Bandsaw Washboarding

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Introduction

The term washboarding is used to describe a very regular sinusoidal-like pattern that sometimes occurs on lumber cut by bandsaws and circular saws. Washboarding is a common problem in the lumber industry and is undesirable because the sawn lumber must be made thicker than normal to allow the planer to produce smooth surfaces. The necessity to saw oversized lumber results in less lumber being recovered from the logs, so that significant income can be lost. Washboarding on unplaned lumber is generally unacceptable. More significantly, washboarding is frequently encountered when reducing the blade thickness, so it is an important factor that limits the use and development of thin kerf saws.

Although saw filers have trial-and-error procedures that sometimes eliminate the problem, the cause of washboarding is not fully understood. Changing the tooth shape usually stops washboarding, but sometimes even radical changes have no effect. The problem is further complicated in that changing the species of wood being cut affects the appearance of washboarding, indicating that the properties of the wood are also involved.

Description of Bandsaw Washboarding

With bandsaws the pattern slopes downwards in the direction of the blade motion as the wood advances in the saw. See 1. The pattern begins within 1 inch of the beginning of the cut and covers the entire depth of the cut. The washboarding usually covers most of the cut surface and can be described by the horizontal pitch P_x and the vertical pitch P_y. Other variables used in this paper are: V, the feed speed; c, the blade speed and; P, the tooth pitch. Typical values for a North American bandsaw are:

P	= 1.75 inches	P_x	= 3.5 inches
c	= 9425 fpm	P_y	= 1.5 inches
V	= 200 fpm		

A significant experimental result is that the vertical pitch is close to, but never greater than the tooth pitch. This observation is not a coincidence.

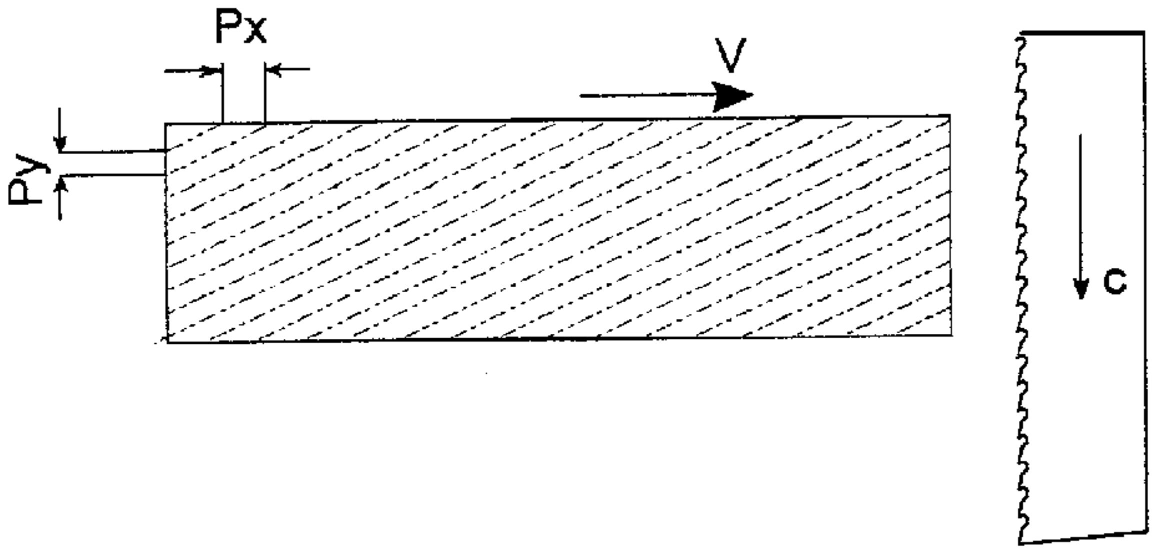

Figure 1 Top: geometry of bandsaw washboard pattern.

1. Deflection of the teeth and blade

Consider an instant in time when the teeth and the washboarding pattern are located as shown in Figure 2. The horizontal axis is through the depth of cut. The dark triangles are the locations of the teeth, which must have been on the washboarding pattern. The curve connecting the teeth turns out to be sinusoidal with wavelength ë .

$$\frac{1}{p_y} = \frac{1}{ë} + \frac{1}{P} \tag{1}$$

Equation (1) is a relationship between the tooth pitch, the wave length of the tooth deflection, and the vertical washboarding pitch. For wide bandsaws, P_y is almost always observed to be slightly smaller than the tooth pitch. For example, if P = 1.75 inches and P_y = 1.5 inches then ë = 10.5 inches.

2. Washboard Frequencies

For the washboard pattern to move downward as the cut progresses, the deflected shape of the teeth must propagate upward. The wave propagation can be seen in Figure 2, in which time is incremented. It can be shown [1] that the frequency of this travelling wave is

$$f_B = f_t - f_w \tag{2}$$

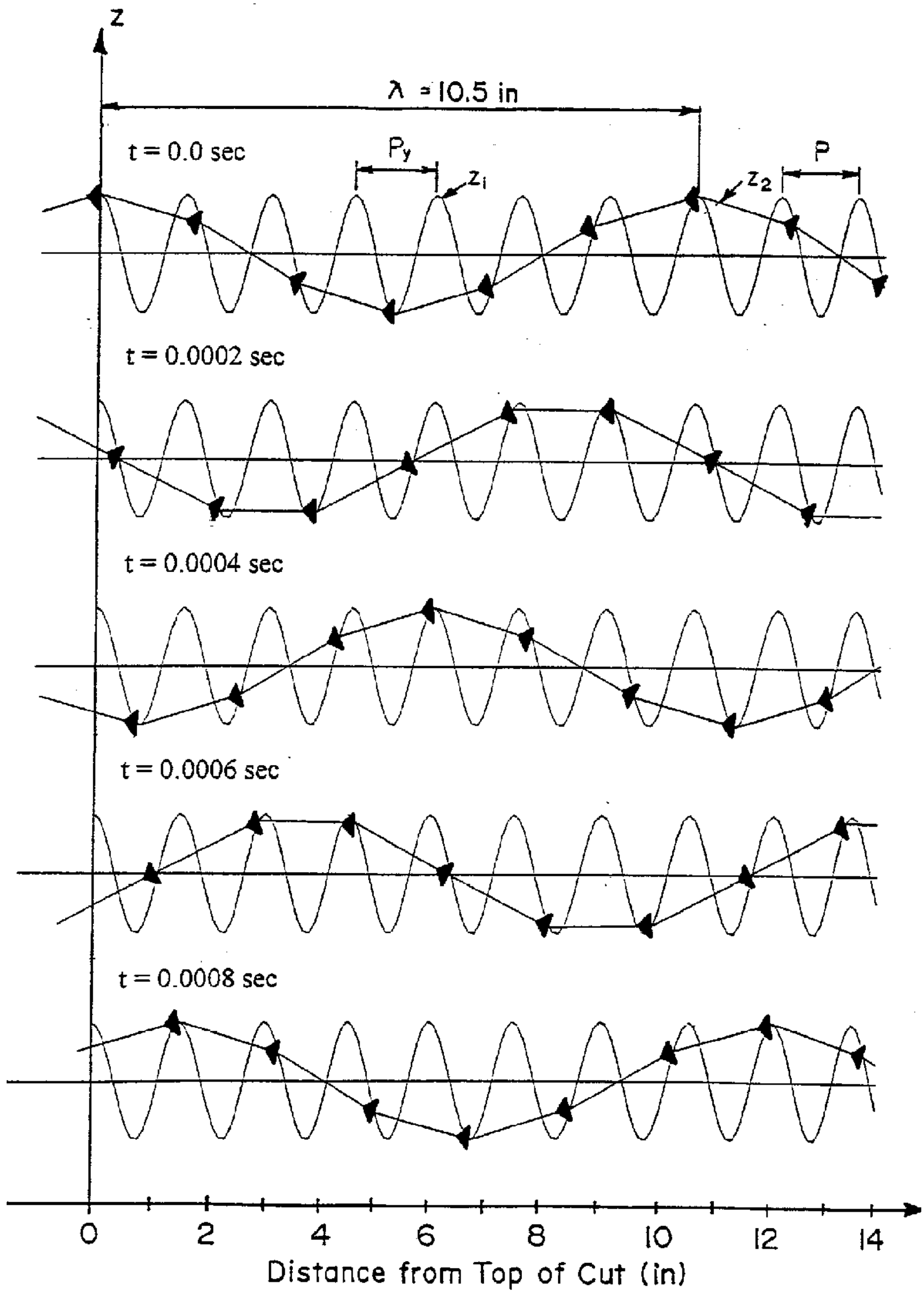

Figure 2. Location of the teeth and propagation of the travelling wave over time.

where

f_t = Tooth impact frequency
f_W = Washboard frequency

To visualize the washboard frequency, imagine a stylus placed at the top of the cut so that as the wood is moved in the feed direction, the stylus follows the washboard pattern. When the wood is moved at the feed speed used to produce the cut then the stylus will move laterally with frequency f_w. Usually, the washboard frequency is less than 20 Hz, which is quite slow.

For the typical values of the variables given above, the following can be calculated:

ë = 10.5 inches
f_t = 1077.1 Hz
f_w = 11.4 Hz
f_B = 1065.7 Hz

This equation relates the blade frequency, the tooth passing frequency and the washboarding frequency. Notice that the frequency of the travelling wave is close to the tooth impact frequency. This derivation is consistent with the experimental result obtained by Okai *et al*[2] that the natural frequency is slightly smaller than the multiples of the tooth passing frequency.

3. Washboarding with narrow bandsaws

Okai, Kimura and Yokochi [2] found from cutting experiments that the natural frequency of the blade vibration was slightly less than the tooth passing frequency when washboarding occurs. Figure 3 is a representation of their data. Several vibration modes can be excited.

Notice that the zones of washboarding begin when the natural frequency and the tooth impact frequency are the same and continues for a narrow range of the wheel speed (tooth impact frequency). This has the implication that if the wheel speed is near the edge of the washboarding zone, then only a small change is needed to stop the washboarding. On the other hand, if the operation is in the middle of a zone, then a larger change is required.

5. Washboarding with wide bandsaws

Tests conducted by Hutton and Zahn [3] with a 10" x 0.065" wide bandsaw showed that large changes in the bite per tooth, the blade speed and bandmill strain had little effect on washboarding. The insensitivity to strain is contrary to common experience in that one expects the frequency to increase with strain, just as a guitar string increases in pitch as it is tightened. However, there are vibration modes in wide bandsaws that are independent of strain and tensioning. These modes only have axial nodes: the blade bends along its width so the natural frequency is dependent mostly on the bending stiffness of the plate. For narrow bandsaws, the blade is very thick relative to its width, so there is insignificant bending across the width of the blade. This is the primary difference between wide and narrow bandsaws.

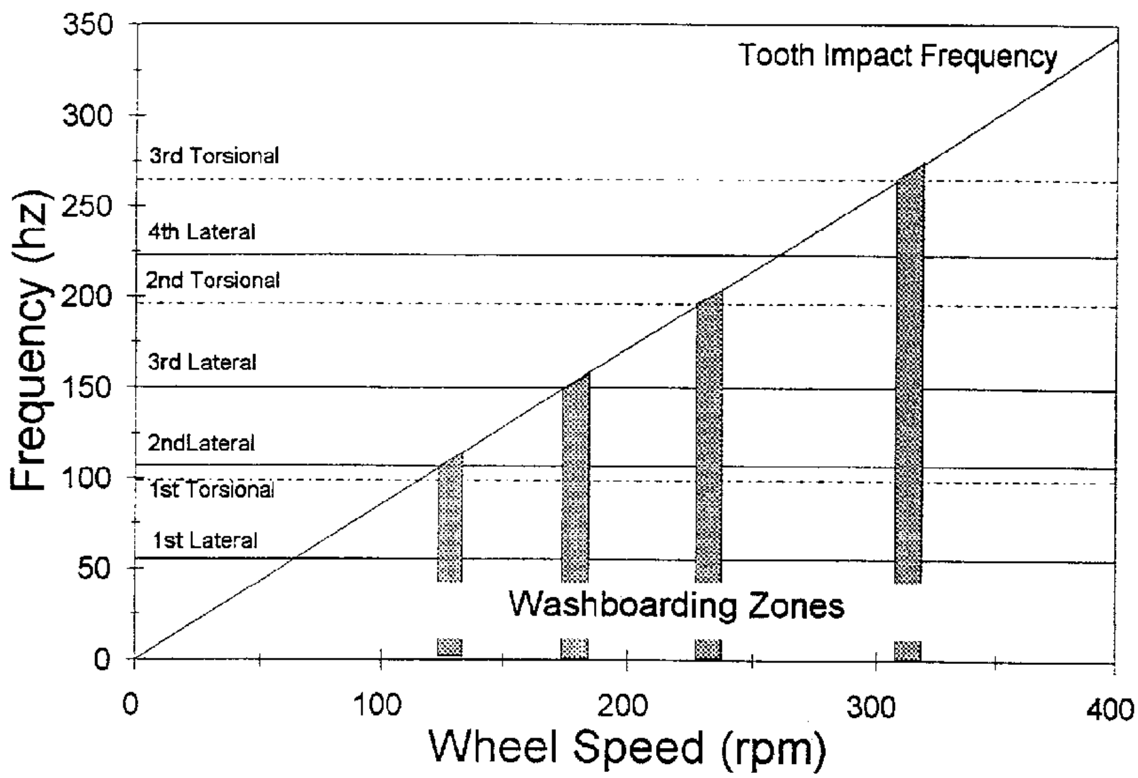

Figure 3. Wheel speeds and tooth impact frequencies when washboarding occurred (after Okai, Kimura and Yokochi [2].)

Forces that generate washboarding

Washboarding in wood sawing has much in common with metal cutting chatter seen on lathes and milling machines. The mechanism of chatter is called regenerative excitation. When either the tool or the work-piece vibrates, the chip thickness varies and the cut surface has an oscillation in it. When the next layer is removed by the tool this oscillating surface will produce a varying chip thickness as the tool passes. See Figure 4 Because the chip thickness is changing, so are the cutting forces, which causes the tool or the work-piece to vibrate. In this way the chatter is perpetuated. The process is called regenerative because the vibration from the previous passage of the tool generates the vibration of the next passage. Washboarding in wood is thought to be

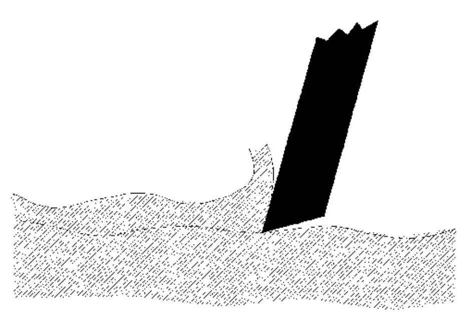

Figure 4 Regenerative chatter.

generated in a similar manner, but the tooth tip moves sideways, rather than vertically, as shown in Figure 4.

The process of cutting on one flank and then the other is thought to be the oscillating lateral force that drives washboarding. This implies that the side clearance angels will affect washboarding. A larger side clearance angle will reduce the amount of flank cutting, and hence, the magnitude of the driving force. This mechanism has not been fully investigated yet, but the author has reduced the severity of washboarding by increasing the tangential side clearance angle from 1 degree to 3 degrees [4]. Also, since the flank cutting forces are influenced by the properties of the wood, one expects that washboarding will be dependent on the wood species and the density.

Tooth Design

Changing the tooth shape is the most common cure for washboarding. From the results presented in this paper there are a number implications for how effective a certain change in tooth shape will be.

1. If the saw is operating in the middle of a washboarding zone, the tooth change may have to be large to stop washboard. On the other hand, if the operation is near the edge of the zone, then only a small change is needed. For instance, a change in the hook length of only 1/16" has been seen to stop washboarding [5].

2. The vibration mode in the blade that causes washboard has a wavelength much longer than the tooth pitch. This means that the tooth deflection is determined by the shape of the plate, not the stiffness of the tooth. Commonly, the advise for stopping washboard is to "have a stronger tooth", but the bending stiffness of the tooth itself is not involved in washboarding. However, reducing the gullet depth or flattening the gullet bottom would have an effect because the base of the tooth can stiffen the plate. Changes to the back of the tooth (i.e., back clearance angle; round versus square back) would not be expected to affect washboarding.

3. Changing the tooth pitch is often effective because this changes the tooth impact frequency. Also, variable pitch saws stop washboard because the impact frequency varies and because the flank cutting forces will not regenerate.

Conclusions

1. The vibration that produces washboarding is not isolated to the teeth: the whole plate is involved.

2. The blade vibration mode and natural frequency can be determined from the dimensions of the pattern on the wood.

3. For narrow bandsaws, the cause of washboarding is well understood.

4. For wide bandsaws, the complexity of a vibrating plate is obscuring the actual mechanism, but the analysis of the wood surface geometry shows that the vibration is excited by the tooth impact.

5. Flank cutting of the tooth appears to be involved.

References

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Description of Washboarding

- **Deflection of teeth and blade**
- **Washboard frequencies**
- **Narrow bandsaws**
- **Wide bandsaws**

Forces that Generate Washboarding

Conclusions

Deflection of Teeth and Blade

Whole blade is involved, not just the teeth

P = Tooth pitch
P_y = Vertical washboard pitch
ë = Wavelength of blade vibration

$$\frac{1}{P_y} = \frac{1}{\text{ë}} + \frac{1}{P}$$

Washboarding Frequencies

f_B = Travelling wave (blade) vibration frequency
f_t = Tooth impact frequency
f_w = Washboard frequency

$$f_B = f_t - f_w$$

Conclusions

1. **Washboard vibration is in the blade, not the teeth.**

2. **The shape and frequency of the vibration can be obtained from the surface of the wood.**

3. **For narrow bandsaws, the cause of washboarding is well understood.**

4. **For wide bandsaws, the plate vibration is more complex, so washboarding is not predictable yet.**

5. **Flank cutting of the tooth appears to be involved.**