SOME MACHINING QUALITIES OF SELECTED LESSER-USED TIMBER SPECIES OF GHANA

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ABSTRACT

In this paper, boring, shaping and turning characteristics of eleven lesser-used species (LUS) are presented. The results showed that, generally, the high-density species have better boring, turning and shaping qualities than the low-density species. That is, whereas Afina (Strombosia glaucescens), Albizia (Albizia ferrugenia), Essia (Petersianthus macrocarpus) and Esa (Celtis mildbraedii) have superior machining qualities, Otie (Pycnanthus angolensis), Ceiba (Ceiba pentandra), Bediwonua (Canarium schweinfurthii) and Bombax (Bombax brevicuspe) do not have very high grade boring, turning and shaping characteristics. Furthermore, the results of the boring test do not seem to indicate any clear relationship between density of wood and the off-sizes in the bored holes.

Keywords: Lesser-used species, machining properties, ecological zones.

INTRODUCTION

Among the important classes of properties that affect the general utility of any wood are its machining properties. Machining properties of wood are associated with standard wood processing operations such as planing, shaping, turning, boring etc. Unlike metals, wood in general is easy to cut or shape. For various usages such as in furniture and fixtures, the smoothness and ease with which woods can be worked may be the most important of all properties. Unless a wood machines fairly well and with moderate ease, it is not economically suitable for such uses regardless of its other virtues.

According to Dinwoodie (1980), machining is a stress-failure process and therefore it is convenient to analyse as an action of a cutting tool on a piece of wood. The direction of motion and configuration of the tool determine the way the stress develops and the wood resists it. He described machining as involving cutting, shaping and surfacing actions. According to Herbert et. al. (1984), the lower the density of the wood, the easier the wood is cut with a tool. Dinwoodie (1980) confirms that as density increases, the blunting time of cutting tools decreases. Kollman and Cote (1968) state that surface quality depends on the wood species and becomes better for denser, harder and drier wood. According to Dinwoodie (1980), the quality of cut depends on the grain direction and mechanics of chop breakage. Cutting along the grain is said to be more efficient and results in better finish quality than cutting against the grain. According to Davis (1938), the rate of feeding samples during machining is quite independent of species and is chosen in relation to the type of knife and the rotation speed of the cutterblock, so that the smoothness of the cut is suitable for the end use of the piece. Extremely low feed speeds may actually result in tearing instead of cutting, producing poor finish. Generally low feed speeds are reported to produce better finish during machining than higher speeds (Davis, 1938). Some tropical hardwoods such as *Milicia excelsa* (Odum) and *Distemonanthus benthamianus* (Ayan) are often found to have some hard deposits like calcium and silica. These deposits are said to have pronounced dulling effect on cutting tools in all directions (Farmer, 1972; Dinwoodie, 1980). The presence of resins and gums are also said to stick to tools and result in overheating and changing the normal working temperature. Dinwoodie (1980) further stated that timber of high moisture content does not machine as well as that of low moisture content due tendency for the thin walled cells to be deformed rather than cut due to their increased elasticity under wet condition. Deformed fibres easily pick up after cutting resulting in poor surfaces.

Boring, for example, is commonly done whenever dowels, spindles and screws are applied in the manufacture of chairs, tables and other hardwood products. Even though some carpenters of today still bore using brace and bits, in industrial woodworking electric power has replaced manpower. The simplest stationary-boring machine is the single spindle, hand-feed type and at the other extreme are automatic multiple-spindle machines that bore several holes of predetermined depth at the same time. Although, not one of the most important woodworking operations, the quality of boring either adds to or detracts from the general utility of any species. A smooth cut, accurately sized hole is necessary for the best glue joint. The extent of off size in bored holes also helps to explain why some species split considerably more than others when doweled and also the difference between dry fit and a loose fit with accurately sized dowels.

A wide variety of turned products such as tool and implement handles, spools and bobbling, and sporting goods, chair, furniture and toy parts, can be produced using the lathe machine. Lathes vary from simple hand operated to specialise automatic machines capable of making several turnings per hour. Although turnings are not very common practice in woodwork, a number of high quality products are often produced from turnings.

Shaping is chiefly done in the furniture industry. The commonest is the cutting of patterns on some curved edge like that of a round table top. There are power-feed automatic shapers, but the most common type is the spindle.

Unlike the physical and mechanical properties of the lesser-used species (LUS), machining properties have had little or no systematic study at all, and there are hardly any publications on the subject. Due to lack of adequate information on the machining properties of the LUS, the wood working industry very oven shuns their use.

Some of the everyday working qualities and machining characteristics of some Ghanaian LUS are presently being studied at the Forestry Research Institute of Ghana (FORIG), under an International Tropical Timber Organisation (ITTO) Project. The objective of the study is to assess the merchantability of the selected LUS so that the industry could be properly advised, and confidence in machining them improved. This paper presents in part the results of the studies made for the benefit of cabinetmakers, furniture manufacturers, and other wood users who can undertake with assurance the use of these new marketable species.

EXPERIMENTAL PROCEDURE

Test Materials

Wood test samples for the investigation were cut from lumber samples from logs of the following eleven species. Three tree samples of each species were collected from each of three forest ecological zones in Ghana for the experiment namely Wet Evergreen (Draw River Forest Reserve), Moist Evergreen (Bura Forest Reserve) and Dry Semi-Deciduous Forest Zones (Opra Forest Reserve):

1. Yaya (*Amphimas pterocarpoides*)
2. Ayan (*Distemonanthus benthamianus*)
3. Bediwunua (*Canarium schweinfurthii*)
4. Denya (*Cylicodiscus gabunensis*)
5. Bombax (*Bombax brevicuspe*)
6. Afina (*Strombosia glaucescens*)
7. Albizia (*Albizia ferrugenia*)
8. Ceiba (*Ceiba pentandra*)
9. Ohaa (*Sterculia oblonga*)
10. Esa (*Celtis mildbraedii*)
11. Essia (*Petersianthus macrocarpus*)

The logs were sawn and the lumber kiln-dried to about 10% moisture content at FABI Timbers in Kumasi and later conditioned to 12% moisture content for the studies. The selection of test samples for the study was in accordance with ASTM, D 143-152 (1979).

Testing Methods

Boring, shaping and turning qualities of dried samples of the above species were investigated using equipment at the timber engineering workshop of the Forestry Research Institute of Ghana (FORIG). Commercial sized machines in good condition were used for the study.

Sharpness of the cutting tools or knives were kept uniform in all the tests through re-sharpening. The quality of the machined piece was used as the basis for evaluation in accordance with ASTMD 1666-64 (1978). Under the study, the quality of machined pieces was assessed by both visual and tactile inspection. All the test specimens were conditioned to 12% moisture content for the tests. The tests were conducted as follows:-

Boring quality test

In this study, the equipment used was a general-purpose stationary type borer with a single spindle employing hand feeding. New single twisted, solid centre bit of size of 28mm was used for boring samples of each species. The selected bit size was large enough for holes to be well inspected. Two separate bit speeds of 600 rpm and 1400 rpm were investigated in the study. A constant bit feed speed of 0.5mm/min was adopted for all tests. Twenty-five test specimens of 50mm x 300mm x 27mm thickness were cut from lumber samples randomly selected from the pile from each ecological zone. For each species a total of 75 specimens were tested from the three ecological zones. Four separate holes were bored in each block sample whilst holding the block firmly in a vice. In all 300 holes were bored for each test condition for each species.

After boring, each hole was carefully examined and graded for smoothness of cut on a scale of 1 to 3 (Fig. 1). Holes with clean, smooth cut with a minimum of fibre tear-out or crushing on the cut surface were graded 1 or excellent, whilst fibrous, rough holes with much fibre tear-out were graded 3 or poor. The percentage of holes in each grade was determined. The exact size of each bored hole was measured with a caliper both in a direction parallel and perpendicular to the grain immediately after boring. The difference between the average measurement in the two directions and the size of the bit for each species was determined as amount of off size in the bored hole. The overall off size for each species was calculated.

Turning quality test

In this investigation the equipment used was the lathe machine of the type that is commonly found in small wood workshops. The machine was used to produce 20 identical turnings from lumber samples randomly selected from the pile from each species from each ecological zone. In all 60 specimens of each, of 37mm x 37mm x 187mm dimensions were investigated from the three ecological zones. The investigations were carried out using a single turning speed of 7900 rpm, and the turning patterns were chosen such that cuts were made along the grain, across the grain and diagonal to the grain.

After turning, each sample was carefully examined and graded taking into account sharpness of cut and smoothness of surface on a numerical scale of 1 to 3 (Excellent, good and poor). The poorest point in a turning was considered the controlling factor in the grading since that point governs the amount of sanding required to make it commercially acceptable. Excellent turning with sharp details and smooth surface were graded 1 whilst poor ones with splits, rough surfaces etc. were graded 3 (Fig. 2). Turnings with quality intermediate between the two were graded 2. The percentage of excellent and good samples was then calculated.

Shaping quality test

This investigation was conducted using a spindle moulder and a bandsaw. The test samples were cut from lumber samples randomly selected from the stockpile of each species from each ecological zone. Samples, which were of 25mm x 75mm x 325mm dimensions, were bandsawed into the shape shown in the attached photograph (Fig. 3) such that it included straight and curved sawing.

Thirty test samples of each species from each ecological zone were cut into the above shape and carefully shaped by an experienced operator using a spindle moulder running at a constant speed of 600 rpm. In all, 90 specimens of each species from all the three ecological zones were investigated. After shaping, each sample was graded on the basis

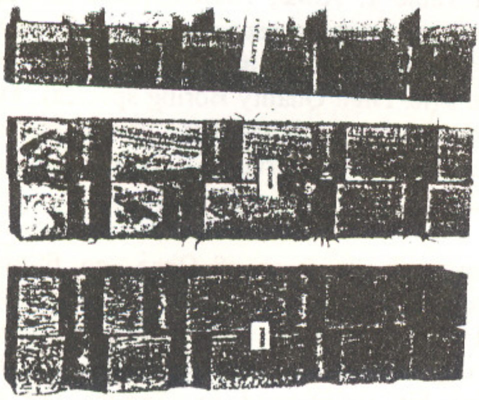

Fig. 1 Boring

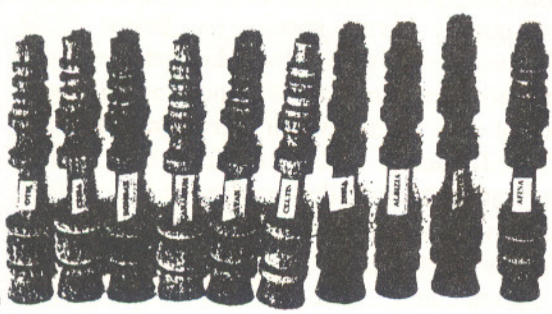

Fig. 2 Turning

Fig. 3 Shaping

of defects such as raised grain, fuzzy grain and torn grain (see definitions in the Appendix). The worst defect in a shaped sample was used to determine the grade of each sample. Three grades were adopted - Excellent, Good and Poor. Excellent samples were those free from any of the defects mentioned above whilst poor ones had several of the defects. Intermediate between the two extreme grades was graded as good (Fig. 3).

RESULTS AND DISCUSSION

The results of the boring quality test have been presented in Table 1 showing the relative smoothness of cut of the individual species at 600 rpm and 1400 rpm respectively and in Tables 2 and 3 showing variations from size of bored holes at the above speeds. The relative turning and shaping qualities of the different species have also been presented in Tables 4 and 5. From the results of the tests, all the species investigated were grouped into quality grades I, II and III as shown in the tables.

Boring Test

Results of the boring studies showed that all the species investigated did not differ so widely in boring qualities for both 600 rpm and 1400 rpm bit (spindle) speeds. Tables 1 indicate that Afina has the best boring characteristics whilst Ceiba has the poorest. The results further indicated that the heavier species produced greater percentage of good and excellent holes compared with the lighter weight species. Thus the heavier species seemed to have superior boring properties. This is in agreement with Davis (1938), Kollman and Cote (1968) and Farmer (1972).

Table 1: Boring: Relative Smoothness of Cut at 600rpm and 1400 rpm

Species	% Good and Excellent		Grade
	600 rpm	1400 rpm	
Afina	100	100	
Albizia	96	94	
Essia	92	92	I
Esa	90	91	
Ayan	88	86	
Denya	85	85	
Ohaa	84	79	
Bediwonua	80	75	
Bombax	78	72	II
Otie	76	68	
Ceiba	74	65	

Results based on 300 holes bored with 28mm bit at feed speed of 0.5mm/min.
I = High Quality Boring Species (85% - 100%).
II = Medium Quality Boring Species (55% - 85%).
III = Low Quality Boring Speed (Below 55%).

Table 2: Boring: Variation from size of Bored Holes at 600 rpm

Species	Amount Off-size (mm)
Esa	0.35
Afina	0.35
Essia	0.36
Albizia	0.37
Bombax	0.38
Ceiba	0.40
Otie	0.41
Bediwonua	0.45
Ayan	0.49
Ohaa	0.57
Denya	0.69

Av. for both across and parallel to the grain measurements feed speed of 0.5mm/min and bit size of 28mm.

From Table 1, Afina, Albizia, Celtis, Ayan, Denya and Ohaa (producing over 85% good and excellent holes) were grouped under Grade I (ie. High Quality Boring species). The superior boring qualities of the denser species is in agreement with Irvine (1961) and Farmer (1972).

However, in the case of Ohaa, no fibrous finish was observed on end grains. No gum build up was also observed in Ayan, causing charring and consequent blunting of the drilling bit as asserted by Farmer (1972). Bediwonua, Bombax, Otie and Ceiba (producing 55% to 85% good and excellent holes) were grouped under Grade II (ie. Medium Quality Boring species).

From the species studied there were no poor or low quality boring species (ie. below 55%). The results in Table 1 for a bit speed of 1400 rpm produced almost the same grading results except for Ohaa, which was, graded under Grade II species. The results in Table 1 further gave an indication that quality of bored holes slightly decreased with increased bit speed. This is in agreement with Davis (1938) and Kollman and Cote (1968). The results presented in Tables 2 and 3 showed that bored holes differed from the actual size of the bit by amounts ranging from between 0.35mm and 0.69mm for bit (spindle) speed of 600 rpm and 0.31mm to 0.68mm for bit (spindle) speed of 1400 rpm.

The results seemed to indicate that whereas for Celtis, Afina and Albizzia the average off-sizes were smaller, that for Denya and Ohaa were bigger than the lightweight species ie. Bediwonua, Otie, Ceiba and Bombax. Thus there seemed to be no clear relationship between density of wood and the off-sizes in the bored holes. The results in Tables 2 and 3 showed that there also seemed to be no clear relationship between bit speed and the amount of off size in the species. There were also no fibres that had been flattened, bent or compressed during boring.

Table 3: Boring: Variation from size of Bored Holes at 1400 rpm.

Species	Amount Off-size (mm)
Esa	0.31
Afina	0.32
Essia	0.32
Albizia	0.34
Bombax	0.38
Ceiba	0.39
Otie	0.48
Bediwonua	0.50
Ayan	0.61
Ohaa	0.64
Denya	0.68

Av. for both across and parallel to the grain measurements Feed speed of 0.5mm/min and bit size of 28mm.

Table 4: Turning: Relative Turning Qualities at 7900rpm

Species	% Good and Excellent	Grade
Afina	100	I
Albizia	90	
Celtis	85	
Essia	80	II
Ohaa	80	
Denya	80	
Ayan	65	
Bombax	45	III
Bediwonua	45	
Ceiba	0	
Otie	0	

I = High Quality Turning Species (85% - 100%)
II = Medium Quality Species (55% - 85%)
III = Low Quality Species (Below 55%)

Table 5: Turning: Relative Shaping Qualities at 7900 Rpm

Species	% Good and Excellent	Grade
Afina	97	I
Albizia	90	
Essia	87	
Denya	87	
Celtis	83	II
Bombax	83	
Ayan	80	
Ohaa	80	
Bediwonua	73	
Ceiba	70	
Otie	63	

I = High Quality Turning Species (85% - 100%)
II = Medium Quality Species (55% - 85%)
III = Low Quality Species (Below 55%)

Turning Test

The results of the study presented in Table 4 indicated that, whereas all samples of Afina tested produced good and excellent turnings, all samples of Ceiba and Otie produced poor or inferior turnings and the variation in quality from excellent to poor was so wide.

The results again seem to indicate that, in general, the medium and heavy species produced better turnings than the lightweight species. This is in agreement with Davis (1938), Kollman and Cote (1968) and Farmer (1972).

The trend of the results may be due to the lower densities of Otie, Ceiba, Bediwonua and Bombax, which had relatively low percentages of good and excellent turnings and the higher densities of species ranging from Afina to Ayan (Table 4), which have comparatively greater proportion of good and excellent turnings. For the purpose of selection in the furniture and woodworking industry, Afina, Albizia and Celtis (with 85% - 100% good and excellent turnings) have been grouped under Grade I or High Quality species category, whilst, Essia, Ohaa, Denya and Ayan (with 65% - 85% good and excellent turnings) have also been grouped under Grade 2 or Medium Quality species category. Bombax, Bediwonua, Ceiba and Otie (with 0% - 45% good and excellent turnings) have also been grouped under Grade 3 or Low Quality species category.

The investigation also revealed that although Afina turns better than all other species, its high splitting characteristics renders it unattractive for users. Otie and Ceiba were also too fibrous or woody and turning was generally not useful.

Shaping Test

The results of the study showed that generally all the species tested had good shaping qualities, which ranged from 63 to 97 percent of samples tested.

The trend of results again gave some indication that the heavier species had somewhat better shaping qualities than the lightweight species. This is in agreement with Davis (1938), Kollman and Cote (1968) and Farmer (1972). From the results, Afina, Albizzia, Essia and Denya were grouped under Grade 1 (ie. High Shaping Quality Species with 85% to 100% good to excellent samples) and all the remaining species grouped under Grade 2 (ie. Medium Shaping Quality species with 55% to 85% good to excellent samples).

It was also observed in the study that raised and torn grain defects were more common in light weight species whilst surface roughness and fuzzy grain defects were also prevalent in heavier species. These results are in agreement with Davis (1938) and Kollman and Cote (1968). It was observed that shaping parallel to the grain and diagonal to the grain gave better results than across the grain in almost all species tested, in agreement with Farmer (1972) who reported that Ayan and Albizia have the tendency to tear and break away at arises. There were also instances of split in shaping in Afina which rendered such samples not useful.

CONCLUSION

The results showed that, generally, the high-density species have better boring, turning and shaping qualities than the low-density species. That is, whereas Afina (*Strombosia glaucescens*) Albizia (*Albizia ferrugenia*), Essia (*Petersianthus macrocarpus*) and Esa (*Celtis mildbraedii*) have superior machining qualities, Otie (*Pycnanthus angolensis*), Ceiba (*Ceiba pentandra*), Bediwonua (*Canarium schweinfurthii*) and Bombax (*Bombax brevicuspe*) do not have very high grade boring, turning and shaping characteristics. Furthermore, no clear relationship between density of wood and the off-sizes in the bored holes was established under the study.

The results of the study have indicated that most of the lesser-used species investigated have promising boring, turning and shaping characteristics to justify their utilisation in the furniture and wood working industries.

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