Wood and Fiber, 9(4), 1978, pp. 245–251

THE EFFECT OF TENSIONING AND WHEEL TILTING ON THE TORSIONAL AND LATERAL FUNDAMENTAL FREQUENCIES OF BANDSAW BLADES

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(Received 26 September 1977)

ABSTRACT

The effects of wheel tilting and saw tensioning on the natural fundamental frequencies of the lateral and torsional vibration of a stationary sawblade have been studied. Tensioning was found to increase the torsional fundamental frequency, but did not affect the lateral frequency. Wheel tilting, on the other hand, influenced both types of vibration by shifting the lateral fundamental frequency downward and the torsional frequency upward.

In predicting the natural frequencies under operating conditions of a bandmill, only the effect of tensioning on torsional vibration has to be taken into account. The effect of wheel tilting was found to be essentially outside the range of tilting angles normally applied in practice.

Keywords: tension stress, frequency prediction, bandsaw blades, tensioning, vibration, machining.

INTRODUCTION

The introduction of thin-kerf sawblades in the sawmilling industry in North America unfortunately has been accompanied by problems, such as gullet cracks, weld failures and, in some cases, reduced cutting accuracy. Most of these problems appear to relate to excessive vibration of blades which, as the frequency of gullet cracks and weld failures indicates, occurs primarily under idling conditions. Excessive or large-amplitude vibrations always occur when a blade vibrates at or near its natural frequencies.

Basically, two types of vibration can be observed in a moving bandsaw blade—lateral and torsional. A schematic drawing of the lateral and torsional motion of a bandsaw-blade section bordered by two pressure guides is presented in Fig. 1. The natural frequencies of both lateral and torsional vibrations are not constant for a given blade, but vary under the influence of a number of parameters. Most important of these are the tension stress, at which a blade is stretched between the two wheels, the span length, and the velocity of the blade. To achieve trouble-free operation of a bandmill, it is desirable to know the natural frequencies of the two types of motion and their dependence on these parameters. By changing parameters, it is possible to shift the natural frequencies and, therefore, to avoid operating conditions that excite the blade at one of its natural frequencies.

Considerable work has been done in recent years to interrelate the natural frequencies with various parameters and derive mathematical solutions that predict the vibrational behavior of a blade. For lateral vibration, Mote (1965a,b, 1968) derived solutions for a simply supported, flexible band considering such parameters as tension stress in the band, span length and band velocity, wheel support, small periodic band-tension variations and periodic in-plane loading. Another solution for lateral vibration was developed recently by Anderson (1974). His solution considers both simple and clamped support, and in addition to tension stress, span length and velocity, also considers bending stiffness of the band.

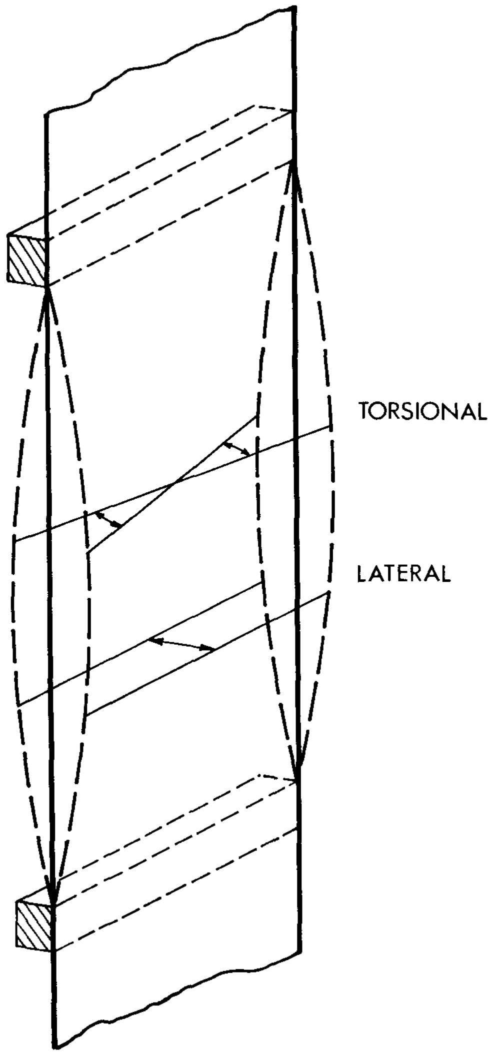

FIG. 1. Torsional and lateral vibration of a bandsaw blade between two guide blocks (pressure guides).

Alspaugh (1967) published a solution for torsional vibration for essentially the same parameters considered by Mote, but, in addition, he also analyzed the torsional vibrations when a moving band is point loaded on one of the edges. Both types of vibrations were also analyzed for the same parameters by Kanauchi (1966) in a theoretical and experimental investigation. A further contribution to this subject was made by Soler (1968) who jointly analyzed lateral and torsional vibration. He showed that point loading can couple lateral and torsional vibration, with the result that the lowest natural frequencies decrease when an applied edge load is close to the static buckling load.

Attempts have been made by bandmill manufacturers to use these solutions for predicting the vibrational behavior of large bandsaw blades. In determining the accuracy of these solutions, it was observed that in general the experimental data deviate considerably from the theoretical data. This indicates that the solutions may not consider all parameters that influence the natural frequencies of large bandsaw blades. Two such parameters may be saw tensioning and wheel tilting.

Common to all theoretical studies discussed here is the assumption of a uniform tension-stress distribution across a blade. This situation, however, applies only to narrow bandsaw blades used in a carpenter's shop. In large blades, to which tensioning and wheel tilting are applied, the distribution of stresses in the blade varies tremendously. Tensioning in this paper always refers to prestressing of the blade by rolling, whereas the term *tension stress* is used for the stress applied by the wheels. By tensioning, a stress profile is established that consists of tension-stress zones along the two edges and a compression-stress zone in the center. Wheel tilting, on the other hand, induces higher tension stresses in the leading than in the trailing edge. It is likely that these variations in stress distribution exert at least some influence on the vibrational behavior of a bandsaw blade.

It was the objective of this study to examine the influence of tensioning and wheel tilting on the natural fundamental frequencies of both the lateral and torsional motions of a sawblade. The study was limited to measurements on a nonmoving blade because strain gages had to be mounted on the blade for measuring wheel tilting.

EXPERIMENTAL

The experimental work was carried out with a production-type bandmill with wheel diameters of 1550 mm. The newly built bandmill was equipped with a hydraulic strain system and pressure guides. The test blade used was a single-cutting bandsaw blade measuring 237 mm in width and 1.6 mm in thickness.

The pressure guides were adjusted to force the blade 9.5 mm out of its natural path between the two wheels, which is the displacement commonly used in sawmilling. The guide blocks, which measured 56 mm in the vertical and 229 mm in the horizontal directions, were carefully machined to ensure that their faces were truly flat.

All tests were carried out under static conditions. The bandsaw blade was first tested in the untensioned state. Thereafter it was tensioned to a profile that is considered in the industry as optimum for good cutting performance. The tension stress and the stresses produced by wheel tilting were determined with strain gages. Four gages were mounted on the blade, two close to the leading edge on either side of the blade and two close to the trailing edge in the same manner (Fig. 2). The tension stress was measured at zero wheel tilt. The tilting was determined by first measuring the stresses at the trailing and leading edges and then by calculating the ratios between the stresses at the two edges. It was impossible to obtain information on the degree of tilt from the tilting device of the bandmill. For this reason, it was decided to specify the tilt by stress ratios ranging from 1.0 (no tilt) to close to 0 (almost no tension stress in the trailing edge).

The effect of tensioning and wheel tilting was studied at three tension-stress levels: 45.3, 53.3 and 70.8 N/mm^2. The tension stress was applied with a hydraulic-strain system.

For determining the natural frequencies, the blade was excited by means of an electromagnet connected to a frequency generator. As shown in Fig. 2, the magnet

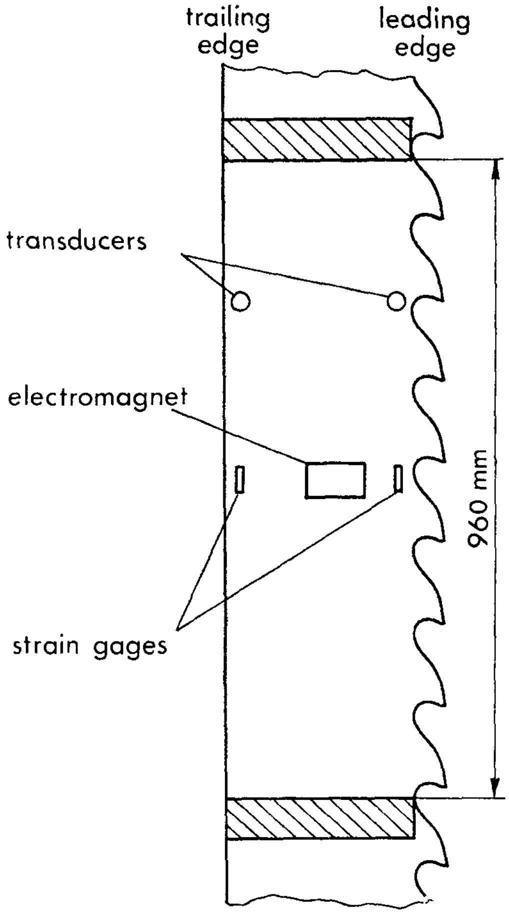

FIG. 2. Position of strain gages, electromagnet, and transducers in relation to the sawblade and guides.

was positioned halfway between the two guide blocks. The frequency band through which the magnet was swept ranged from 2 to 200 Hz. Two noncontact, eddy-current displacement transducers were used to pick up the induced vibration from positions as shown in Fig. 2. An oscilloscope was employed to identify lateral and torsional natural frequencies.

RESULTS AND DISCUSSION

The study results are presented in Figs. 3 to 5 and Table 1. Each figure shows the effect of tensioning and wheel tilting on lateral and torsional fundamental fre-

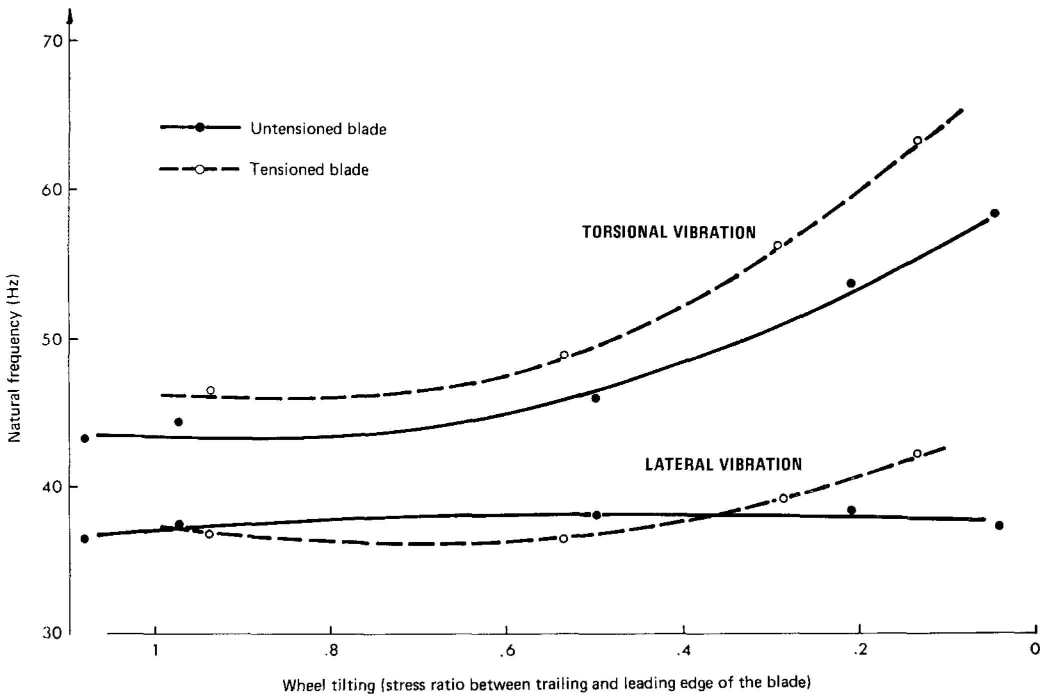

FIG. 3. The effect of tensioning and wheel tilting on the lateral and torsional fundamental frequency at a stress level of 45.2 N/mm² and a span length of 943 mm.

quencies for a particular tension-stress level. Table 1 presents experimental data obtained with the untensioned blade at zero tilting and corresponding theoretical data calculated with Mote's flexible band solution for lateral vibration (1965a) and Alspaugh's solution for torsional vibration (1967).

It is evident from the three figures that the two parameters, tensioning and wheel tilting, influence the vibrational behavior of a bandsaw blade, but their influence is highly diverse. By tensioning a marked shift in fundamental frequency occurred in torsional vibration; an upward shift of 2 to 5 Hz is evident. It appears that this shift is somewhat more pronounced at larger tilting angles, i.e. lower stress ratios. The magnitude of the shifting varies only slightly between the three tension-stress levels. It can be concluded that the overall influence of tension stress on the difference in torsional fundamental frequency, between the tensioned and untensioned blade, is insignificant, at least at stress levels applied in this study.

Contrary to torsional vibration, the fundamental frequency of lateral vibration is found to be unaffected or only slightly affected by tensioning. As can be seen in Figs. 4 and 5, which show the effect at the two higher tension-stress levels, the lateral fundamental frequencies of the tensioned and untensioned blade coincide extremely well. At the lower stress level (Fig. 3), the two curves are also in good agreement.

Wheel tilting, i.e. the difference in stress between the trailing and leading edge of the blade, affected both types of vibration. Most characteristic of this effect is that the shifting of the two natural frequencies occur in opposite directions, whereby the torsional fundamental frequency experienced an upward shift and the lateral frequency in general experienced a downward

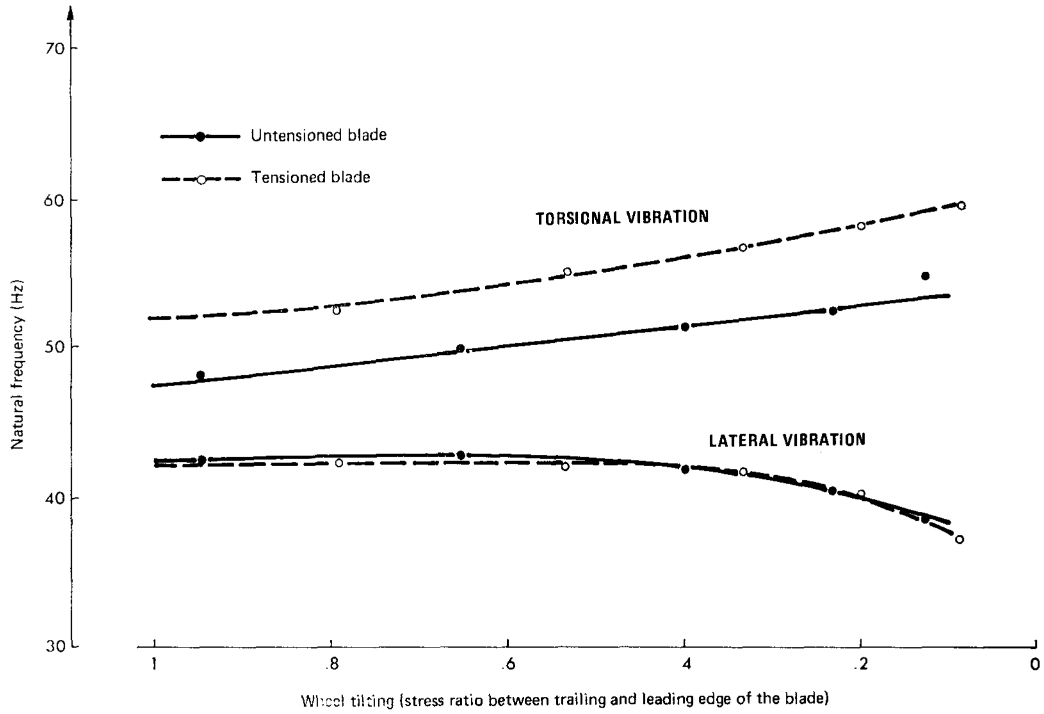

FIG. 4. The effect of tensioning and wheel tilting on the lateral and torsional fundamental frequency at a stress level of 53.3 N/mm^2 and a span length of 943 mm.

shift. The magnitude of these shifts appears to be influenced by tension stress. In the case of torsional vibration, the effect of wheel tilting was somewhat higher at the lowest tension-stress level (45.3 N/mm^2) than at the two higher levels. As can be seen in Fig. 3, the torsional fundamental frequencies of tensioned and untensioned blades increases by approximately 8 Hz from a stress ratio of 1.0 (no tilting) to ratios close to 0.1 (almost no tension stress at the trailing edge). At 53.3 and 70.8 N/mm^2, the upward shifts of the torsional natural frequency were less pronounced and did not exceed 6 Hz. The shifts at these two levels did not differ significantly (Figs. 4 and 5).

The effect of wheel tilting on lateral fundamental frequency is not consistent and varies with stress level. At the lowest tension-stress level, the untensioned blade showed essentially no change in lateral fundamental frequency and the tensioned blade showed a slight increase and this in the range of larger tilting angles, i.e. lower stress ratios. At higher tension stress, the effect of wheel tilting on the lateral frequencies appears to have changed very little in the range of stress ratios from 1.0 to approximately 0.6, but they showed a marked drop of 4 to 5 Hz in the range of lower stress ratios (0.6 to 0.1).

The practical significance of these findings is limited to the effect of tensioning on the torsional fundamental frequencies. As shown, tensioning does not significantly affect the lateral vibrational behavior of a bandsaw blade. Wheel tilting in practice is confined to the range of higher stress ratios, in which the two frequencies showed little or no variation.

For the use of theoretical solutions for predicting the vibrational behavior of a bandsaw blade under working conditions,

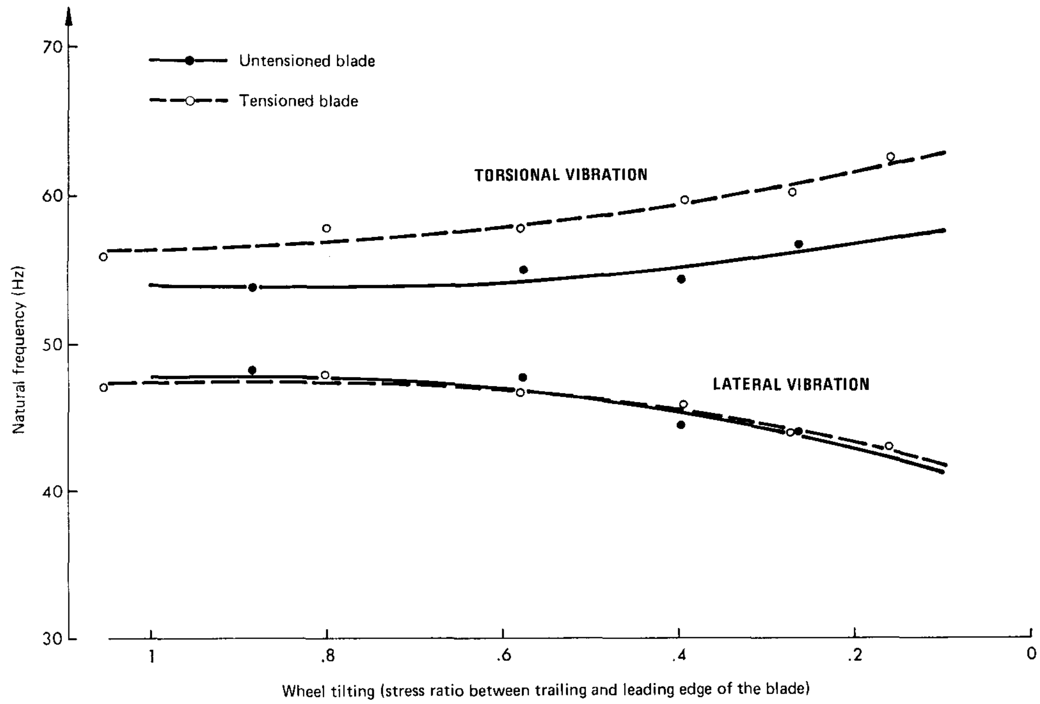

FIG. 5. The effect of tensioning and wheel tilting on the lateral and torsional fundamental frequency at a stress level of 70.8 N/mm² and a span length of 943 mm.

it is obvious that Alspaugh's solution for torsional vibration (1967) should be extended to include the effect of tensioning. This, however, is presently not feasible, as the knowledge of tensioning is limited and does not allow a quantitative evaluation of the stress pattern in a blade. For this reason, it is suggested to make use of Alspaugh's solution in its present form and consider the theoretical values as lower boundaries of the actual frequencies.

Incidentally, the experimental values obtained with the untensioned blade at zero wheel tilt show reasonably good agreement with the theoretical values determined by Mote's (1965a) and Alspaugh's (1967) solutions. As can be seen in Table 1, the difference between measured and predicted fundamental frequencies did not exceed 2.5 Hz.

CONCLUSIONS

The conclusions which can be drawn from this study are as follows:

TABLE 1. *Theoretical and experimental data on the lateral and torsional fundamental frequencies of the tested untensioned sawblade (all data refer to zero wheel tilting)*

Tension stress N/mm²	Lateral fundamental frequency (Hz)		Torsional fundamental frequency (Hz)	
	Theoretical [Mote 1965a]	Experimental	Theoretical [Alspaugh 1967]	Experimental
45.3	39.6	37.2	45.4	43.4
53.3	44.5	42.2	49.4	47.7
70.8	49.4	47.8	54.2	54.1

Increasing the wheel tilting caused an upward shift of the torsional fundamental frequency, and a downward shift of the lateral fundamental frequency.

Tensioning of a sawblade increased the torsional fundamental frequency, but had little or no effect on the lateral fundamental frequency.

The shift of the two natural frequencies by wheel tilting varied considerably with tension stress, whereas the shift of the torsional fundamental frequency caused by tensioning showed only minor variation between the stress levels tested.

The effect of tensioning on torsional vibration is of practical significance. It should be considered in predicting torsional natural frequencies. The effect of wheel tilting, however, can be ignored in predicting the vibrational behavior of a bandsaw blade under operating conditions. This effect lies essentially outside the range of tilting angles used in sawmilling.

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