, 60 *mV*, respectively. Accumulated AE count, AE count rate, and the load that AE generation started during bending tests were investigated, respectively.

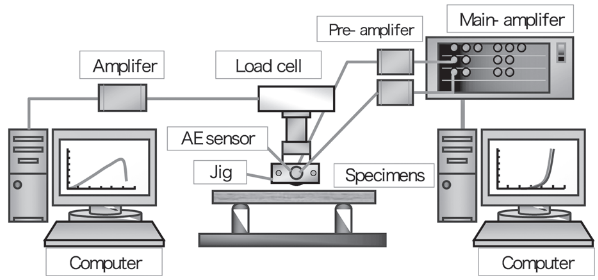

Fig. 2. Schematic diagram of bending test and AE measurement in this study.

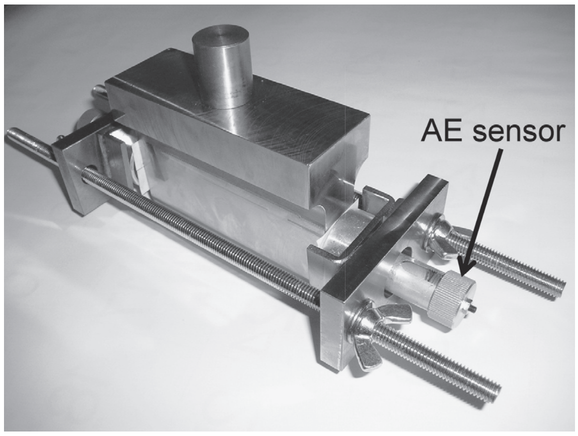

Fig. 3. Photograph of a special attachment (jig) for AE sensor.

RESULTS AND DISCUSSION

Behavior of AE generation

Figure 4 shows the typical waveforms of both AE accumulated count and AE count rate for C– and NH–laminae in the threshold of 20 *mV* during bending tests. Both AE signals in NH–laminae were measured at the early stage of the bending test as compared with C–laminae. As clarified by these previous researches (Yano *et al*., 2007), this suggested that the gaps and the destruction of based part caused by the starved jointed in the finger–joint were AE source.

AE generation load

The load when AE generation started was assumed as the AE generation load. Figure 5 shows the relationships between AE generation load and threshold in C–

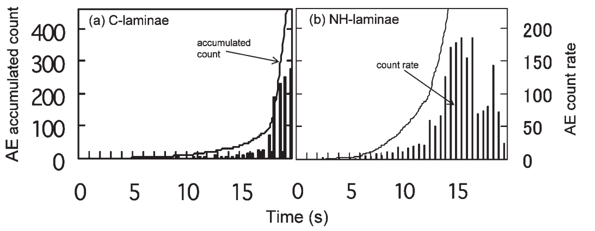

Fig. 4. Typical waveforms of both AE accumulated count and AE count rate.

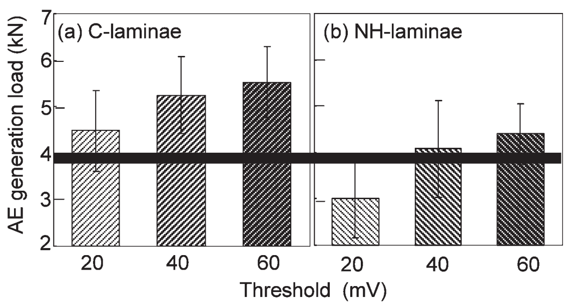

Fig. 5. Relationships between AE generation load and threshold.

and NH–laminae. In each threshold, the AE generation load of NH–laminae showed a small value as compared with that of C–laminae, and the AE generation load showed a small value with decreasing threshold. In these thresholds of the test, the AE generation load showed the smallest value in 20 mV. Therefore, it became clear that the difference between C– and NH–laminae at the early stage during bending test will be able to detect in the setting of the threshold to 20 mV.

Bending strength properties

Figure 6 shows the relationship between MOR and MOE for each C– and NH–laminae. Both MOR and MOE of NH–laminae showed small values than that of C–laminae. Thus, it was clear that the starved joints without hardener greatly influence the decrease of bending strength properties of finger–jointed laminae. In addition, this tendency corresponds to that of AE generation load (Fig. 5). Therefore, these results suggested that AE technique was promising for detection of the decrease of strength properties of laminae.

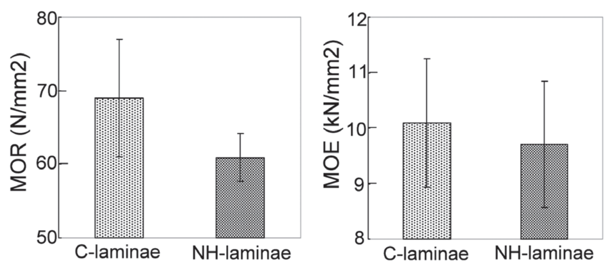

Fig. 6. MOR and MOE for each C– and NH–laminae.

Verification test

From the result of the AE generation load as shown in Fig. 5, the bending load needed to detect NH–laminae under the 20 mV in threshold was set to 4 kN (detection load), and the verification test was conducted under the detection load. C– and NH–laminae were prepared ten specimens, respectively. In the verification test, the process was performed in three stages as follows; first, the detection load was given to each laminae under the same condition of the previous bending test. Secondly, the detection load was unloaded, and the usual bending test for confirming the bending strength properties was conducted again. Finally, the relation between the AE generation load and the bending strength properties was examined.

The obtained results are shown in Table. 1. This table shows the AE generation load when the detection load was given to NH–laminae. From this result, the AE generation was admitted under the detection load of 4 kN in seven in ten NH–laminae. In this condition, it became clear that NH–laminae can be detected at the probability of about 70%. Figure 7 shows MOE and MOR of C–laminae when the beding test was conducted after unloading. For the sake of comparison, the value of C–laminae in the usual bending test is added in Fig. 7. Thus, it became clear that the bending strength properties of laminae was unaffected in the detective load of 4 kN because the difference between MOR and MOE by the presence of the detection load was not admitted.

From these results, in the case of loading to the finger–jointed part of laminae in 4 kN as the detection load,

Table 1. Result of verification test

NH–lamine	AE generation load (kN)
1	2.9
2	–
3	2.2
4	–
5	2.5
6	–
7	3.1
8	3.6
9	2.3
10	3.6

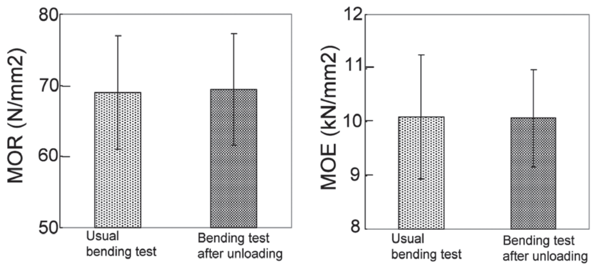

Fig. 7. MOR and MOE for C-laminae after unloading.

the possibility of the detection of the starved joints by AE with the jig as a non–destructive method was suggested without influencing to the bending strength properties of the laminae.

CONCLUSIONS

In this study, hinoki finger–jointed laminae with starved joints were prepared, and the evaluation of finger–joint properties was conducted with a special attachment (jig) for installing the AE monitoring method into the production line of laminae. That is, bending tests for these laminae with the jig were performed, and AE generated during the bending test was measured along with the load. Then, AE characteristics and bending strength properties of these laminae were examined. In addition, the verification test with the jig under the bending load for detecting the laminae with starved joints was performed. The main results are summarized as follows:

1) AE signals of laminae with starved joints in the threshold of 20 *mV* were measured at the early stage of the bending test as compared with laminae without starved joints.
2) The AE generation load of the laminae with starved joints showed a small value and showed the smallest value in 20 *mV*. Therefore, it became clear that AE technique in the setting of the threshold to 20 *mV* will be promising for the detection of the difference between the laminae with starved joints and without starved joints at the early stage during bending test
3) MOR and MOE of the laminae with starved joints showed small values than that of without starved joints. Thus, it was clear that the starved joints without hardener greatly influences the decrease of bending strength properties of finger–joint laminae.
4) From the result of the verification test with the jig under the detection load (4 *kN*) and the threshold (20 *mV*) for the detecting the laminae with starved joints, it became clear that the laminae with starved joints could be detected at the probability of about 70% under these conditions. The bending strength properties of laminae were unaffected in 4 *kN* as the detection load.

From the above results, in the case of loading to the finger–jointed part of laminae in 4 *kN* as the detective load with the jig, the possibility of the detection of the starved joints by AE as a non–destructive method was suggested.

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