Tools for Designing Bandsaws: Load Index and Fatigue Index

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Introduction

Optimization of a sawing system requires compromises to be made. The problem is that there are so many factors involved in saw design that predicting the effect of a change is difficult. The desired goal is a thin saw that can be fed very fast. The only guide for selecting feed speeds is the Gullet Feed Index (GFI), which is a formula that warns if the gullets are overloaded with sawdust. As long as the GFI is less than 0.7 (for bandsaws) then sawing accuracy will not be affected by sawdust spillage. The GFI formula predicts the maximum allowable feed speed, but it does not predict sawing accuracy.

The Load Index (LI) was originally developed by Lutz Claassen at Canadian Car in the 1970's for predicting the cutting accuracy of collared, strobed and guided circular saws (Nyberg, 1977; Szymani, 1978). In extensive laboratory and mill tests Claassen showed that the Load Index is related to sawing accuracy. The Load Index presented here is based on the same principles, but is modified for bandsaws. With the Load Index it is possible to optimize a sawing system in terms of kerf, sawing deviation and feed speed

One strategy to increase blade stiffness is to increase the strain. However, a limitation of bandsaws is that they may crack if they are over-stressed. Hence, there is a limit to how much strain can be put on a blade. The Fatigue Index (FI) was developed to predict the allowable stresses on a blade.

Part 1 Load Index

The Cutting Process

Sawing deviation is the result of two processes:

1. The cutting forces acting on the blade
2. The blade stiffness resisting the cutting forces

This means that the Load Index should increase when the cutting force increases or the blade stiffness decreases. The formula

$$L.I. = \frac{Force}{Stiffness}$$

has this property. The problem is to define the force and the stiffness.

1 Cutting Forces

The cutting force that pushes the blade sideways is not a single number like 5 lbs. It is known, however, that it is affected by the characteristics of the wood such as density and moisture content. The one aspect of the cutting force that can be measured or calculated accurately is the power. It has the properties of being affected by the wood properties and cutting conditions, as desired.

The best way to calculate the power is to measure it at the motor, but it can be estimated with a simple formula

$$P = Ckfd$$

where

C = Specific Cutting Energy
k = Kerf
f = Feed Speed
d = Depth of Cut

Table I provides a list of the specific cutting energies for common wood species.

Species	Specific Cutting Energy = 'C'	
	hp-min/ft^3	MJ/m^3
North American Softwoods	35	55
Southern Yellow Pine	60	95
Dry fir	45	71
Hardwoods	70	111

Table I. Specific cutting energy for common wood species.

Example:

C = 35 Hp-min./ft^3 (55 MJ/m^3) f =200 fpm (61 m/min)
k = 0.135 inches (3.43 mm) d =14 inches (357 mm)

$$P = \frac{(35)(0.135\ )(200fpm)(14\ )}{(144\ in^2/ft^2)} = 92hp\ \ (68.6kW)$$

Power can be converted into a cutting force by dividing by the blade speed. This force is called the tangential or downward cutting force. For the above example, if s = 9000 sfpm (45.7 m/sec), then

$$F_T = \frac{P}{s} = \frac{(92hp)(33{,}000)}{9000sfpm} = 340lbs\quad(1512N)$$

This tangential force is not the force that deflects the blade because it acts in a different direction.

However, the primary assumption of the Load Index method is that the factors that affect it will have a similar effect on the lateral (sideways) cutting force. The Load Index uses the tangential cutting force as a measure of the lateral cutting force because it is an easy and reliable calculation.

2 Blade Stiffness

The blade stiffness is affected by many variables:

- Plate thickness
- Strain
- Guide span
- Tensioning
- Blade width
- Tooth stiffness
- Wheel speed
- Strain system

The stiffness calculations must be done by a computer, or the actual blade stiffness can be measured.

Examples of the Load Index

Table II. Examples of Load Index and Fatigue Index for Various Size Bandsaws.

	Portable Bandmill	**54 " Resaw**	**6' Resaw**	**8' Headrig**
Strain	3,000 lbs	6,000 lbs	15,000 lbs	32,000 lbs
Plate thickness	0.042"	0.049"	0.065"	0.095"
Width	1.25"	8"	10"	16"
Span	16"	12"	20"	48"
Depth of cut	8"	8"	12"	45"
Feed speed	40 fpm	180 fpm	275 fpm	120 fpm
Run time	4 hrs	4 hrs	8 hrs	8 hrs
Load Index	0.17	0.28	0.73	1.19
Fatigue Index	1.3	5.5	3.2	3.3
Sawing Deviation	<0.010"	0.005"-0.010"	0.025"- 0.030"	0.040"-0.045"

In general, the Load Index has a value between 0.2 and 1.4, which corresponds to a range of sawing deviations from 0.005 inches (0.13 mm) to 0.045 (1.1 mm) inches. Table II shows the within-board sawing deviation and Load Index for a range of bandsaws. Note that a range of sawing deviation is quoted. This is because there are factors such as alignment, the degree the wood is controlled, the rate of tooth dulling, variations in wood properties, etc. that are not accounted for by the Load Index. As a rule of thumb, the within-board deviation, in inches, is equal to the Load Index divided by 35.

$$S_W \simeq \frac{LI}{35}$$

Use of the Load Index

The primary value of the Load Index is its ability to predict how the sawing deviation will change as a result of a change in blade design, feed speed or wood supply.

For example, consider a bandmill with the following cutting conditions:

Depth of cut	12 in.	(300 mm)
Feed speed	150 fpm	(45 m/min).
Plate thickness	0.065 in.	(1.65 mm)
Bandmill strain	13,000 lbs.	(57.8 kN)

The current measured sawing deviation is 0.022 inches (0.56 mm). For these conditions the Load Index is calculated to be 0.47. If the blade thickness were reduced to 0.058 inches (1.47 mm). The calculation shows that the Load Index increases to 0.51, so the new sawing deviation will be

$$S_W = (0.022'')\frac{0.51}{0.47} = 0.024'' \quad (0.61mm)$$

An increase in sawing deviation by 0.002 inches requires a 0.004 inches larger target size (Brown, 1982), which is more than offset by the 0.007 inches savings in kerf. Another option would be to increase the strain to 15,000 lbs. (66.7 kN), or to reduce the feed speed to 140 fpm (43 m/min). Both changes bring the Load Index back to 0.47. In these cases there is no increase in sawing deviation, but there is a full 0.007 inches savings in kerf.

Part II Fatigue Index

The limitation to increasing saw stiffness is gullet cracking. Every change that would increase blade stiffness - more strain or tension - also increases the likelihood of cracking. The question is how much stress can be put on the blade to maximize stiffness without causing an excessive number of cracks.

Gullet cracks form because of metal fatigue, which is a very different process from the blade being pulled apart in tension. The first difference is that fatigue cracks form when the stress alternates. Secondly, cracks form even though the stresses are much lower than the tensile failure stress.

For example, it is impossible to break a paper clip (by hand) by pulling on the wire. However, if the wire is bent back and forth a few times, the wire will break. The bending is the alternating stress required for the cracks to form.

Another aspect of fatigue is the number of times the part can be stressed before it fails. In the paper clip example, it is the number of times the wire needs to be bent before it breaks. With bandsaws, the alternating stress comes from bending over the wheels. The time for a gullet crack to form is determined by how many times the blade is bent over the wheels. (On a 5-foot bandmill, the blade will be bent a quarter of a million times in an 8 hour shift.)

Other factors that affect blade life are:

> Smoothness of the gullets - coarse grinding and burrs are ideal places for cracks to start. A rough surface could be considered to already have cracks.
>
> Shape of the tooth - a small radius at the bottom of the gullet increases the stress (stress concentration).

The stresses from tensioning always puts more stress on the gullets. Even a roll that takes tension out of a blade puts more stress on the gullet. The only method that reduces the gullet stress is peening. In addition to stresses from bending, strain and tensioning, there are stresses generated by wheels that are not round, not balanced or have too much crown.

Given the stresses on the blade, there are formulas for estimating the number of hours a blade can run before cracks occur. For cracking not to be a problem, the time to crack must be longer than the running time. The Fatigue Index is the ratio

$$F.I. = \frac{Calculated\ \ Time\ \ to\ \ Crack}{Running\ \ Time}$$

For example, if the time to crack is 18 hours and the time between saw changes is 8 hours, then

$$F.I. = \frac{18\ \ hours}{8\ \ hours} = 2.25$$

The Fatigue Index should always be greater than 1.0 to avoid gullet cracks and preferably greater than 1.5 to allow for not exactly knowing the stresses in the blade. The larger the Fatigue Index, the less likelihood that cracks will appear.

The Fatigue Index is used as a limit on how much stress can be put on the blade in an attempt to increase blade stiffness.

Examples of Load and Fatigue Indices

Table II contains data from typical bandmills. The data also shows that the Fatigue Index is greater than 1 and usually greater than 2.

Discussion

Considering its simple principles, the Load Index is proving to be a useful and reliable guide for selecting and optimizing bandsaws. It is the link between saw design and performance that is necessary for investigating the many compromises involved when configuring a bandsaw. The factors that can be included in an optimization analysis include wood properties, feed speed, blade thickness, strain, and guide location.

An important factor that the Load Index calculation does not include is the alignment and condition of the feed system. The examples of within-board deviation in Table II are for bandmills with average alignment accuracy and control of the wood. Exceptional feed systems can result in cutting deviations much smaller that what is predicted by the Load Index.

Conclusions

1. The Load Index can be used to predict how a change in blade design or operating conditions will affect sawing deviation.

2. The Fatigue Index warns if too much stress is being put on the blade, thus avoiding the problem of gullet cracks.

3. The Load and Fatigue indices are tools for optimizing the trade-offs between kerf, feed speed and sawing deviation.

Literature Cited

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