Effect of wood characteristics on properties of paper from eucalyptus spp. and tropical hardwoods

SINGH, S.V., BHANDARI, S. S., SINGH, S. P. & SHARMA, Y. K.*

ABSTRACT

The paper reports the data on wood characteristics (density and fibre-vessel structure) of *E.qrandis* and *E,tereticornis* of two different age groups and of the following speices of tropical hardwoods: *Acacia catechu, Anogeissus latifolia. Boswellia serrata, Cleistanthus collinus, Diospyros melanoxylon, Pterocarpus marsupium* and *xylia xylocarpa* and their influence on surface properties of paper (roughness and apparent density). The investigations on these species have revealed interesting correlations between the Runkel ratio and shape factor of the fibre and pulp and paper properties essential for printability. It has been found that wide variations occur in morphological characteristic and density in these hardwoods. The degree of variation between density, the Runkel ratio and the shape factor and their influence on surface roughness of paper did not follow the same pattern for all the species reported here. There were clear-cut indications that the rate of increase in paper roughness with density of hardwoods comprising of *E.grandis* (14-15 yrs), *B.serrate*, *C.collinus* and *X xylocarpa* (group X) was higher than that was observed for the species *E grandis* (18-19 yrs). *E tereticornis* (5-6 yrs and 14-15 yrs), *D.melanoxylon*, *A latifolia* and *A.catechu* (group y.) This shows that in this particular study the species of group 'Y' would produce better pulp for printing papers.

The relationship between wood density and morphological structure of hardwoods is of growing economic interest for domestic paper industry which is looking for increasing the use of hardwood fibres in various papermaking furnishes. Therefore, an understanding of the effect of wood characteristics (density and fibre/vessel structure) on paper properties is going to contribute to a wider utilization of hardwoods (both mixed plantation grown ones and naturally cccuring tropical hardwood species) by the paper industry.

The present study was designed to provide such data on *Eucalyptus tereticornis* and *Eucalyptus grandis* of two different age groups with a view to examine the effect of age on wood and paper properties, and on the following species of tropical hardwoods which are commonly used in the industry: *Acacia catechut, Anogeissus latifolia, Boswellia serrata, Cleistanthus collinus, Diospyros melanoxylon Pterocarpus marsupium* and *xylia xylocarpa.*

EXPERIMENTAL

Fibre diameter and wall thickness and vessel dimensions and frequency were measured (100 measurements of each) on sections cut from wood chips as used for pulping. Fibre length was determined using bleached pulp samples (200 measurements). The density of wood was determined as per IS specification number IS : 1708 : 1969 on oven dry weight and green volume basis.

Kraft pulps were prepared at first under identical conditions chip charge 400g o.d., sulphidity 25%, chip to liquor ratio 1:3.5 (including chip moisture), time to maximum temperature 120 minutes (room temp. to 100°C : 15 min, 100°–170° C : 105 min), time at 170°C : 60 min. For *Eucalyptus grandis,* 15% active alkali was required to cook to 20±1 Kappa number, whereas *E.tereticornis* required 17% active alkali. In case of tropical hardwoods 17% active alkali was used excepting *Cleistanthus collinus* which was cooked with 15%.

RESULTS AND DISCUSSION

Table 1 gives the data on density and fibre vessel characteristics of all species reported in this investigation. The pulp and paper properties are given in Table 2.

*Cellulose and Paper Branch
Forest Research Institute & Colleges, Dehradun.

TABLE—1

DENSITY AND FIBER/VESSEL CHARACTERISTICS

Sl. No.	Species with age	Basic density g/cm³	Vessel diameter μm	Vessel length μm	Vessel frequency per mm²	Fiber length μm	Fiber diameter d	Lumen diameter l	Wall thickness (μm)2w	Runkel ratio (2w/l)	Shape factor $(d^2-l^2/d+l^2)$
1.	*E. grandis* (5–14–15 Yrs)	0.390	193.20	549.33	6.0	969	20.63	13.93	6.70	0.4806	0.5439
2.	*E. grandis* (18–19 Yrs)	0.378	201.08	464.86	7.0	991	21.07	14.83	6.24	0.4211	0.3376
3.	*E. tereticornis* (5–6 Yrs)	0.580	145.4	368.47	10.0	735	14.22	7.63	6.59	0.8630	0.5526
4.	*E tereticornis* (14–15 Yrs)	0.530	158.8	377.06	9.0	728	12.95	5.09	7.87	1.5466	0.7328
5.	*Acacia catechu*	0.975	145.8	270.0	17	913	14.8	5.85	4.49	0.7675	0.7297
6.	*Anogeissus latifolia*	0.773	122.5	316.8	27	1151	13.57	3.69	4.94	1.338	0 8622
7.	*Boswellia serrata*	0.394	162.9	367.8	33	935	36.44	28 85	3.79	0.1313	0.2294
8.	*Cleistanthus collinus*	0.659	155 4	492.0	121	1130	26.62	12.80	6.90	0.539	0.6244
9.	*Diospyros melanoxylon*	0.659	155.4	368.0	29	877	15.0	6.99	4.05	0.5793	0.6431
10.	*Pterocarpus marasupium*	0.734	150.5	303.7	13	895	17.45	9.675	3.89	0.402	0.5297
11.	*Xylia xylocorpa*	0.766	142.6	311.4	21	1014	18.61	9.50	2.17	0.2284	0.5865

TABLE—2

PROPERTIES OF PULP AND PAPER FROM HARDWOODS

Sl. No.	Name of species with age group	PFI Rev	CSF (ml)	Kappa number	Apparent density (g/cm³)	Air resistance S, (gurley)	Roughness (μ)	App. density at 250 CSF (g/cm³)	Roughness at 250 CSF (μ)	Unscreened Yield (%)
1	2	3	4	5	6	7	8	9	10	11
1.	*E. grandis* (14–15 Yrs)	0	670		0.60	2	5.00		3.25	52 42
		1000	550		0.72	9	3.90			
		2000	498	20.4	0.78	16	3.25	0.87		
		4000	419		0.84	55	3.00			
		8000	273		0.84	200	3.10			
2.	*E. grandis* (18–19) Yrs)	0	640		0.61	2	4.75			
		1000	555		0.76	11	3.45			
		2000	525	21.0	0.80	16	3.20	0.85	2.75	54.39
		4000	449		0.84	39	2.85			
		8000	319		0.87	107	2.80			
3.	*E. tereticornis* (5–6 Yrs)	0	550		0.61	3	4.25			
		1000	440		0.70	9	3.48			
		2000	410	21.7	0.72	15	3.35	0.75	2.75	44.11
		4000	350		0.75	21	2.95			
		8000	230		0.82	61	2.80			
4.	*E. tereticornis* (14–15 Yrs)	0	570		0.61	2	4.60			
		1000	436		0.65	4	4.30			
		2000	406	21.6	0.68	5	3.85	0.75	2.95	42.52
		4000	367		0.73	9	3.30			
		8000	307		0.77	15	3.10			
5.	*Acacia catechu*	0	570		0.59	1	5 60			
		1000	485		0.65	2	4.78			
		2000	440	47.0	0.68	3	4.55	0.72	3.75	46.90
		4000	260		0.77	13	3.87			
		8000	170		0.82	149	3.52			

1	2	3	4	5	6	7	8	9	10	11
6.	*Anogeissus latifolia*	0	632		0.52	1	6.14			
		1000	540		0,59	2	5.29			
		2000	488	40.2	0.63	4	4.81	.71	3.55	45.35
		4000	380		0.67	13	4.10			
		8000	205		0.74	148	3.69			
7.	*Boswellia serrata*	0	545		0.62	5	4.17			
		1000	475		0.78	15	3.57			
		2000	385	41.2	0.83	40	3.32	.89	3 4	36.67
		4000	235		0.89	310	4.46			
		8000	166		0.93	600	4.29			
8.	*Cleistanthus cellinus*	0	345		0.56	1	6.40			
		1000	210		0.65	5	5.75			
		2000	130	28.8	0.70	11	5.25	.64	5.85	41.16
9.	*Diospyros melanoxylon*	0	515		0.60	3	4.40			
		1000	460		0 68	7	3.95			
		2000	405	24.7	0 70	9	3.80	.76	3.10	42.48
		4000	335		0.72	15	3.50			
		8000	188		0.77	56	3.15			
10.	*Xylia xylocarpa*	0	630		0 53	1	6.32			
		1000	570		0.61	1	5.62			
		2000	510	46.8	0.64	3	4 92	.72	4.45	47 21
		4000	430		0.68	11	4.48			
		8000	260		0.73	78	4.42			

Pulping conditions

- Chips charge $= 400$ gm O.D.
- Active alkali $= 15$–17% as Na_2O
- Sulphidity $= 25\%$

Chip to liquor ratio 01:3.5 (including chip moisture)
Time to 100° 15 min

100° to 170° = 150 min
at 170° = 60 min

Fibre/Vessel characteristics

The data on fibre/vessel characteristics indicate that a wide variation exists between species. The mean fibre length varied from 728 μm *(E.tereticornis)* to 1130 μm (*C.collinus*), the mean fibre diameter (d) from 1290 μm *(E.tereticornis)* to 36.44 μm (*B.serrata*), the mean lumen diameter (l) from 3.69 μm *(A.latifolia)* 14.83 μm *(E.tereticornis)* and the wall thickness (2w) from 2.17 μm *(x.xylocarpa)* to 7.78 μm *(E.tereticornis)*. Thus the Runkel ratio ($2\omega/1$) and the shape factor (d^2-l^2/d^2+l^2) varied from 0.13 *(B.serrata)* to 1.54 *(E.tereticornis)* and 0.22 *(B.serrata)* to o,86 *(A.latifolia)* respectively.

In case of Eucalyptus species, *E.tereticornis* have lower fiber length, fibre diameter and lumen diameter, as compared to *E.grandis*. With in species there was no significant effect of age on these characteristics in either case. It will be further seen from the Table 1 that the wall thickness did not vary appreciably either with species or with age. The values of the Runkel ratio and shape factor for *E.grandis* were lower than those found for *E.tereti cornis*. In case of *E. tereticornis* these values increased with age, whereas in case of *E.grandis* there was no appreciable change with age.

A perusal on data on vessel dimensions and frequency shows that both varied widely with species. The vessel length varied from 270 μm (*A.catechu*) to 549 μm (*E.grandis*-14 years). The vessel diameter from 122 μm (*A.latifolia*) to 201 μm (*E.grandis*-18 years) and the vessel frequency from 6/mm^2 (*E grandis*-all age groups) to 121/mm^2 *C.collinus)*.

Within Eucalyptus spp. that is *E.grandis* and *E.tereticornis* the variation in vessel frequency was in a narrow range (6-10/mm^2), as compared to tropical hardwoods (13-121/mm^2). There was no variation in vessel frequency with age in either case. Both the vessel diameter and the vessel length were lower in case of *E.tereticornis* as compared to *E.grandis*. These values also did not change appreciably with age in either case.

Wood Properties Vs Paper Properties

The variation in basic density ranged from 0.37 g/cm^3 (*E.grandis)* to 0.97 g/Cm^3 *(A.catechu)* within Eucalyptus spp. *E.grandis* had lower basic density (0.37-0.39) as compared to *E.tereticornis* (0.53 to 0.58). It will be further seen that there was not much influence of age on basic density in case of both the species.

The properties of wood which influence the basic density and in term of paper properties could be shown as depicted in Fig. 1.

It has been found that wood density is highly related to collapsibility/conformability of the fibre.

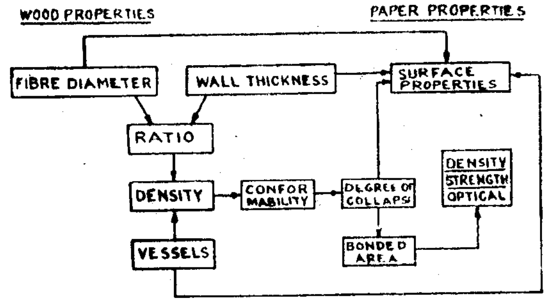

FIG. 1. RELATIONSHIP BETWEEN SOME PHYSICAL CHARACTERSTICS OF WOOD IN PAPER PROPERTIES.

Fibres of high density are cylindrical and rigid, whereas those of low density woods are ribbon like and flexible. The fibre characteristics are collectively represented by Runkel ratio (2w/l) and shape factor (d^2-l^2/d^2+l^2); where (2w) is wall thickness, (l) is lumen diameter and (d) is fibre diameter.

It has been observed that both these characteristics increase with basic density. Thus it will be seen that the basic density, the Runkel ratio and shape factor are interrelated.

It will be seen from Fig. 2 that the fibre shape factor increased but non-linearly with increase in wood density in case of both Eucalyptus spp. and tropical hardwoods. However, the rise in values followed slightly different pattern in the two cases. Fig. 3 indicates the relationship between wood density and the Runkel ratio. It will be seen that in case of Eucalyptus spp. there is an abrupt rise in the Runkel ratio within the limit of wood density 0.37 to 0.58gm/cm^3. In case of other hardwoods, two types of relationship were observed. The

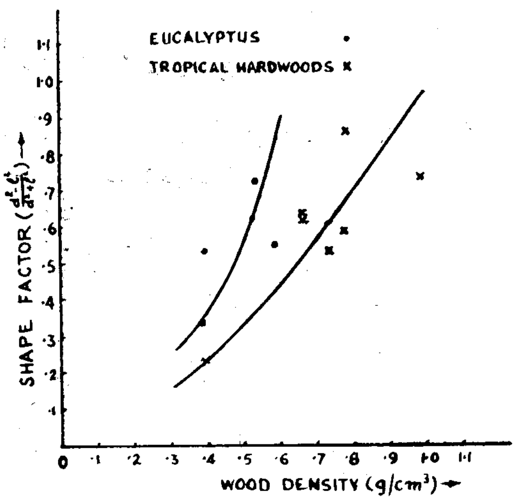

FIG. 2 WOOD DENSITY Vs FIBRE SHAPE FACTOR.

species *Boswellia serrata, Cleistanthus collinus, Diospyros melanoxylon* and *Anogeissus latifolia* (curve AB) followed the same pattern as observed with Eucalyptus, whereas in case of species *Xyiia xylocarpa, P.morsupium, A.catechu* and *B.serrata* (curve AC) such an abrupt rise was not observed, (*B. serrata*) representing the starting point for both these curves.) Fig. 4 shows the relationship between wood density and paper surface roughness. It will be seen from the graphs that the variation of surface roughness of the paper with wood density can be classified into two group (X) comparising of the species: *E. grandis* (14-15 yrs), *Boswellia serrata, C. collinus* and *Xylia xylocarpa* and the group (y) comparising of species : *E. grandis* (18-19 yrs), *E. tereticornis* (5-6 yrs) *E. tereticornis* (14-15 yrs), *D. melanaxylon, A. latifolia* and *A. catechu.*

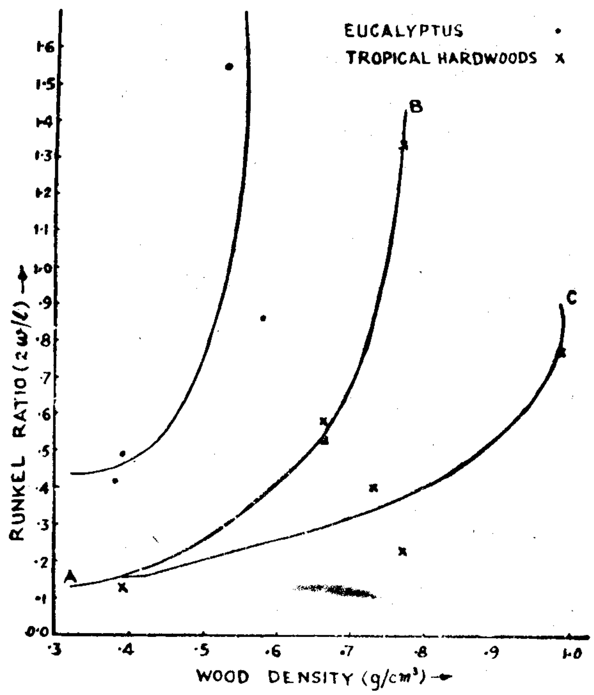

FIG. 3 WOOD DENSITY Vs RUNKEL RATIO

In the former group (X) the values fall on the curve AB which shows sharp rise in the values of surface roughness with increase in density. For the group (y) the values lie on the curve CD which shows gradual rise in the values of surface roughness with increase in density.

The effect of cooking on surface roughness is shown in figure 5&6 in terms of kappa number and pulp yield. From fig. 5 it could be concluded that the surface roughness increased with increase in a kappa number irrespective of wood species, *Cleistanthus collinus*) being the exception. The presence of shives in less cooked pulps appears to contribute to high surface roughness values.

Restrictions on accesibility of the pulping liquor in high density chips may lead to very considerable loss in polysaccharides in preparing pulps of same kappa numbers The loss of substance will

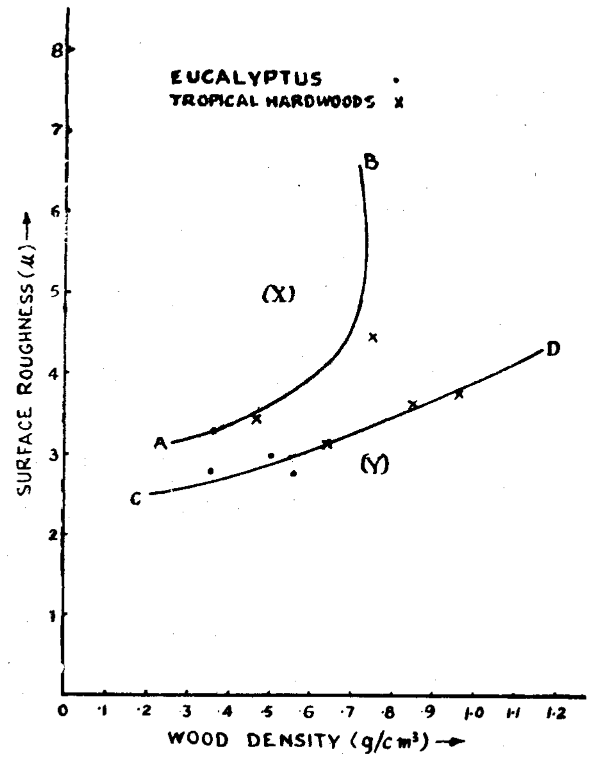

FIG.4 WOOD DENSITY Vs PAPER SURFACE ROUGHNESS AT 250 ml CSF.

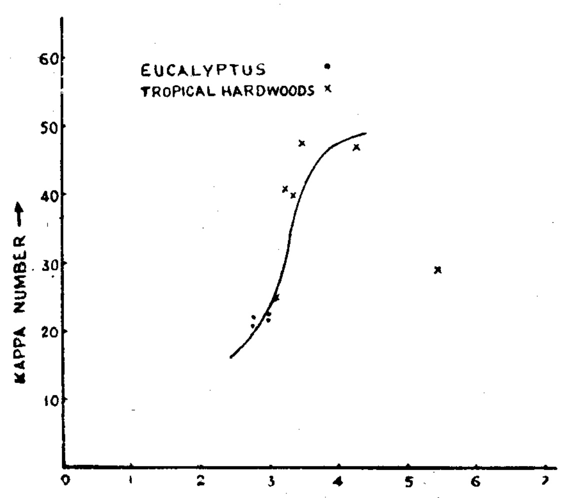

FIG. 5 KAPPA NUMBER Vs SURFACE ROUGHNESS (μ) AT 250 ml CSF.

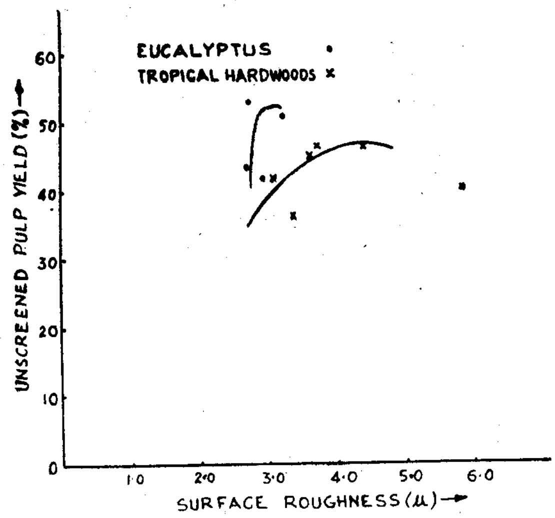

FIG. 6 UNSCREENED PULP YIELD Vs SURFACE ROUGHNESS (μ) AT 250 ml CSF.

lead to weakening of secondary wall and an increase in lateral conformability with a consequent decline in surface roughness. Therefore the comparision had been made for pulps obtained by using constant amount of total active alkali.

CONCLUSSIONS

On the basis of above experimental facts and relationships between wood characteristics derived therefrom, it could be easily concluded that density and fibre characteristics have in general marked influence on pulp (Kappa no. and shives) and paper properties (surface roughness). However the degree of variation between density and the Runkel ratio and shape factor and their influence on surface roughness of paper did not follow same pattern for all the speices investigated. There were clear-cut indications that the rate of increase in paper surface roughness with density for the group (X) of hardwoods comprising of *E. grandis* (14-15 yrs) *Boswelliaserrata*, *Cleistanthus colllnus* and *Xylia xylocarpa* was higher, than that observed for the species of group (Y) comprising of *E. grandis* (18-19 yrs), *E. tereticornis* (5-6 yrs), *E. tereticornis* (14-15 yrs), *Dispyros melanoxylon*, *Anogeissus latifolia* and *Acacia catechu*. This shows that in this particular case the species of group (Y) would produce better pulps for printing papers.