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Study of Relationship of Mechanical Properties of Indian Wood Species with Cutting Forces and Surface Finish in Slot milling using a High Speed 3-axis Vertical CNC Router System

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Abstract: -- Wood is an important natural material and being used for various applications since ages. The larger percentage of the timber wood is used for furniture making as well as a construction material in addition to being used as an engineering material. The wood as an engineering material possess anisotropic properties and some time has random defects. During manual wood machining operations one can take care of anisotropic nature of wood properties as well as the random defects but it is obtained at the cost of a lot of time. The CNC machining of wood can help us save a lot of machining time while simultaneously offer better machining accuracy, but it is desired that the relationship of machining parameters to be selected and the desired machined properties of the wood samples be studied to explore the full potential of using CNC wood machining systems. The wood as an engineering material has several mechanical properties but those mechanical properties which directly influence the machinability of wood are required to be studied.

In this present work the previously published literature has been studied in detail to identify the mechanical properties of wood which affect the machinability of wood. Further a systematic approach has been used to determine the values of these mechanical properties as per standard procedure available from the Bureau of Indian Standards as well as standard published standard procedures. The six Indian wood species are used in the present study and an effort is made to establish a correlation between the mechanical properties of these wood species with the cutting forces observed in slot milling and the surface finish obtained in the bottom of the slotted cut.

It has been observed that the wood grain orientation is a key factor for machinability of wood because different slot milling orientation gives different measurable output of surface finish and cutting forces. Procedures to find out different mechanical properties are discussed and their averaged values are considered for analysis. A high rpm 3-axis vertical CNC router is used in the present study for slot and plunge milling while a force dynamometer is used for recording the magnitude of cutting forces thus produced. A stylus type surface roughness tester was then used to measure surface roughness of various machined samples. The results of different mechanical properties, various cutting forces and surface finish are thus analysed to identify the relationship among them.

Keywords: Wood machining, CNC router, Mechanical properties, Surface finish, Cutting forces

I. INTRODUCTION

Wood is an important construction and engineering material which is being used in ornamental, furniture, building construction and number of applications since ages. There are various grades of wood depending upon their texture, mechanical properties and durability which are identified over a period of time. Many of the applications are done manually so various carpenters and artesian identified wood varieties which shows good machinability. When these woods are identified and these wood varieties are used in abundance. This results in increasing price of these wood varieties and facing some problem like shortage of these wood varieties because more trees are cut than plant. The government sometimes takes actions to defend the forest area where these wood varieties are planted. In this work an attempt is being made to identify wood species which can be used instead of class I wood species and also an attempt is being made to correlate some required mechanical properties of wood species Vis-avis with cutting forces and surface finish.

II . MATERIALS AND METHODS

Procedures Used to Determine Mechanical Properties

Hardness

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Rockwell Hardness testing machine was used to measure the hardness of the samples. For softer material like wood, aluminium the scale B is preferred. Samples measuring 20 mm x 20 mm x 20 mm of various wood varieties were prepared. Sample is appropriately mounted on the machine and load (in kN) is applied at a load rate of 6 mm/min by penetrating the steel ball of diameter 1.128 cm up to a depth of 0.564 cm.

Density

As per ASTM D-143 samples measuring 20mm x 20mm x 20 mm were prepared. It was not possible to prepare exact samples with said dimension but samples were prepared as close as possible. Five readings were taken for each dimensions and after averaged. For dimension accuracy digital caliper was used having least count of 0.01 mm. Density is measured with the help of oven and weighing machine. A digital oven has been used to drive out the moisture content from wood samples and have 0% moisture content. Maximum temperature of oven is 200°C. Then specimens were kept in an oven at a temperature of 103 ± 2°C for 24 hrs to remove its all moisture content. At 0% moisture content weight of each sample was measured. Oven-dry density was calculated using the following formula:

$$Do = {}^{M_o}/_{V_o} \qquad (1)$$

Where Do, M_o and V_o are the oven dried density, weight and volume of samples respectively.

Modulus of Rupture and Modulus of Elasticity

As per the IS: 1708:5-1986 measuring 20mm x 20mm x 300mm as were prepared and tested on Universal testing machine (HUNG Ta Instrument Go., Ltd Make) which is fully computerised machine with servo control and having capacity of 1000 kN.

The load was applied continuously through-out the test with a rate of 1.0 mm.min-1. The wood specimen was placed in horizontally position and load was applied on the center of the specimen. The load was calculated till the specimen broke. The following equations were used to determine values of Modulus of Rupture and Modulus of Elasticity:

$$M.O.R. = \frac{3Pl}{2bh^2} \qquad (2)$$

$$M.O.E. = \frac{Pl^3}{4\Delta bh^3} \qquad (3)$$

Where $\boldsymbol{P}$ = Load (N), $\boldsymbol{l}$ = Effective length (mm), $\boldsymbol{b}$ = Breadth of Specimen (mm), $\boldsymbol{h}$ = Depth of Specimen (mm), $\boldsymbol{\Delta}$= Deflection (mm).

Maximum Crushing Strength

Maximum crushing strength (MCS) is the ability to withstand axial load. For wood there are two types of crushing strength:

The test was performed according to standard IS: 1708:8-1986 for MCS parallel to the grain and IS: 1708:9-1986 for MCS perpendicular to the grain. The size of specimens for parallel to grain was 20mm x 20mm x 80mm and for perpendicular to grain was 20mm x 20mm x 100mm. Rate of loading for both was same that is 0.6 mm per minute.

A UTM was used for this test. In this test specimen was placed vertically between movable and fixed head of machine and load was applied continuously at a load rate 0.6 mm per minute till the fracture occurred.

The load was calculated and following equation was used to determine maximum crushing strength:

$$\sigma = \frac{P}{A} \qquad (4)$$

Where $\boldsymbol{P}$ is Load (N) and $\boldsymbol{A}$ is Cross sectional area of specimen (mm^2)

Grain Orientation of Wood for Machining

Wood grain is longitudinal arrangements of wood fibre. While milling on wood the effect of wood grain direction is important because interaction of the tool with the grains along different directions imposes varying cutting loads and also yields varying levels of surface finish. The following combinations of tool interaction with the wood grain along different direction (as shown in Fig 1) in milling operation have been considered in the present study.

1) Cut along the fibre (With tool axis aligned normal to fibre)

2) Cut across the fibre (With tool axis aligned normal to fibre)

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3) 45° Inclined cut across the fibre (With tool axis aligned normal to fibre)

4) Cut across the fibre (With tool axis aligned parallel to fibre)

5) Plunge (When tool axis aligned normal to fibre)

6) Plunge (When tool axis aligned parallel to fibre)

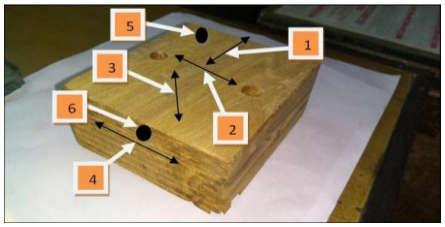

Fig 1:- Slot milling different direction

The following table 1 show the codes which are assigned to different cutting direction. These codes are used for further discussion.

Table 1:- Codes assigned to different cutting direction:

S.No.	Code	Cutting direction
1.	90-0	Cut along the fibre
2.	0-90	Cut across the fibre
3.	0-45	45° Inclined cut across the fibre
4.	90-90	Axial cut

Machine Setup for Milling

Machine setup consists of a CNC wood router, a Kistler make Dynamometer and details of the set up are as under:

Three-Axis Wood Router

For machining a 3-axis wood router with X,Y,Z axis was used. Each axis had motors attached with its each axis for movement

On wood router table a dynamometer was attached to measure cutting forces encountered during in the machining. The machining parameters include feed rate, depth of cut and spindle rpm. The router was connected to a laptop for tool positioning movement commands via a controller. Rated spindle rpm of the router was 35000 rpm. High rpm is generally employed in order to avoid the local burning of wood.

Dynamometer

Dynamometer (KISTLER LTD.) has been used to measure the cutting forces during the operation. There are two types of dynamometer available (i) Stationary dynamometer (ii) Rotating dynamometer. Depending upon nature of machining suitable dynamometer is selected. Stationary is used where the work piece is stationary like milling and rotating is generally used in lathe machine where work piece is rotating. It is attached with an amplifier to the computer to measure the forces. In the present study stationary dynamometer was used in the machining.

Cutting Tool

A high carbide steel flat end mill cutter tool with four cutting edges has been employed in this study.

Machining Parameters

As discussed earlier, wood carving using a milling CNC router has mainly three parameters viz.: feed rate, depth of cut and spindle rpm. Objective of this study is to explore the interaction these parameters with respect to the cutting forces and the resultant surface finish for a variety of class II wood species. Table 2 shows the values of these three parameters that have been used for machining of various wood species in this study:

Table 2:-Parameters for machining of wood species

Type of operation	FEED RATE (mm/min)	DEPTH OF CUT (mm)	SPINDLE SPEED (rpm)
CUT	200	5	33000
PLUNGE (DRILLING)	200	10	33000

The parameters were same for every wood species cut and surface roughness of cutting slot was measured after milling.

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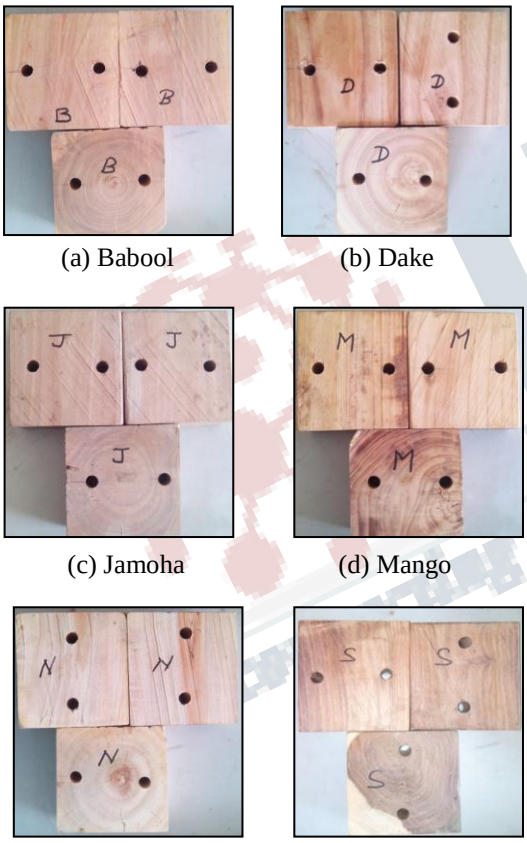
Specimens for Machining

The specimens were mounted on the dynamometer table with the help of bolts. So the specimens had pre drilled holes to receive the bolts to fix the specimen on top of dynamometer. Dynamometer readings were found be sensitive with respective to the position of the work piece on top table. So all the work specimen sized to fit within the top surface of the dynamometer. A Fig 3 shows specimen of different wood species measuring was 95mm x 95mm x 45mm. Even during the machining of different specimens, it was assured that tool position and tool travel remains unaltered with respect to the dynamometer in order to avoid spurious data collection



(a) Babool (b) Dake

(c) Jamoha (d) Mango

(e) Neem (f) Sheesham

Fig 3:- Specimens of different wood species for machining

Procedure of Cut and Plunge

The Fig 4 shows different machining trials capturing different interactions of the tool and wood grains. Fig 4 a, b, c and d show the slot milling operations in which the tool axis is kept normal to the wood grains while the tool travel is along, across and oblique to the wood grains respectively. Similarly Fig 4 (a) also shows a tool plunge operation in which tool axis as well the tool travel is oriented normal to the wood grains leading to plunging of the tool in to the wood for each of these trials dedicated. Tool paths were generated using the relevant G & M codes. The one by one different slot cut was performed on different wood species. Their forces were measured and recorded in computer using software Dynoware.

(a) 90-0 (b) 0-90

(c) 0-45 (d) 90-90

Fig 4:- Machining trials showing different interactions of tool and wood grain (for mango wood)

Surface Roughness

Surface roughness of the machined surface generating by slotting operation was measured by Mitutoyo surface roughness tester Model SJ-400. It has trace length of 8mm. It operates on a contact stylus method in which a tip called stylus moves on surface of the specimen whose surface roughness has to be measured. Each wood species had four different direction slot cut which already discussed earlier. Two readings were taken

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for each slot cut from different places and after averaged value for slot milled.

III. Results and Discussion

Forces Produced In Slot Milling

The forces produced during slot milling and drilling operations in various directions of wood species are shown in Table 3.

Table 3:-Forces produced during slot milling in different direction

Wood species	90-0			Plunge on 90-0					0-90		
	Iteration 1	Iteration 2	Average	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Average	Iteration 1	Iteration 2	Average
Babool	11.2190	10.4071	**10.8130**	8.3471	7.1665	7.9939	8.1546	**7.9155**	8.0890	12.2256	**10.1573**
Dake	12.8904	13.1354	**13.0129**	4.3085	4.3415	3.9425	4.4000	**4.2481**	8.0985	17.9388	**13.0186**
Jamoha	13.0226	10.9758	**11.9992**	5.5000	5.3363	6.1406	5.1175	**5.5236**	14.0561	14.1834	**14.1197**
Mango	11.5078	10.2118	**10.8598**	8.6953	5.7197	5.6134	7.5554	**6.8959**	11.3569	11.3619	**11.3594**
Neem	14.7621	14.4222	**14.5922**	7.4801	7.4268	6.7214	6.6286	**7.0642**	9.0091	11.4122	**10.2106**
Sheesham	14.0154	13.4112	**13.7133**	7.0926	6.5418	6.9937	5.8638	**6.6230**	6.7396	10.3364	**8.5380**

	0-45			90-90			Plunge on 90-90				
	Iteration 1	Iteration 2	Average	Iteration 1	Iteration 2	Average	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Average
	10.3931	13.6431	**12.0181**	8.6888	7.7856	**8.2372**	7.2688	7.5616	6.9642	8.0831	**7.4694**
	11.0673	14.6988	**12.8831**	5.4493	8.7810	**7.1152**	5.4126	5.7353	4.7500	5.6630	**5.3902**
	14.1780	9.3387	**11.7584**	6.8506	7.0075	**6.9290**	6.9808	5.9654	7.7240	6.5329	**6.8008**
	11.0826	10.4356	**10.7591**	8.4383	11.1476	**9.7930**	7.1712	6.4959	8.4858	9.6093	**7.9406**
	10.0973	9.3487	**9.7230**	6.8193	7.1546	**6.9869**	8.5437	9.5848	9.0822	9.7945	**9.2513**
	16.0128	15.0562	**15.5345**	7.4086	8.8328	**8.1207**	6.8095	7.0787	4.7858	9.6254	**7.0749**

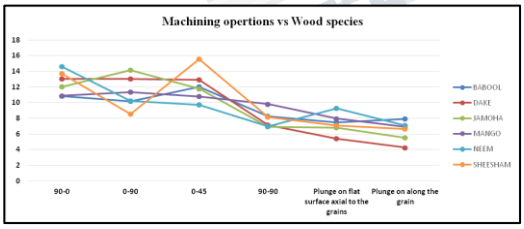

Fig 5:- Trends of different cutting directions with cutting forces

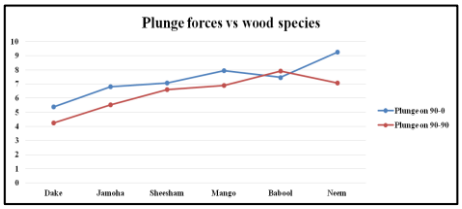

Fig: - 6 Plunge forces in different wood species

In Fig:-5 trends are shown of different cutting directions for different wood species. From graph it can be seen that force trends is continuously decreasing. Maximum forces are occurred in 90-0 direction slot milling and minimum forces are occurred in 90-90 direction slot milling. From Fig:-6 it is observed that during 90-90 direction drilling less force is occurred than 90-0 drilling except babool.

Surface Roughness of Various Wood Species

Surface roughness of slots milled in various directions is shown in tabular form. Surface roughness has three parameters Roughness average (Ra), Mean roughness depth (Rz) and Root mean square average (Rq). These three parameters are measured with Mitutoyo SJ-400 surface roughness tester. Two iterations for each slot were noted and after averaged to get final value.

Table 4:-Surface roughness for various wood species in different slot milling direction

Cutting Direction	Wood Species	Neem			Babool			Sheesham		
	Surface Finish Parameter	Ra	Rz	Rq	Ra	Rz	Rq	Ra	Rz	Rq
90-0	Iteration 1	2.11	13.10	2.67	2.08	14.90	2.74	2.89	14.60	3.62
	Iteration 2	3.20	17.90	4.11	2.30	14.10	2.87	3.21	17.00	4.05
	Mean of Iteration 1 and 2	**2.66**	**15.50**	**3.39**	**2.19**	**14.50**	**2.81**	**3.05**	**15.80**	**3.84**
0-90	Iteration 1	4.04	21.45	4.68	3.97	23.20	4.87	6.51	39.60	8.53
	Iteration 2	3.50	22.95	4.64	4.22	26.10	5.38	4.15	27.05	5.50
	Mean of Iteration 1 and 2	**3.77**	**22.20**	**4.66**	**4.10**	**24.65**	**5.13**	**5.33**	**33.33**	**7.01**
0-45	Iteration 1	4.71	23.00	5.83	3.86	21.40	4.77	3.36	20.62	5.12
	Iteration 2	4.01	19.60	4.74	5.88	30.50	7.38	6.65	40.50	8.44
	Mean of Iteration 1 and 2	**4.36**	**21.30**	**5.28**	**4.87**	**25.95**	**6.08**	**5.00**	**30.56**	**6.78**
90-90	Iteration 1	2.55	15.50	3.29	2.59	16.40	3.40	2.05	15.60	2.92
	Iteration 2	2.38	13.50	2.96	3.50	23.80	4.79	2.57	19.40	3.70
	Mean of Iteration 1 and 2	**2.46**	**14.50**	**3.12**	**3.05**	**20.10**	**4.10**	**2.31**	**17.50**	**3.31**

Jamoha			Dake			Mango		
Ra	Rz	Rq	Ra	Rz	Rq	Ra	Rz	Rq
2.48	15.50	3.16	1.78	9.60	2.18	2.24	14.60	2.81
2.40	13.65	2.97	3.01	20.25	4.00	2.26	13.50	2.78
2.44	**14.58**	**3.06**	**2.39**	**14.93**	**3.09**	**2.25**	**14.05**	**2.80**
5.33	31.90	6.68	3.70	20.25	4.52	10.61	57.80	13.89
4.91	30.00	6.06	4.05	25.05	5.27	4.49	26.30	5.74
5.12	**30.95**	**6.37**	**3.87**	**22.65**	**4.89**	**7.55**	**42.05**	**9.82**
5.55	29.50	6.78	6.11	31.95	7.69	10.50	53.30	13.00
5.75	33.85	7.29	8.64	44.65	10.82	7.51	42.70	9.61
5.65	**31.68**	**7.04**	**7.37**	**38.30**	**9.25**	**9.01**	**48.00**	**11.31**
2.40	14.85	3.05	3.00	21.45	3.59	2.01	16.00	2.87
4.11	26.60	5.56	4.86	35.20	6.75	2.04	13.00	2.58
3.26	**20.73**	**4.31**	**3.93**	**28.33**	**5.17**	**2.03**	**14.50**	**2.73**

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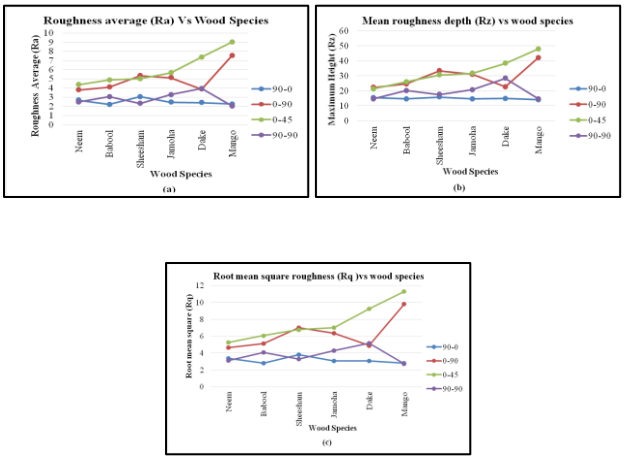

Fig:-7 Comparison of (a) Ra, (b) Rz and (c) Rq values for different directions of six wood species

In Fig:-7 (a,b,c) show comparison of Surface roughness parameter Ra, Rz and Rq with respect to different wood species and different wood grain direction slot milling. It is observed that these wood species have same trend and also it is shown that surface finish is better in slot milling direction 90-0 and 90-90 for wood species. 0-45 slot milling direction is increasing in all the surface roughness parameters. So it is preferable that for better surface finish slot milling should be done on along the grain or axial to the grain of wood species.

In Fig:-8 (a,b,c,d,e,f) individual graphs were plotted for each wood species having values of Ra, Rz and Rq. Graphs show that Rz values are way higher than Ra and Rq values. By comparing in terms of Rz values the result of mango is highest in 0-45 and Neem is lowest in 90-90 slot cutting direction. In slot cutting direction 0-90 and 0-45 Rz values are almost highest in all wood species except Dake. 90-0 and 90-90 both direction has minimum Ra values in all wood species. Ra ,Rz and Rq have same trends and Ra is roughness average which is a main parameter to analyze a surface so this is a reason for choosing only Ra for analysing different slot milled surface in next section.

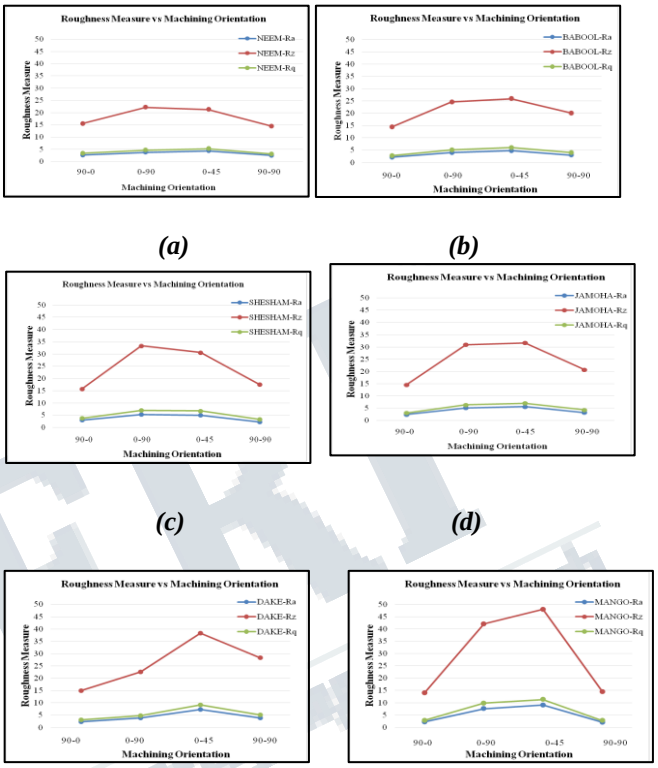

Fig :- 8 Surface roughness average (Ra), Mean roughness depth (Rz) and Root mean square (Rq) for (a) Neem (b) Babool, (c) Sheesham, (d) Jamoha, (e) Dake and (f) Mango

Table 5:- Averaged values of surface roughness for various wood species

Cutting Direction	Wood Species	Sr No.	Babool			Dake			Jamoha			Mango			Neem		
	Surface Finish Parameter		Ra	Rz	Rq	Ra	Rz	Rq	Ra	Rz	Rq	Ra	Rz	Rq	Ra	Rz	Rq
90-0	Mean of Iteration 1 and 2	1	2.19	14.50	2.81	2.39	14.93	3.09	2.44	14.58	3.06	2.25	14.05	2.80	2.66	15.50	3.39
0-90	Mean of Iteration 1 and 2	2	4.10	24.65	5.13	3.87	22.65	4.89	5.12	30.95	6.37	7.55	42.05	9.82	3.77	22.20	4.66
0-45	Mean of Iteration 1 and 2	3	4.87	25.95	6.08	7.37	38.30	9.25	5.65	31.68	7.04	9.01	48.00	11.31	4.36	21.30	5.28
90-90	Mean of Iteration 1 and 2	4	3.05	20.10	4.10	3.93	28.33	5.17	3.26	20.73	4.31	2.03	14.50	2.73	2.46	14.50	3.12

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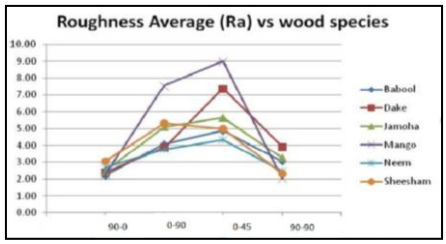

Fig:-9 Surface roughness of different direction slot milled for various wood species

In Fig:-9 trends show for surface roughness of various wood species in different directions. It is observed that trends is same for every wood species and 90-0, 90-90 direction gives better surface finish so in slot milling these directions are best for good surface finish.

Mechanical Properties Correlation

Table 6:-Averaged values for mechanical properties, surface roughness and different wood species

Wood species	Hardness (HRB)		Maximum crushing strength Parallel to grain (Mpa) (P2)	Maximum crushing strength Perpendicular to grain (Mpa) (P2')	Modulus of rupture (Mpa) (P3)	Modulus of elasticity (Mpa) (P4)	Density (Kg/m^3) (P5)
	Along the grain (P1)	Across the grain (P1')					
Mango	55	54	43.5074	8.0364	40.2881	5742.5117	580.1136
Sheesham	49.4	41.8	39.2992	8.9064	84.3994	6824.1811	656.1369
Neem	45.6	50.2	27.6282	5.3190	48.5792	2810.1535	604.3313
Babool	43.6	49.8	36.9796	12.6125	78.1785	8530.3912	609.7452
Jamoha	59.6	53.4	34.5156	7.2663	43.8979	4312.0866	658.9171
Dake	51.6	46.4	24.1877	5.9715	34.0974	4528.2572	509.7641

90-0		0-90		0-45		90-90		Plunge cutting force on the 90-0	Plunge cutting force on 90-90
R1	F1	R2	F2	R3	F3	R4	F4	F5	F6
R_a (µm)	Force (N)	R_a (µm)	Force (N)	R_a (µm)	Force (N)	R_a (µm)	Force (N)	Force (N)	Force (N)
2.25	10.8598	7.55	11.3594	9.01	10.759098	2.03	9.7930	6.8959	7.9406
3.05	13.7133	5.33	8.5380	5.00	15.534472	2.31	8.1207	6.6230	7.0749
2.66	14.5922	3.77	10.2106	4.36	9.72298	2.46	6.9869	7.0642	9.2513
2.19	10.8130	4.10	10.1573	4.87	12.018094	3.05	8.2372	7.9155	7.4694
2.44	11.9992	5.12	14.1197	5.65	11.758353	3.26	6.9290	5.5236	6.8008
2.39	13.0129	3.87	13.0186	7.37	12.883087	3.93	7.1152	4.2481	5.3902

Fig: - 10 Correlation matrix

	R1	F1	R2	F2	R3	F3	R4	F4	F5	F6
P1	-0.11	-0.25	0.55	0.73	0.54	0.00	0.11	0.02	-0.57	-0.38
P1`	-0.73	-0.55	0.36	0.55	0.35	-0.83	-0.09	0.19	0.16	0.34
P2	-0.03	-0.59	0.82	-0.35	0.26	0.17	-0.70	0.83	0.57	0.25
P2`	-0.27	-0.65	0.09	-0.39	-0.18	0.30	-0.11	0.46	0.62	-0.02
P3	0.44	0.01	-0.12	-0.78	-0.60	0.58	-0.32	0.17	0.62	0.15
P4	-0.16	-0.60	0.18	-0.44	-0.03	0.49	-0.11	0.55	0.48	-0.19
P5	0.45	0.04	0.16	-0.28	-0.57	0.21	-0.45	-0.04	0.46	0.36

CORRELATION VALUES LESS THAN -0.5 (NEGATIVE CORRELATION)

CORRELATION VALUES MORE THAN 0.5 (POSITIVE CORRELATION)

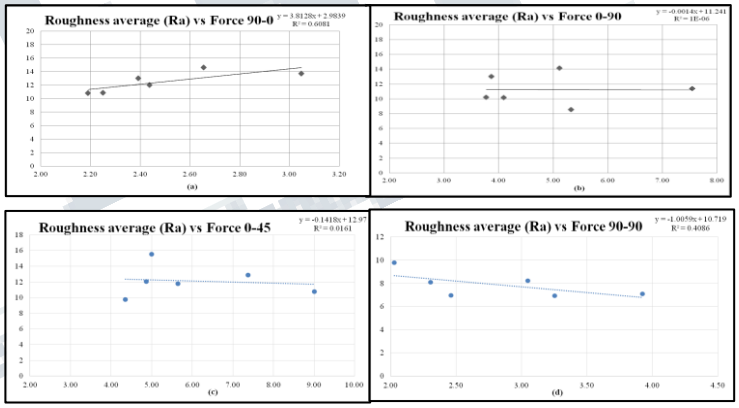

Fig :- 11 (a) Surface roughness vs. force in direction 90-0, (b) Surface roughness vs. force in direction 0-90, (c) Surface roughness vs. force in direction 0-45, (d) Surface roughness vs. force in direction 90-90

In correlation matrix mechanical properties denoted as P, Surface roughness as R and machining forces as F. It is observed form correlation matrix that maximum correlation is found between Maximum crushing strength (Parallel to grain) and Surface roughness in 0-90 (Across the grain) that is 0.82 and with forces in 90-90 (Axial to the grain) that is 0.83. Hardness has a good correlation with surface roughness in direction of 0-90 and 0-45 that is 0.55 and 0.54 respectively.

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Fig:-11(a) to Fig:-11(d) shows linear regression of different direction slot milled surface roughness between their forces. The maximum linear regression coefficient (R2 = 0.60) was found between surface roughness and forces in 90-0 direction. Earlier it was already found that minimum forces and good surface finish is in 90-90 direction so for further analyses surface roughness (Ra) and forces only in 90-90 direction is considered. In further analyses regression coefficient is found between mechanical properties with surface roughness and forces in 90-90 direction.

Analysis of Mechanical Properties Viz A Viz Cutting Forces and Surface Finish for 90-90 Slot Milling Direction

Regression coefficient for different mechanical properties with surface roughness and forces in 90-90 direction is analysed. It observed that maximum regression coefficient is found in surface roughness with maximum crushing strength (Parallel to grain) that is R^2=0.49, with density R^2=0.20 and with modulus of rupture R^2=0.10.

CONCLUSION

Maximum crushing strength (Parallel to grain) has maximum correlation with surface roughness in 90-0 direction of wood species. Maximum regression coefficient was found in maximum crushing strength (Parallel to grain). Maximum forces are produced while slot milling in 90-0 direction and minimum forces are produced while slot milling in 90-90 direction of wood species. Forces produced in case of plunge (drilling) in 90-0 direction are more than 90-90 direction. Better surface finish was found in the 90-0 and 90-90 slot milling directions than 0-90 and 0-45 of wood species so it is preferable to milled on 90-0 and 90-90 directions to achieve better surface finish.

REFERENCES

[1] Aknouche, H., Outahyon, Nouveau, C., Marchal, R., Zerizer, a., & Butaud, J. C. (2009). Tool wear effect on cutting forces: In routing process of Aleppo pine wood. Journal of Materials Processing Technology, 209(6), 2918–2922.

[2] Akyildiz M. Hakan and Kol Hamiyet Sahin (2010). Some technological properties and uses of paulownia (Paulownia tomentosa Steud.) wood. Journal of Environmental Biology, 31, 351-355.

[3] Aslan, S., Coşkun, H., & Kılıç, M. (2008). The effect of the cutting direction, number of blades and grain size of the abrasives on surface roughness of Taurus cedar (Cedrus Libani A. Rich.) woods. Building and Environment, 43(5), 696–701.

[4] Bansal Vikrant, Duvedi R.k, Sharma Sandeep (2013). Thesis report: Ranking of wood species for automated ornamental carving on CNC router using MADM approach.

[5] Barbosa, R. I., & Fearnside, P. M. (2004). Wood density of trees in open savannas of the Brazilian Amazon. Forest Ecology and Management, 199(1), 115–123.

[6] Carrillo Artemio, Garza Miriam, Nañez María de Jesús, Garza Fortunato, Foroughbakhch Rahim, Sandoval Sadoth (2011). Physical and mechanical wood properties of 14 timber species from Northeast Mexico. Annals of Forest Science, 68, 675–679.

[7] Chomsamutr, K., & Jongprasithporn, S. (2010). The cutting parameters design for product quality improvement in turning operations: Optimization and validation with Taguchi method. Computers and Industrial Engineering (CIE), 2010 40th International Conference.

[8] Cristóvão, L., Lhate, I., Grönlund, A., Ekevad, M., & Sitoe, R. (2011). Tool wear for lesser known tropical wood species. Wood Material Science and Engineering, 6(3), 155–161.

[9] Davim, J. P. (2001). A note on the determination of optimal cutting conditions for surface finish obtained in turning using design of experiments. Journal of Materials Processing Technology, 116, 3–6.