Recent Advances in the Machining of Lesser-Used Species

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Abstract

Over exploitation of the commercial wood species has led to a fast decline or degradation of the tropical forest. It is expected that efficient utilization of the lesser-used wood species would improve sustainability of the tropical timber resources and reduce negative ecological impacts. These objectives can be achieved if appropriate technologies for processing the lesser-used wood species are developed. It is also expected that some of the recent advances in machining of the commercial wood species would be applicable to the lesser-used wood species. This paper highlights some of the recent advances in wood machining with emphasis on sawing and planing.

Introduction

In recent years, considerable interest has been generated towards efficient wood machining practices as a result of the high cost of raw material and labour. Until recently, much attention was focused on processing of the commercial wood species thus neglecting the so-called lesser-used wood species.

Over exploitation of the commercial wood species, has led to a fast decline or degradation of the tropical forest. It is expected that efficient utilisation of the lesser-used wood species would improve sustainability of the tropical timber resources and reduce negative ecological impacts. These objectives can be achieved if appropriate technologies for processing the lesser-used wood species are developed. It is also expected that some of the recent advances in machining of the commercial wood species would be applicable to the Lesser-Used wood species.In this paper, some recent advances in wood machining with emphasis on sawing and planing is discussed.

A Review of Recent Advances in Wood Machining

Sawing

In the conversion of logs to sawn lumber, pit sawing was once practiced extensively in some parts of the world. This crude method of sawing using obsolete and inefficient saws resulted in wood waste and low productivity. Recent technology, however, shows tremendous improvement in the conversion processes. Automated band-mill and twin band-mill with which logs are automatically sawn into lumber have been developed. This has resulted in reduction of operator's work, and an upgrade in machining efficiency.

Productivity, recovery and quality

It is well known that three factors compete for attention during the specification of a sawing process. These factors are productivity (workpiece feed rate), recovery (amount of sawdust production), and quality (wood surface finish and dimensional accuracy). These three factors are closely interconnected, and to a large extent are mutually exclusive. It must be emphasized that an improvement in one factor can be achieved only at the expense of one or both of the other two. For example, reductions in saw plate thickness and kerf reduce sawdust production and increases recovery of solid wood. However, this change can also impair sawcut quality and can require a reduction in workpiece feed speed. Saw tensioning provides an important exception to the above mutually exclusive pattern. Tensioning increases the stiffness and critical speed of saw blades through the deliberate induction of in-plane membrane stresses typically by hammering or rolling (Szymani & Mote, 1977; Schajer, 1984, 1992; Hutton, 1991). The increased saw stiffness and critical speed allow any of the three factors to be improved without impairing the other two. A thinner circular saw blade with a narrow kerf tends to lower the critical rotation speed owing to its low natural frequency (Angelo & Mote, 1988). The cutting operation cannot be continued when the critical rotation speed is lower than the operating speed because the stiffness against the lateral deflection disappears. The relationship between the natural frequency and rotation speed of a circular saw blade is shown in Figure 1.

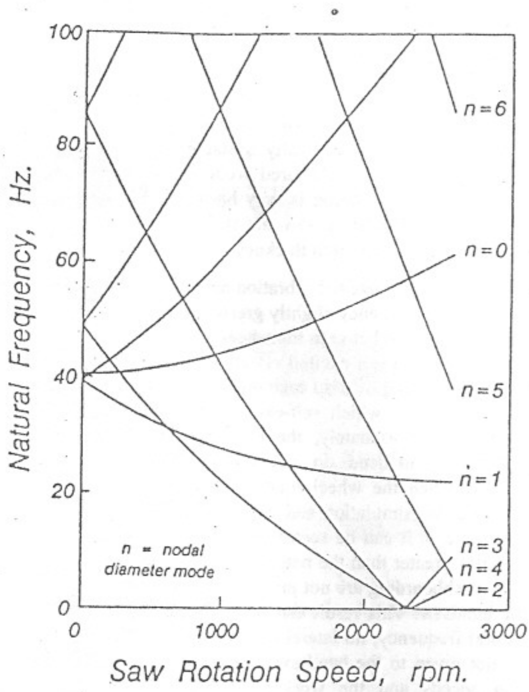

Figure 1. Natural frequencies of an unguided circular saw vrs. Rotation speed.

Vibration of Saw Blades

There are many different causes for the vibration in bandsaw blades and circular saws during machine operation. Once vibration is induced in saw blades, whatever the cause may be, it results in an increase in saw kerf losses, wood losses from cutting inaccuracies and poor surface finish. Vibration is moreover considered to be an indirect source of the increase in cutting force, a decrease in tooth life, the generation of gullet cracking and excessive noise levels. To prevent the lateral vibration and the whistling noise of circular saw blades, some techniques have been introduced such as tensioning (Schajer & Mote, 1984), the use of high damping alloy (Hattori *et al.,* 1993), vibration damping due to air film (Trochidis, 1989), stiffening by thermal membrane stresses (Mote et *al.,* 1981), and guided saw blades (Hutton *et al.,* 1987). In the actual woodworking field, an asymmetric circular saw blade is frequently used, in which several slots are made on the circular saw blade from the periphery of the blade towards its center. Such a blade is useful to prevent the lateral vibration both in idling and cutting operation (Dugdale, 1979; Mote & Yu, 1987).

The literature on bandsaw vibration can be divided into two general categories. The first is concerned with resonance vibration of a saw blade between two guides or wheels (Mote 1965, Alspaugh 1967, Ulsoy & Mote 1980). These analyses are based upon the model of an axially moving beam or plate subjected to fixed support boundaries at the guide or wheel. The second category focuses on the static or divergence buckling associated with edge cutting forces (Mote, 1980; Foschi & Porter, 1970, Pahlitzsch & Puttkammer, 1974; Garlicki & Mirza, 1978). Fixed support boundaries are imposed at ends of a saw blade in these analyses as well. A basic assumption in all previous research has been that the cutting span between the guides can be examined independent of the band outside the cutting region. The implied assumption is that the guides or wheels isolate the band in the cutting region from the remainder of the system. Research has shown that vibration of the span between the saw guides and spans which include the remainder of the bandsaw blade are coupled together (Wu & Mote 1982). These band regions can never be designed and analysed as independent systems as long as the bending stiffness of the band blade is significant.

Dynamic stability of tools: self-excited vibration

The bandsaw vibration is affected by the system dynamics, which is important in determining the sawing accuracy of the bandsaw. If the system is dynamically unstable, even the finely constructed and most accurately aligned machined will not produce the desired products considering accuracy and productivity. Operating a system close to an unstable condition is very hazardous from safety point of view as well. Typical results of saw instability are undulating sawcuts such as washboards, poor surface finish and sawcut width several times wider than the saw tooth thickness.

Recent studies have demonstrated that self-excited vibration and washboarding are induced during cutting with a bandsaw under a tooth passage frequency slightly greater than the natural frequency of the bandsaw (Okai *et al.,* 1996, 1997). The relationships between the wheel rotation speed of a 410mm bandmill and the natural frequencies of the saw blade when self-excited vibration and washboarding are induced is shown in Figure 2. If the unstable regions for sawing overlap each other, then one has to select rotation speeds lower than the minimum rotation speed under which self-excited vibrations and washboarding are induced, neglecting efficiency of production. Fortunately, the rotation speed ranges under which self-excited vibrations and washboarding were induced do not overlap. Then the self-excited vibration and washboarding can be controlled when the wheel rotation speeds are in the stable region considering efficiency of production. A computer simulation and experimental results for self-excited vibration and washboarding are shown in Figure 3. It can be seen that the bandsaw vibrations are excited only under tooth passage frequencies slightly greater than the natural frequencies of the bandsaw. It also can be seen that self-excited vibration and washboarding are not induced when the tooth passage frequency is equal to the natural frequency of the bandsaw. This result can be explained as follows: when the tooth passage frequency is equal to the natural frequency, no lateral cutting resistance is induced on the side of a tooth, and consequently, energy is not given to the bandsaw vibration to grow (Okai 1997). The relationships between the wheel rotation speeds and the workpiece thickness when self-excited vibration and washboarding are induced under a fixed height of the feed table is shown in Figure 4. The shaded area is the unstable region for sawing, and the unshaded areas represent the stable regions for sawing. It can be seen that as the workpiece thickness increased under a self-excited vibration, the wheel rotation speed range within which sawing becomes unstable, increases. Figure 4 can be used as a stability diagram to control self-excited vibration and washboarding by considering the trend line for the minimum and the maximum wheel rotation speed when self-excited vibrations and washboarding are induced.

Sawing Tropical Woods: Characteristics and Difficulties

The tropical forest is characterised by:

- A mixed species forest with a large range of properties (from 200 up to 1200 kg/m3 density).
- A large distribution of log sizes with a large proportion of big trees.
- Problems of forest accessibility and logging which favours the development of small sawmills with poor performance.
- A tremendous variability of sawing equipment.
- Difficult maintenance (especially sharpening and tensioning) through lack of qualified sawdoctors and equipment.

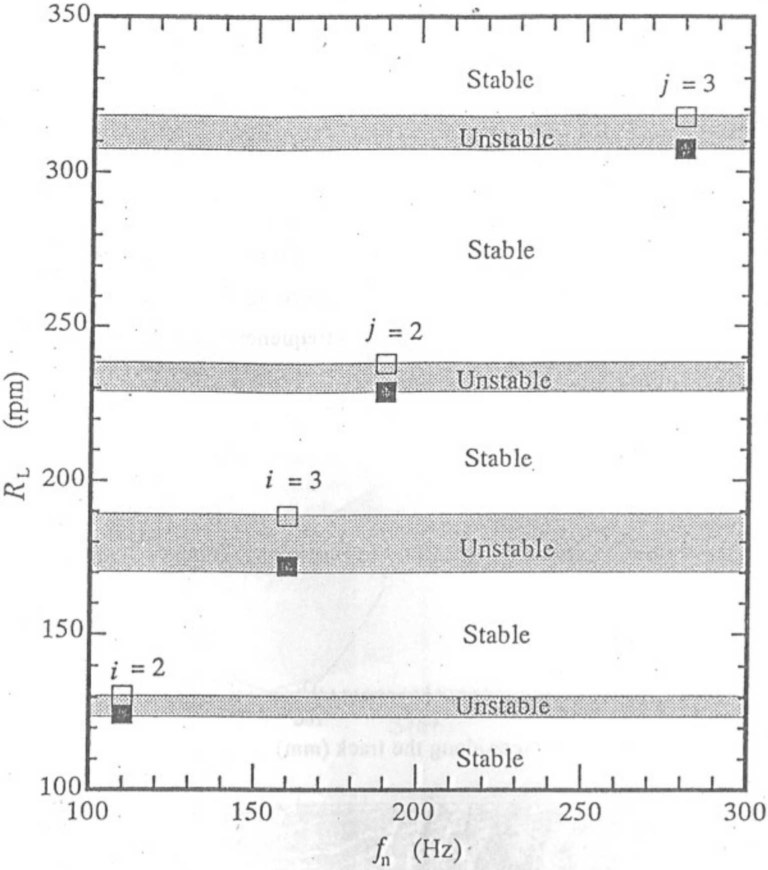

Figure 2. Relationships between the wheel rotation speeds during sawing R_L and the natural frequencies of the bandsaw f_n when self-excited vibrations and washboarding are induced under a constant free length of the saw blade.

Legend:

- ■ *Minimum wheel rotation when self-excited vibrations and washboarding are induced.*
- □ *Maximum wheel rotation when self-excited vibrations and washboarding are induced.*
- *i* *transverse vibration mode.*
- *j* *torsional vibration mode.*

Note: Workpiece thickness = 35 mm constant.

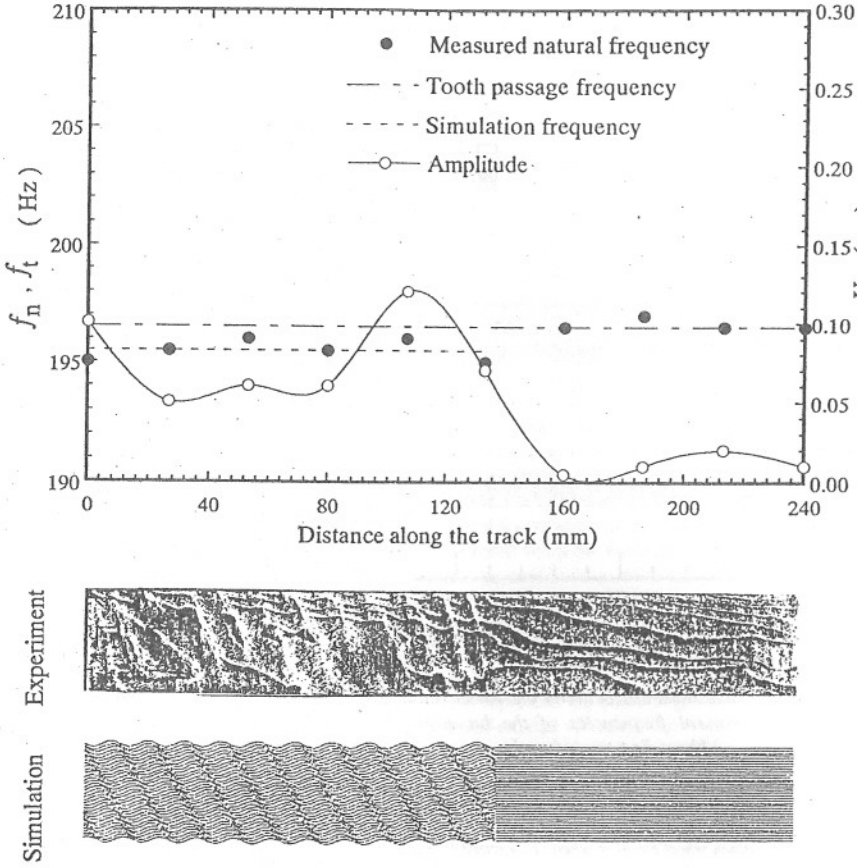

Figure 3. Self-excited vibration and washboarding during sawing with a bandsaw under a tooth passage frequency slightly higher than the 2nd torsional natural frequency.

Legend:

f_n	*Measured natural frequency*
f_t	*Tooth passage frequency slightly*
U	*Amplitude*

Notes: Set-up wheel rotation speed – 229 rpm; Feed speed – 11.97 mm s^{-1}

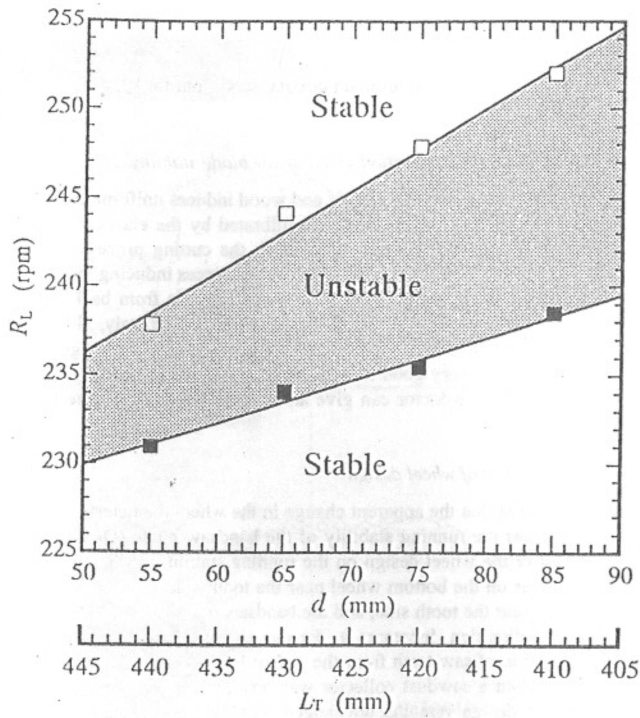

Figure 4. Relationship between the wheelrotation speeds during sawing R_L and the workpiece thickness d, or the free length of the bandsaw blade L_T from the top of the workpiece to the band/top wheel contact point when self-excited vibration and washboarding are induced under a fixed height of the feed table.

Legend:

- ■ *Minimum wheel rotation when self-excited vibrations and washboarding are induced.*
- □ *Maximum wheel rotation when self-excited vibrations and washboarding are induced.*

Two main difficulties in sawing tropical woods are:

- High cutting force due to density and sawing depth. In Africa and south America, more than 50% of the logs sawn have a diameter greater than 60 cm and a dry wood density higher than 700 kg/m3 (Sales *et al.*, 1988).
- Fast tooth wear due to density gravity which gives high cutting force thus increasing friction, mechanical and thermal wear. High proportionate of silica content in certain species also contributes to fast tooth wear.

Fast tooth wear: solutions

For ripsawing, tungsten carbide is commonly used on circular saws, and for bandsaw blades, stellite tipping remains the most efficient solution.

Effect of temperature during sawing and its action on bandsaw blade stability

During sawing, the friction of the blade on the wheels and wood induces uniform overheating. The thermal expansion of the blade caused by this overheating is equilibrated by the elasticity of the mechanism for maintaining tension between the wheels. On the other hand, the cutting process, especially for tropical hardwoods, heats the tooth edge which can rise several hundred degrees inducing thermal gradient from the front to the back of the blade. This causes a displacement of the blade from back to front and a loss of tensioning thus reducing the mechanical performance of the blade. Fortunately, although the temperature can be very high, the surface concerned is very small and located near the tooth edge. The thermal input is limited and the tooth body acts as a very good radiator, limiting the temperature gradient even for heavy woods. To balance this effect, the sawdoctor can give an additional tension on the front of the blade by introducing a back-crown.

Blade stability on the wheels: Effect of wheel design

Recent studies have demonstrated that the apparent change in the wheel diameter near the tooth side or the rear side of the blade influences the running stability of the bandsaw blade (Okai *et al.*, 1996). Figure 5 shows the effects of sawdust or the wheel design on the running stability of the bandsaw blade. It can be seen that when sawdust adheres on the bottom wheel near the tooth side of the blade, there is an apparent change in the wheel diameter near the tooth side, and the bandsaw moves to the region of increasing wheel diameter, or the counter feed direction. Increases in the movement of the saw blade in the counter-feed direction increased the projection of saw teeth from the end of band wheel, and sawing becomes unstable. As depicted in Figure 5(b), when a sawdust collector was positioned under the workpiece to collect the sawdust produced, the wheel design remains unchanged and the running position of the bandsaw is stabilised.

The lesser-Used Wood Species

The following wood species in Ghana are classified as lesser-used wood species: Canarium *(Canarium schweinfurthii*), Ceiba (*Ceiba pentandra*), Celtis (*Celtis mildbraedii),* Okan *(Cylicodiscus gabunensis*), Ayan (*Distemonanthus benthamianus*), Essia (*Petersianthus macrocarpus*), Sterculia (*Sterculia rhinopetala*), Bombax (*Bombax brevicuspe*), Albizia (*Albizia ferruginea*), Aprokuma (*Antrocaryon micraster*), and Akasa (*Chrysophyllum albidum*), (Ayarkwa *et al,* 1993).

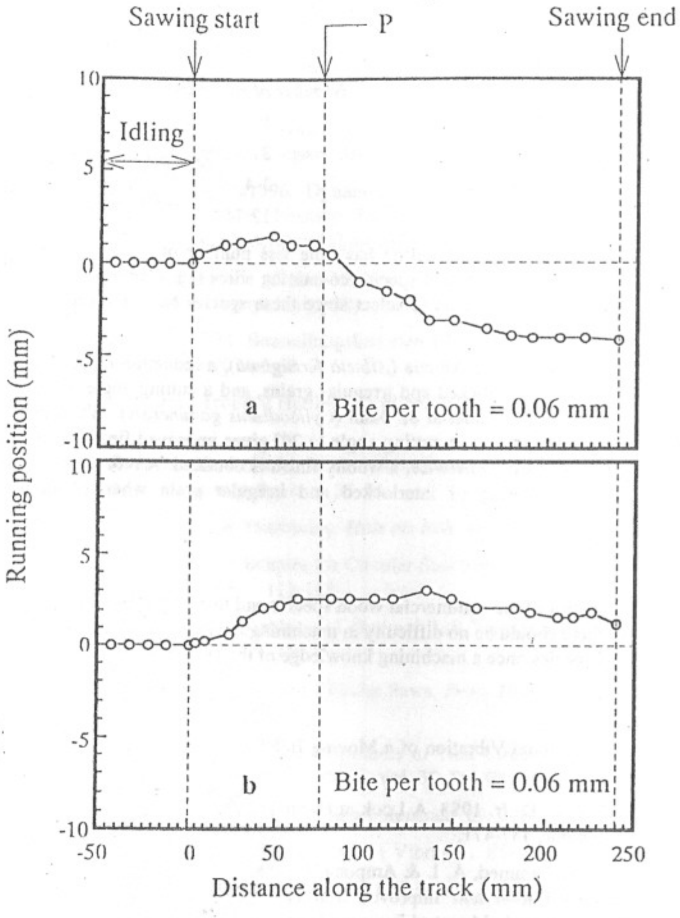

Figure 5. Relationships between the running positions of the bandsaw and the distances along the track of the bandsaw teeth under identical bites per tooth.

Legend:

a: The sawdust produced adhered to the bottom wheel.

b: The sawdust produced was collected by a sawdust collector.

P: Distance along the track of the tooth sides of the saw blade at the instant the rear side of the saw blade entered the workpiece.

Note: Setup wheel rotation speed: 235 rpm

Some of the above species are characterised by high wood density, interlocked grains, high silica content, severe blunting effect, and woolly surface, thus restricting the use of the timber of these species in the past. However, recent studies have demonstrated that the lesser-used wood species can be sawn or planed if the appropriate machinery and tools are selected. (Sales 1985) studied the wear of different materials such as speed steel, high speed steel, stellite, and tungsten carbide during planing of Makore (*Tieghemella africana*) at 15% moisture content and silica content of 0.3%. For the same planing length on makore, the following results were obtained:

Tools	***Number of sharpening***
Tungsten carbide	1
Stellite	2
High speed steel	3-4
Speed steel	12-15

It can be seen that tungsten carbide and stellite have the less number of sharpening, and these results indicate that when planing lesser-used wood species containing silica (eg. *Canarium* and Ayan), tungsten carbide or stellite are the appropriate tools to select since these species have a severe blunting effect on tools.

Studies have shown that when planing Albizia (*Albizia ferruginea*), a reduction of cutting angle of 15° is necessary to prevent tearing of interlocked and irregular grains, and a cutting angle of 10° is required for satisfactory planing of quater sawn material of Okan (*Cylicodiscus gabunensis*). When planing Canarium (*Canarium schweinfurthii*), a reduction in cutting angle to 20° gives improved finish on interlocked grains provided the cutters are kept sharp. Otherwise, a woolly finish is obtained. A reduction in cutting angle of 15° is necessary to prevent tearing of interlocked and irregular grain when planing Celtis (*Celtis mildbraedii*).

Conclusion

The machining characteristics of the commercial wood species and that of the lesser-used wood species are almost the same. Thus, there should be no difficulty in machining the lesser-used wood species as substitute to the commercial wood species once a machining knowledge of the latter is known.

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