Saw Blade Heating and Vibration Behavior in a Circular Gang Edger

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Abstract

Saw blade temperature gradients and lateral movement were measured on a circular gang edger under normal sawmill production conditions. Wood cutting tests were conducted to identify saw behavior under desirable operating conditions and to determine the effects of three adverse factors that are expected to cause increased sawing variation. The adverse factors were saw blade overtensioning, saw heating as a result of inadequate guide cooling, and guide movement during sawing. The third factor, guide movement during sawing, was found to be the most detrimental. Combinations of adverse factors damaged wood dimensional accuracy much more than did the individual factors acting alone.

Introduction

Saw stability and its attendant effects on sawing accuracy have become increasingly important as sawmills seek to minimize kerf losses by reducing saw plate thickness. However, kerf loss is not the only issue involved. USDA Forest Service, Sawmill Improvement Program, sawmill studies (Lunstrum 1981) show that saw kerf reductions are frequently accompanied by increases in sawing variation. The combined total of saw kerf plus allowance for sawing variation often remains almost a constant. Thus, in many cases, the losses from increased sawing variation entirely consume the gains from reduced saw kerf.

Guided splined arbor circular gangsaws are used in many sawmills to break cants down to finished lumber thickness. Practical experience has shown that these guided circular saws are more accurate than unguided saws of the same thickness (Steele et al. 1986). Guides improve saw cutting accuracy by increasing saw lateral stiffness in the cutting zone (Schajer 1986). This increased stiffness resists lateral cutting forces, so that saw lateral deflections are reduced.
Optimal tensioning for greatest lateral stiffness is a balance between two extremes. Undertensioning leads to critical speed instability and "snaking" sawcuts. Overtensioning results in "dishing" and is one cause of wedge-shaped lumber. Thermal gradients in the radial direction, as little as 20°F (see Table 1 for SI conversion) from center clamp to rim, were shown to dramatically alter the saw stability and cutting accuracy of clamped saws (Mote et al. 1981). Frictional heating of the saw teeth and rim from the cutting action reduces the effective tensioning of the saw. The cutting edge is free to deflect in the cut, leading to increased within-board sawing variation. In extreme cases, saw "snaking" occurs. Conversely, frictional heating near the center of the saw as a result of poorly lubricated guides increases the effective tensioning. Saw dishing and wedge-shaped lumber can result.

Many factors beyond the saw plate can affect the temperature of saws during operation. Some factors related to guides include size, location, alignment, rigidity, and lubricant cooling effectiveness. Factors related to the sawing machine include alignment and wear of the arbor, linebar, feed rolls, and press rolls.

Little information is available that describes how these factors affect saw temperature distribution and cutting stability in practical mill operation. How these factors interact, for example, when an overtensioned saw runs on a poorly aligned edger, is also unknown. Knowledge of these factors and their interactions can help saw filers and sawmill management better understand the importance of both filing room practices and mill maintenance. This study was conducted to observe the thermal and vibration behavior of thin kerf saws in a guided splined arbor edger operating under sawmill production conditions and to relate this behavior to sawing variation. Starting from the base case of good sawmill practice, three factors that can adversely affect saw performance were considered: saw blade overtensioning, saw heating as a result of inadequate guide cooling, and guide movement during sawing.

**Equipment**

The two saws used in the study were 20-1/2 in. outside diameter, 8 in. diameter center hole or eye, 0.049 in. thick with a kerf (tooth width) of 0.072 in. One saw was properly tensioned to the standards used at the mill. The other was overtensioned and “loose” in the eye. Static runout of both saws was 0.008 in.

Two guide designs were tested. One design (Fig. 1) cooled the saw quite well. This design has two water holes at the top, joined by a water distribution channel. The other design (Fig. 2) has only one central water hole. The upper corner of the guide nearest the eye apparently received little water, and it locally heated the saw surface during operation.

One guide mounting arm was rigid and did not move during sawing. The other guide mounting arm was worn and allowed some guide movement during sawing. This effect represents guide arm wear or the flexibility of long guide arms that can occur in circular gang edgers with fixed saw positions. The plane of the guide pads was within _+_0.003 in. of a plane perpendicular to the arbor axis.
Methodology

Sensors were attached to one guide of the pair for each of two saws. Thermocouple probes (1/16 in. diameter) were spring loaded against the saw plate to measure temperature at four locations radially across the saw plate. Running the saws for extended periods, but without sawing, showed that these small probes did not cause changes in the saw plate temperature distribution. Eddy current displacement probes measured saw plate lateral movement near the rim, just behind the gullet, and next to the eye, about 3/8 in. from the arbor. Sensor location is shown in Figure 3. The sensors were attached to the guides by fixtures bolted to the guides.

Four sets of Douglas-fir (Pseudotsuga menziesii) cants were run through the edger. Each set was subjected to two different combinations of the three adverse factors: saw blade overtensioning, inadequate guide cooling, and guide movement during sawing. In total, eight possible combinations of the three factors were studied. This forms a complete factorial experiment with three factors and two conditions for each factor. A different combination of factors was used on each adjacent saw/guide pair. The following combinations of factors were studied:

<table>
<thead>
<tr>
<th>Tensioning</th>
<th>Guide Cooling</th>
<th>Guide Rigidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proper</td>
<td>Good</td>
<td>Rigid</td>
</tr>
<tr>
<td>Overtensioned</td>
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<tr>
<td>Overtensioned</td>
<td>Inadequate</td>
<td>Moves</td>
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</table>

Between 15 and 20 8- and 10-ft long cants were resawn in the edger during the test run for each set of factors. The cants were nominally 4 in. thick by 10 in. wide. They were broken down into nominal 3- by 4-in. lumber. Feed speed was approximately 140 ft/min.

Saw plate temperatures and lateral movement were collected by a computerized data acquisition system at the rate of 10 sets of measurements per second. Data collection started just before the saws were turned on. Each set of measurements consisted of running the saws up to speed, 4 to 9 seconds of the saws idling, then sawing two cants with about 8 seconds of idling between them.

Each piece of lumber was marked with the cant number and the saw that made each opposing face. Lumber thickness was measured with a Trienco lumber thickness gauge.

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1 The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.
Saw Temperature and Vibration Performance

The design of the edger made it impossible to duplicate the conditions of saw tensioning, guide cooling, and guide rigidity on both faces of a given piece of lumber. Therefore, the following discussion describes the temperature and vibration behavior of one saw/guide set at a time. The effect on lumber sawing accuracy is described separately, considering that each face was made by a different saw/guide combination.

Figure 4 shows the saw temperatures when a properly tensioned saw is run with well-cooled, rigidly secured guides. The saw temperature behaved in an expected way. Plate heating did not begin until about a quarter the length of the cant had been sawn. The rim and outer center portion of the plate heated the most, with the inner center portion of the plate and the eye progressively cooler. The overall temperature rise was minimal, less than 15°F. Rim-to-eye temperature gradients during sawing were also less than 15°F.

The lateral movement (Fig. 5) shows how the rim stayed stiff with little lateral deflection. The lateral movement was actually less than the static runout. In contrast to the rim, the eye floated freely back and forth on the arbor, allowing relief of stresses that were built up by constraining the rim at the guides. This free eye movement apparently maintained the stability of the cutting edge. Thrasher (1972) suggested that controlling the saw with guides close to the gullet while allowing the eye to float freely on the arbor eliminates much of the saw vibration.

The overtensioned saw moved laterally almost immediately when the drive motor was turned on, as shown by the saw lateral movement in Figure 6. The rim moved one direction while the eye moved away an equal distance in the opposite direction. During sawing, lateral movement of the rim increased slightly compared to that of the properly tensioned saw. The saw rim also remained dished during sawing, although the amount of lateral displacement varied. The eye still moved on the arbor, although not as freely as did the properly tensioned saw.

The guides provided good cooling so that plate temperature gradient followed the same pattern of progressively decreasing temperature from rim to eye for the properly tensioned saw (Fig. 7). In this case, dishing resulted from overtensioning the saw, not from excessive temperature gradients.

Guide movement during sawing caused saw plate heating in the inner center zone and close to the eye, resulting in significant dishing. The mechanism is illustrated in Figure 8. The nonrigid guide and saw rubbed against each other, heating the saw and guides by friction at the inner corners of the guide. The saw was then overtensioned by heat as illustrated in Figure 9. The temperature graph (Fig. 10) shows heating of the inner center of the saw immediately after it started rotating. This caused the eye of the saw to expand, effectively adding tension in this area, causing the saw to dish as shown by the movement of the eye in Figure 11. Under most circumstances of saw dishing from thermal tensioning, the eye remained displaced to one side, rather than floating freely on the arbor as shown in the first example (Fig. 13). Unfortunately, the sensor next to the eye failed during this test run, so eye movement was not measured.
However, other tests using the same guides indicated that the eye would move on the arbor and the saw would dish.

When two or more adverse conditions occurred at the same time, the effect on saw behavior was usually much more severe and erratic.

Running the overtensioned saw with the nonrigid guides resulted in the rim moving laterally and vibrating during sawing. Figure 14 shows the eye shifting on the arbor and remaining shifted over. Apparently the saw dishing, coupled with the random movement of the guide, caused the saw to rub against the inner corner of the guide at times during sawing. This heated the inner central area of the plate erratically (Fig. 15).

Inadequately cooled guides, coupled with the nonrigid guides, caused the properly tensioned saw to vibrate erratically at the rim (Fig. 16). The temperature gradients varied, as shown in the different temperature distributions of the first and second cants (Fig. 17). This was probably caused by the random movement of the guide. Depending on its position, the saw might not rub as much at the inner corner, resulting in less saw plate heating in the inner center.

The overtensioned saw run with rigid but inadequately cooled guides heated in the inner center zone (Fig. 18). The rim moved somewhat erratically during both idling and sawing (Fig. 19). However, the eye showed comparatively little movement compared to the extreme sideways movement that occurred under other adverse conditions. Eye movement occurs when the saw blade is forced to be nonperpendicular to the arbor because the guide is loose or the blade is not flat. This is related to the "hunting" phenomenon described by Schajer (1988). Heating of the outer body and rim of the saw that occurred at times during sawing would tend to reduce the dishing.

The combination of all three adverse factors, the overtensioned saw run with the inadequately cooled, nonrigid guides, showed the worst saw performance degradation. The saw heated not only in the inner central zone, but more than previously observed in the outer central zone (Fig. 20). The saw dished severely (Fig. 21), and the rim laid over to one side during sawing. The eye moved laterally on the arbor and remained displaced to one side during sawing.

Effects on Sawing Accuracy

As mentioned, each face of the lumber was made with a different combination of saw and guide condition. The adverse influences affected the lumber sawing accuracy differently, depending upon which combinations occurred together. All lumber measurements showed some front-end “snipe.” This is most likely a function of too high a feed speed entering the cut and is not directly related to the conditions studied here. In all figures plotting lumber thickness, the left side was the leading end where the saw enters the cut.

Figure 22 shows thickness measurements at the top (saw entering the cut) and bottom (saw exiting) along the length of one board. One face was made with the properly tensioned saw and rigid, well-cooled guides, (conditions shown in Figs. 4 and 5). The other face was made with
the overtensioned saw and the nonrigid guides (conditions in Figs. 14 and 15). End-to-end thickness variation resulted from the saw lateral deflection. Slight top-to-bottom taper occurred, but was not too severe.

Switching the saw positions so that the overtensioned saw was on the rigid guide (Figs. 6 and 7) while the properly tensioned saw was on the nonrigid guide (Figs. 10 and 11) resulted in more severe end-to-end variation (Fig. 23). It appears the saw that was initially properly tensioned became thermally overtensioned by frictional contact with the nonrigid guide, thus the combination of two overtensioned saws degraded sawing accuracy even more. The saws did not dish the same amount sawing different cants. This led to high between-board thickness variation.

Inadequately cooled guides caused a progressive thickness increase throughout the length of the board (Fig. 24). Top-to-bottom taper became more noticeable. In this example, the properly tensioned saw was used with the rigid guide (Figs. 12 and 13), while the overtensioned saw was on the nonrigid guide (Figs. 20 and 21). The properly tensioned saw appeared to withstand the heat well enough so that it compensated somewhat for the adjacent overtensioned saw--nonrigid guide combination.

Conclusions

Three adverse sawing factors were studied: saw blade overtensioning, saw heating as a result of inadequate guide cooling, and guide movement during sawing. Guide movement during sawing was found to degrade sawing performance the most. This is because the guide movement not only causes saw heating and thermal overtensioning, but it also mechanically displaces the saw, causing further vibration and within-board sawing variation.

Inadequate guide cooling and overtensioning also result in saw dishing, causing wedge-shaped lumber. Inadequate guide cooling causes thermal overtensioning and excessive rim vibration. If the saw is initially overtensioned, it remains dished while running in the machine, but the rim may remain relatively stable during idling, thus thickness variation along the length of the lumber may not occur.

Two or more adverse conditions existing at the same time result in erratic saw behavior, which is difficult to explain in terms of any single cause. Typically, both within-board and between-board sawing variation are more severe.

All three conditions have the same net result--wedge-shaped lumber, thus, determining the cause (or causes) may be difficult. Heat marks on the saw or guides are evidence of guide heating. Severe dishing can sometimes be seen when watching the saws during run up or idling. This may be caused by either overtensioning or guide movement. If thickness varies excessively along the length of the lumber, with varying thick and thin areas at the same time, guide movement is a more likely cause.
Literature Cited


Table 1 -- SI conversion units.

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<thead>
<tr>
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<td></td>
<td>20 °F</td>
<td>11 °C</td>
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<td>Saw plate dimensions</td>
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<tr>
<td>8 feet</td>
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<td>10 feet</td>
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<td>Feed speed</td>
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Figure 1. Well-cooled guide pad showing water hole locations.

Figure 2. Inadequately cooled guide pad showing water hole location and areas of heating.
Figure 3. Sensor location.

Figure 4. Temperature distribution of properly tensioned saw run with well-cooled, rigidly secured guides.
Figure 5. Rim stayed stiff with little lateral deflection.

Figure 6. Overtensioned saw moved laterally almost immediately when drive motor was turned on.
Figure 7. Guides provided food cooling so that plate temperature gradient followed the same pattern on progressively decreasing temperature from rim to eye.

Figure 8. Saw plate heating from friction in the inner center zone and close to the eye, resulting in significant dishing.
Figure 9. Effect of heating near the center of the saw. The saw becomes overtensioned and dishes.

Figure 10. Heating of inner center of saw immediately after it started rotating.
Figure 11. Thermal tensioning, causing saw to dish by movement in the eye.

Figure 12. The inner center of the plate heated.
Figure 13. The rim vibrated excessively during idling and sawing.

Figure 14. The eye shifting on the arbor and remaining shifted over.
Figure 15. Saw dishing and random movement of the guide that heated the inner central area of the plate erratically.

Figure 16. Adequately cooled guides and nonrigid guides caused saw to vibrate erratically at the rim.
Figure 17. Varying temperature distributions of the first and second cants sawn.

Figure 18. Over-tensioned saw run with rigid but inadequately cooled guides heated in the inner center zone.
Figure 19. Rim moved somewhat erratically during idling and sawing.

Figure 20. Saw heated in the inner central zone and more than previously observed in the outer central zone.
Figure 21. Saw dished severely and rim laid over to one side during sawing.

Figure 22. Thickness measurements at top and bottom along the length of one board.
Figure 23. Severe end-to-end variation.

Figure 24. Progressive thickness increase throughout the length of board.
Figure 25. Severely degraded saw performance caused lengthwise thickness change and top-to-bottom wedging.