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ORIGINAL ARTICLE

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Deviations of kerf by handsaws III: the bend of saw blade by unsymmetrical set

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Abstract To clarify the inducing mechanism of kerf deviation caused by unsymmetrical set of the handsaw, we hypothesized that the moment on the bottom edge of the saw blade, which is generated by the unsymmetrical set on handsaw teeth, bends the saw blade and this deformation should be one factor of the kerf deviation. To verify this hypothesis, the bend of a saw blade was examined by experiment and by calculation. In the experiments, a model tooth was attached to an actual handsaw. In the calculations, a saw model with a rectangular prism as the model tooth was analyzed by the finite element method. Loads were applied on the model tooth or the rectangular prism. From both the experiments and the calculations, the following results were obtained: (1) the deformation of the handsaw was caused by the unsymmetrical set in the length direction and the height direction of the saw blade; (2) the deformation and the inclination of the blade was larger at the front part of the saw than at the butt part; and (3) comparing the saw handle fixing conditions, the kerf deviation in the sawing line was supposed to be larger in the free handle condition and that kerf deviation in the depth direction was larger in the fixed handle condition. Based on the above results, it is apparent that one of the kerf deviation mechanisms originated from unsymmetrical set on the saw teeth.

Key words Handsaw · Unsymmetrical set · Deviation of kerf · Bend of blade · Finite element method

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Introduction

It is believed that the deviation of kerf occurs in handsawing when the set on the right and left sides of the blade is not symmetrical.[1–3] We have studied the cutting resistances on the single crosscut model tooth[4,5] to clarify this deviation mechanism, but the obtained results were could not explain the mechanism adequately.

Then we considered that the deviation of kerf is caused not only by the cutting resistances on the tooth but also by the tooth blade deformation. Here, as shown in Fig. 1, the moment on the bottom edge of the saw blade, which is generated by the unsymmetrically set saw teeth, bends the blade. We hypothesized that this blade deformation caused the kerf deviations, and in this study, we examined the blade deformation precisely by experiment and through calculation.

Methods

Examination by experiment

The handsaw studied was a double-tooth saw used for ripping and crosscutting. The saw blade was composed of carbon tool steel (SK-5) and the blade was fixed to a saw handle by a wing nut at the neck. As shown in Fig. 2, a single crosscut-type model tooth was attached to the handsaw blade at its left side, where the model tooth tip was positioned 5 mm from the saw blade. This model tooth was the same one used in our previous study.[4,5] We considered that the large induced moment would facilitate observation of saw blade deformation.

In this study, the directions "left" or "right" are defined from the viewpoint of an operator. Loads corresponding to the biased cutting resistances were put on the tip of the model tooth, and the induced bend of the saw blade was measured by a photographic measurement method. To determine the effect of the loading position on the blade deformation, the model tooth was attached at three different

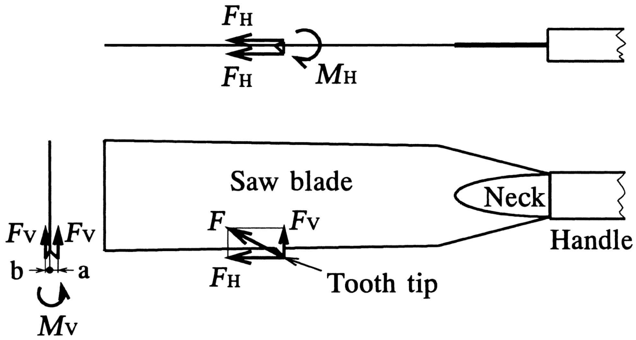

Fig. 1. The moments placed on the teeth by the cutting resistances when the left saw set is larger than the right

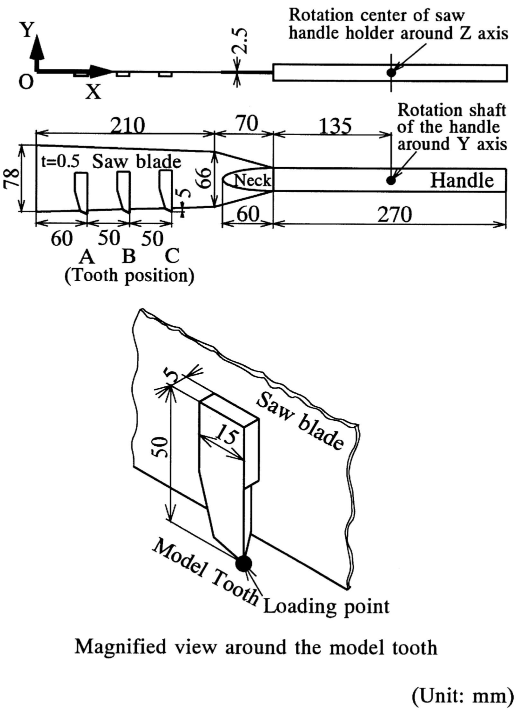

Fig. 2. Saw blade with model tooth

positions: 60 mm, 110 mm, and 160 mm from the front end of the saw blade, which are referred to as positions A, B, and C, respectively, (see Fig. 2).

The experimental device is shown in Fig. 3. The saw was clamped by the saw handle holder, which enabled the saw handle to rotate around the shaft when the locking screw bolt was loosened. This rotation was inhibited by fastening the locking bolt.

The cutting resistance on the tip of the model tooth was measured by a dynamometer. The load corresponding to vertical force was applied on the tip of model tooth by placing a weight on the saw handle head.

The main force of 19 N was applied by pulling the knob of the sliding board and the vertical force of 10 N was applied by the above-mentioned method. These two values were determined from a preliminary experiment on handsaw cutting.

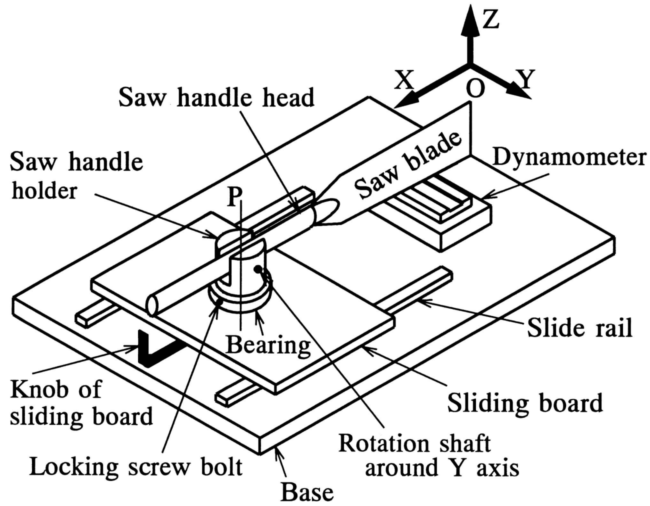

Fig. 3. Experimental device

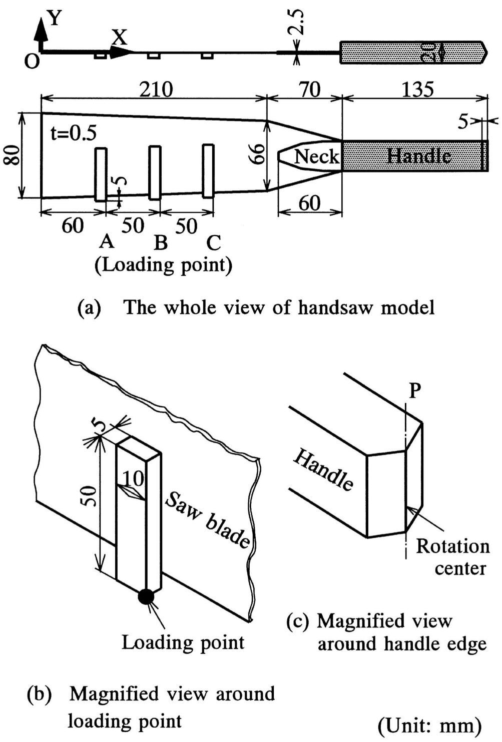

Fig. 4. Handsaw model for finite element model (FEM) calculation

Analysis by the finite element method

The deformation of the saw blade was calculated by the finite element method ("ANSYS University Rel.6.1 High Option") for the same cutting conditions as used in the experiments.

The saw was modeled as shown in Fig. 4 for the finite element calculation. The neck part was treated as one united body with the saw blade, in spite of the experimental saw being an exchangeable blade type. The model tooth was represented by a rectangular prism in the calculations, which had the same loading points as in the experiment (A, B, and C).

The conditions for fixing the saw handle were as follows: (1) two planes of the handle (which correspond to the center of the saw handle) were fixed in all directions for the fixed handle condition, (2) only the rotation center P was fixed in all directions for the handle free rotation condition (Fig. 4c).

The material constants of SK-5 (Young's modulus: 206×10^3 N/mm, Poisson's ratio: 0.3)[6] were employed for all models. The finite elements were made by automeshing using three-dimensional ten nodes tetrahedron structure solids ("SOLID92") and three-dimensional twenty nodes structure solids ("SOLID95"). The generated number of nodes was about 30000, and the number of elements was about 16500. The calculations were made under linear elastic conditions. The applied load was the same as the experimental load, that is, 19N as the main force and 10N as the vertical force.

Results and discussion

Examination by experiment

The saw blade was bent and the front end was inclined to hold a straight line by applying load to the tooth tip. The displacement and the inclination angle of the saw blade were measured by comparing the pictures taken under no load and with full load. Figure 5 shows the measured displacement of the top end of the saw blade, and Fig. 6 shows the inclination angle of the front end of the saw blade.

First, we discuss the fixed handle condition. In all loading position cases, the saw blade was bent so that the front end of the saw blade moved to the right (Fig. 5). When sawing is done under this condition, as the saw blade moves along the line tangential to the warped blade at the cutting saw tooth, the kerf deviates to the left from the intended line of the work. From Fig. 6, we see that the saw blade inclined to the clockwise direction, and this might also hold at the loading positions. This phenomenon might explain the reason that the groove trace turns to the left in the depth direction. Therefore, thinking that the degree of the deviation of the kerf would be greatly influenced by inclination angles of the tooth tip vicinities, we precisely measured the rotations of the loaded model tooth.

Figure 7 shows the rotation angle around the Z axis θ_H and that around the X axis θ_S. From these results, we think that our hypothesis was confirmed. In Fig. 7, θ_H and θ_S become large when the loading point nears the front end of the saw blade. This result seems to explain why bended kerf easily occurs when sawing is done using the front part of the blade.

For the free handle condition, in all three loading positions, the saw handle rotated anticlockwise, increasing its degree as the loading point neared the front end of the saw blade (Fig. 5). The inclination angle of the front end of the blade was smaller than for the fixed handle condition (Fig. 6).

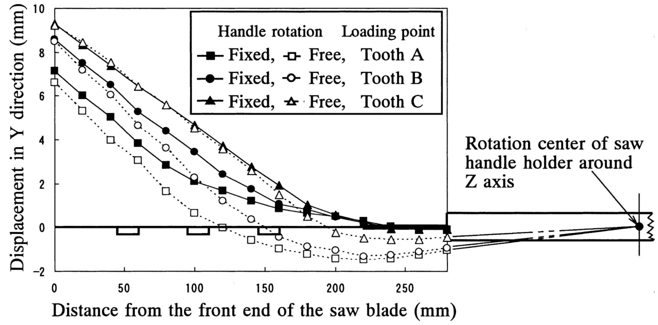

Fig. 5. Experimental displacement of the top end of the saw blade

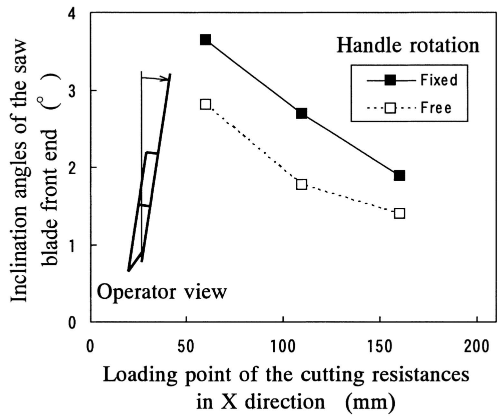

Fig. 6. Experimental inclination of the saw blade

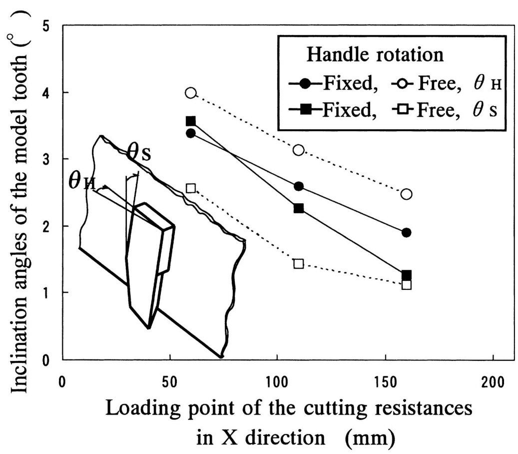

Fig. 7. Experimental inclination of the the model tooth. θ_H, inclination angle of model tooth from X direction in top view; θ_S, inclination angle of model tooth from a normal line in operator view

From Fig. 7, in the free handle condition, we see that the rotation angle θ_H is larger and θ_S is smaller when compared with the fixed handle condition. From these results, it seems that the kerf deviation in sawing line is larger in the free handle condition and the kerf deviation in the depth direction is larger in the fixed handle condition.

Examination by calculation using the finite element method

In the calculation using the finite element method, the loading point on the rectangular prism was restrained in the Y direction to prevent sideways movement. Figure 8 shows the results obtained for the deformation shown by the finite element calculation with ten times displacement magnification. In both loading conditions of fixed handle and free handle, the simulated results represented well the experimental ones.

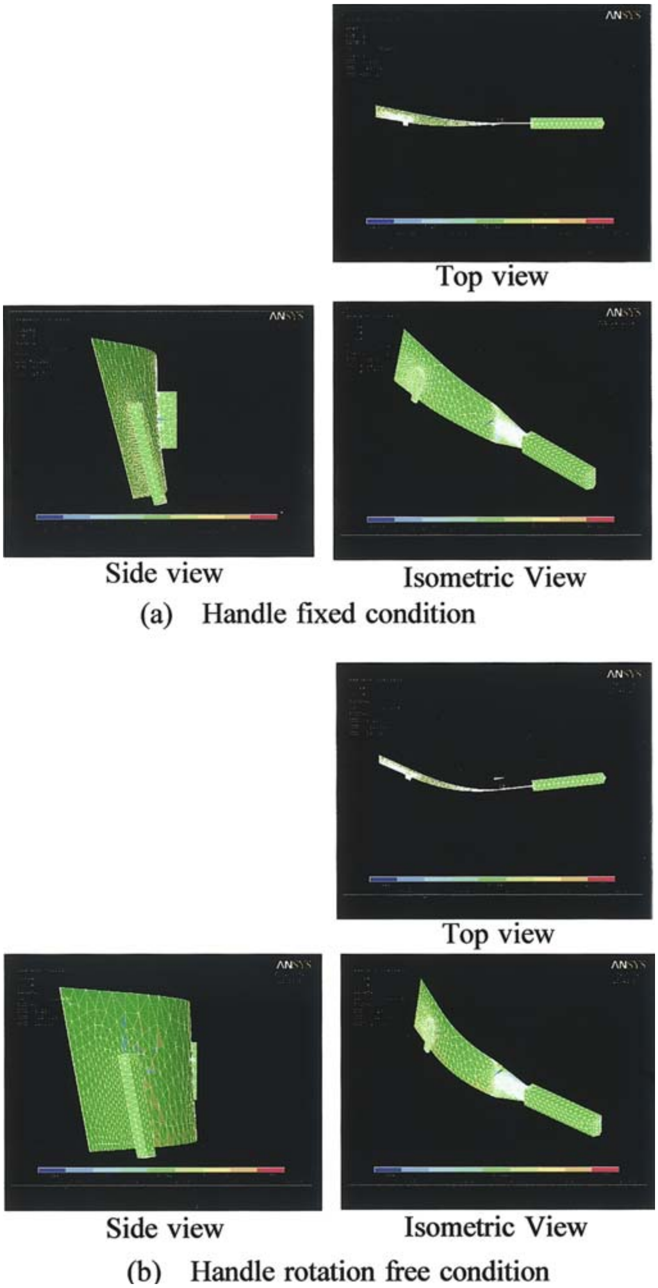

Fig. 8a,b. Deformation obtained by the finite element calculation for **a** fixed handle and **b** free handle conditions. Loading position: rectangular prism A, load values: F_H 19 N, F_V 10 N, Displacement magnification: ×10

Figure 9 shows the displacement of the top end of the saw blade, Fig. 10 shows the inclination angle of the front end of the saw blade, and Fig. 11 shows the rotation angle around the Z axis (θ_H) and that around the X axis θ_S. These calculated results show good agreement with the experimental results for deformation tendencies. However, the amount of the deformation according to the calculation is a little smaller than that obtained by experiment. We considered that this was caused by weakness at the saw neck, which has an exchangeable blade mechanism.

An important difference between experimental results and the calculated results is the value of displacement in the Y direction in the free handle conditions. In the calculated results, the concave deformation of the blade top to the left is very large compared with that of the other side (Fig. 9 vs Fig. 5). We considered that a restricted handle rotation by the bearing's friction in the experiment to be one of the reasons for such a difference.

Another difference between the experimental and calculated results was the displacement of the top front end, which was largest when loaded at the handle side (point C) in the experiment, but was smallest according to calculation

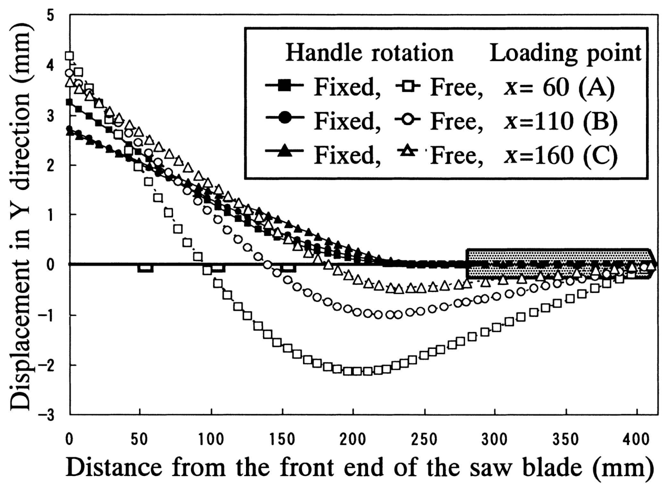

Fig. 9. Displacement of the top end of the saw by FEM calculation

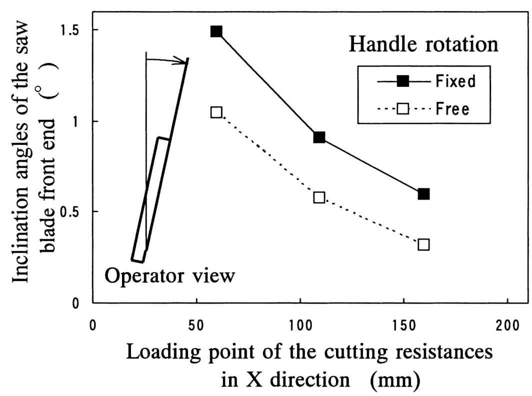

Fig. 10. Inclination of the saw blade by FEM calculation

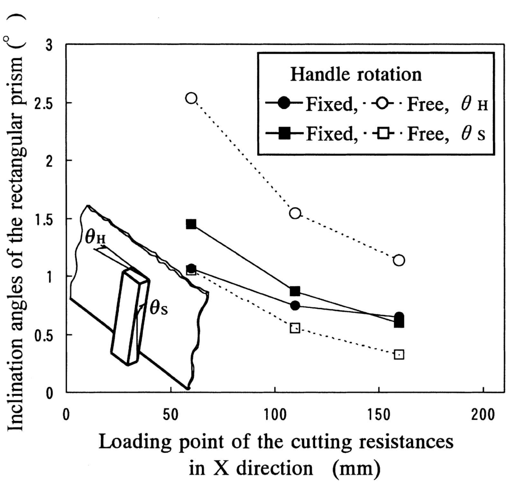

Fig. 11. Inclination of the rectangular prism by FEM calculation

(Fig. 9 vs Fig. 5). The ratios of θ_H under the free handle condition to the fixed handle condition were much larger in the calculated results than in the experimental results (Fig. 7 vs Fig. 11). The reasons for these differences were not clear.

Conclusions

We suspected that the induced bend on handsaw teeth of the saw blade is the main reason for handsaw kerf deviation, and under this assumption we examined bending of the saw blade by experiment and by finite element method calculations.

From both experimental work and FEM calculations, the following results were obtained:

1. In the FEM calculation, although the values were a little smaller than those of the experimental results, we obtained good qualitative results for the deformation behavior of the saw blade.
2. The deformation and the inclination of the blade is larger at the front part of the saw than at the butt part. This result gives collateral evidence that straight cutting is more easily performed at the butt part of the saw blade.
3. Between the fixed and free conditions of the saw handle, the deformation properties were varied. From these results, we concluded that the kerf deviation in sawing line should be larger in the free handle condition and the kerf deviation in the depth direction is larger in the fixed handle condition.

Based on the above results, it is apparent that one of the kerf deviation mechanisms originates from the unsymmetrical set of the blade.

References

1. Sato S (1956) Illustrated woodworking technology (in Japanese). Kyoritu Shuppan, Tokyo, Japan, p 64
2. Hirata S, Takahashi H (1990) Blade thickness, setting and deviation of kerf of handsaw used in junior high school (in Japanese). J Fac Edu Tottori Univ (Edu Sci) 32:263–274
3. Yamashita A, Miyazaki M, Fruno T, Inoue H, Banshoya K, Ishimaru S (1994) Properties and machining of wood (in Japanese). Kairyudo, Tokyo, Japan, p 119
4. Hirata S, Okano T, Ohta M (1993) Deviations of kerf by handsaw I (in Japanese). Mokuzai Gakkaishi 39:763–769
5. Hirata S, Okano T, Ohta M (1996) Deviations of kerf by handsaw II. Mokuzai Gakkaishi 42:944–952
6. Japan Institute of Metals (JIM), Iron and Steel Institute of Japan (1995) Iron and steel material handbook (in Japanese). Maruzen, Tokyo, pp 715–716