Innovative Systems Design and Engineering www.iiste.org
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.6, No.4, 2015

Plank Shootback from Table Saws – Its Causes and Effects

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Abstract
Plank shoot – back is an undesirable phenomenon that occurs in the sawing of planks with table saws. This paper shows the results of an study of the phenomenon to establish its causes, frequency of occurrence, and its consequences. A theoretical energy analysis of the phenomenon was used to explain the results obtained from interviews with table – saw operators.

1. INTRODUCTION

Plank shoot – back is the backward movement of a piece of plank being sawn on a table – saw. The effect of plank shoot – back on the operator of a table – saw could be disastrous; it could cause serious injuries on the operator and in very severe cases, it cause his death.

The table – saw is the most widely used sawing machine in Nigeria due mainly to its relatively low cost. This machine constitutes a very large percentage of sawing machines used in the local saw mills. This means that the lives of a very large percentage of table - saw machine operators are in danger due to plank shoot – back. Thus it became necessary to investigate the shoot – back phenomenon in order to determine its causes, frequency of occurrence, and the degree of injuries it can cause an operator and to suggest ways of reducing and or containing it. A table – saw system and its accessories are shown in the schematic drawing in fig. 1. In order to obtain the necessary field information, several sawmills in Port Harcourt Nigeria were visited and sawmill operators were interviewed.

2.0 FIELD WORK

2.1 Site Visitation

Three main locations with sizeable number of sawmills were visited. These sites were visited in order to

(i) Study the operation of the table – saw,
(ii) Interview operators in order to establish the occurrence of plank shoot – back, its causes and effects on the operators: and
(iii) Take measurements of necessary saw and plank parameters.

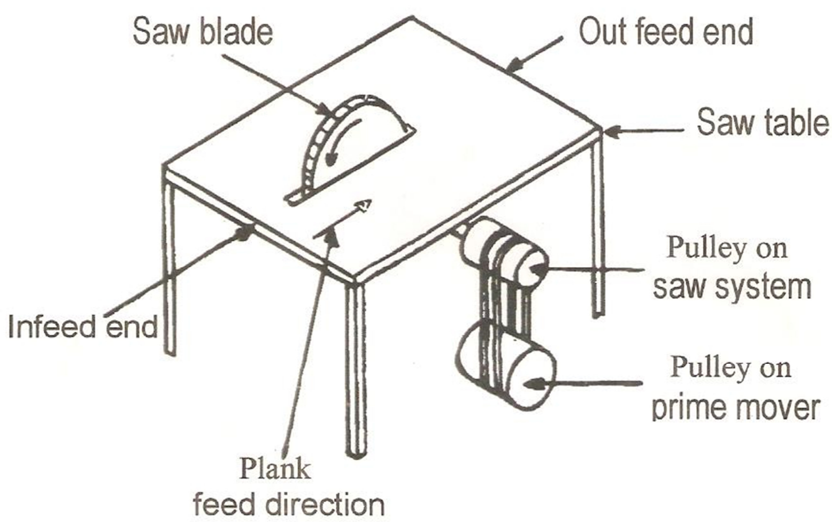

Fig. 1: Schematic diagram of table and saw system.

2.2 Interview Results

A total of eight (8) table – saw operators were interviewed at different times. All the operators unanimously described the causes of plank shoot – back as

(i) Shoot – back occurs if a small piece of the plank flakes off and falls back on the teeth of the rotating blade.

(ii) Shoot – back occurs if the operator's assistant at the out - feed end of the table mistakenly raises his end and lowers the in – feed side of the plank to contact the teeth of the rotating blade while pulling it through the table – saw.

The frequency of occurrence and the degree of injuries plank shoot – back has inflicted on operators or bystanders as obtained from the interview are as shown in table 1.

2.3 Parameter Measurements

The table saw system consists of the saw blade, a shaft and a pulley (see .fig. 2).

TABLE 1: RESULTS OF INTERVIEW WITH TABLE SAW OPERATORS

Location	Operator	Years of Experience	Frequency of Shoot Back Seen or Experienced	Number of Injuries	
				Serious	Death
I	1st	10	10	5	0
II	1st	6	3	3	0
	2nd	1	0	0	0
	3rd	7	3	3	0
III	1st	12	4	3	0
	2nd	8	10	2	0
	3rd	6	1	0	1
	4th	5	0	0	0

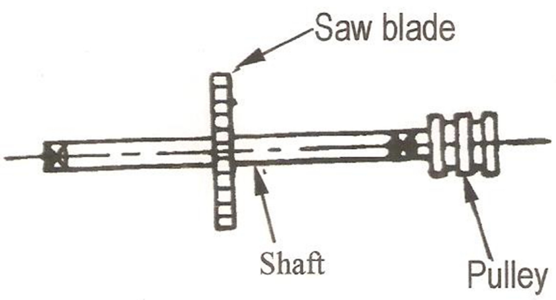

Fig. 2: Schematic diagram of saw-system.

In order to calculate the power available in the saw system for the sawing opration, the necessary parameters for the saw blade, the shft and the pulley were measured and shown in tale 2. The actual speeds of the saws were also measured with with a portable electronic tachometer without load.

Table 2: TABLE SAW SYSTEM PARAMETERS

Prime Mover	Cutting Speed (rpm)	Saw Dia. (m)	Saw Thickness (m)	Shaft Dia. (m)	Shaft Length (m)	Pulley Dia. (m)	Pulley Length (m)	Calculated System Moment of Inertia (kgm^2)
Lister Diesel Engine	900	0.45	0.003	0.035	0.65	0.20	0.095	0.194
Hatz Diesel Engine	6200	0.35	0.003	0.038	0.55	0.14	0.062	0.0487
Ruston Diesel Engine	850	0.56	0.003	0.034	0.57	0.18	0.057	0.248
Electric Motor (15KW)	1900	0.54	0.003	0.032	0.46	0.145	0.047	0.194
Electric Motor (18.5KW)	2000	0.41	0.003	0.032	0.653	0.14	0.061	0.0734
Electric Motor (15KW)	1250	0.59	0.003	0.032	0.65	0.145	0.042	0.269
Electric Motor (20KW)	1950	0.51	0.003	0.035	0.63	0.152	0.048	0.161
Electric Motor (18.5KW)	1375	0.46	0.003	0.031	0.55	0.14	0.048	0.107

3.0 THEORETICAL ANALYSIS OF SAW – PLANK SYSTEM

3.1 The Saw - Plank Syatem

The system consists of the saw blade, shaft and pulley (see figure 2) and the piece of plank in being shot back. During the process of cutting, power is constantly transmitted to the saw system by the prime mover through a belt connected to the pulley. This power is either expended in cutting the plank or is transmitted to the piece of plank during the contact. The piece of plaknk is therefore either sawn or it acquires kinetic energy and moves with a high veocity in the case of small pieces.

3.2 Kinetic Energy of The Saw – System

The total kinetic energy possessed by the saw – system is expressed as [1],

$$KE_s = \frac{1}{2} I\omega^2 \quad \text{.........(1)}$$

$$\text{where } KE_s = \text{kinetic enrgy of the saw - system and}$$
$$\omega = \text{the anguler velocity of the saw - system.}$$

The mass moment of inertia of the saw system is

$$I = I_{blade} + I_{shaft} + I_{pulley}$$

$$\text{where } I_{blade} = \text{the mass moment of inertia of the saw blade,}$$
$$I_{shaft} = \text{the mass moment of inertia of the shaft and}$$
$$I_{pulley} = \text{the mass moment of inertia of the pulley.}$$

The constant power transmitted to the saw – system over atime interval Δt can be expressed as

$$P = \frac{KE_s}{\Delta t} = \frac{I\omega^2}{\Delta t} \quad \text{.........(2)}$$

Since this power is transmitted to the saw – system through the pulley in form of a torque, it can also be expressed as [2],

$$P = T\omega \quad \text{...(3)}$$

where T is the torque applied to the pulley.

3.3 Impact Forces

During the impact, the saw blade exerts a force of magnitude F on the piece of plank being shot – back and the piece of plank in turn exerts a reaction force F_R equal and opposite to F on the saw blade (Fig. 3). The constant torque T supplied by the prime mover during the short time interval must therefore be equal to

$$T = F_R R \quad \text{...(4)}$$

Substituting for Eq. 4 into Eq. 3 yields

$$P = F_R R\omega \quad \text{...(5)}$$

Thus equating the right hand sides of Eq. (2) and Eq. (5) gives,

Or $$\frac{I\omega^2}{2\Delta t} = F_R R\omega \quad \text{...(6)}$$

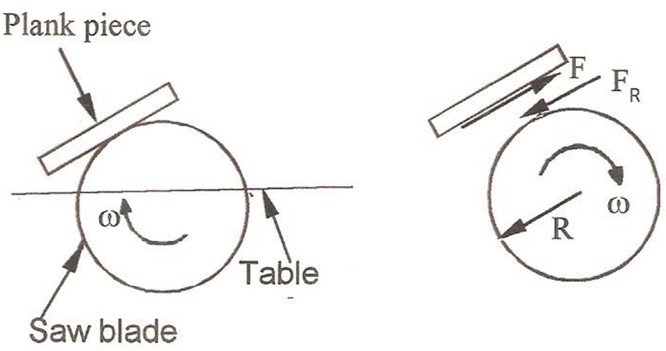

Fig. 3: Interaction between saw blade and piece of plank.

or $$F_R = \frac{I\omega}{2R\Delta t} \quad \text{...(7)}$$

and consequently, the magnitude of the force F on the piece of plank is,

$$F = \frac{I\omega}{2R\Delta t} \quad \text{...(8)}$$

3.4 Kinetic Energy of the Plank

It was assumed that for the small piece of plank, the initial velocity V_1 with which it contacts the saw blade is small (negligible) compared to the resulting velocity after the impact. Thus $V_1 = 0$.

Applying the principle of impulse and momentum which states that impulse on a body is equal to its change in momentum, to the plank gives,

$$\int_{t_1}^{t_2} F dt = M(V_2 - V_1)$$

$$\text{or } F[t_2 - t_1] = F\Delta t = MV_2 \quad \text{.....................................(9)}$$

where M = the mass of the piece of plank and

V_2 = the plank's velocity afterimpact.

Substituting for Eq.(8) into Eq. (9) gives,

$$\frac{I\omega\Delta t}{2R\Delta t} = MV_2$$

$$or \quad V_2 = \frac{I\omega}{2MR} \quad \text{..(10)}$$

The kinetic energy of the piece of plank as it leaves the saw blade is expressed as,

$$KE_P = \frac{1}{2}MV_2^{\ 2} \quad \text{.......... ....(11)}$$

Substituting for V_2 in Eq. (11) gives,

$$KE_P = \frac{1}{2}M\left(\frac{I\omega}{2MR}\right)^2 \quad \text{..............................(12)}$$

$$or\ KE_P = \frac{I^2\omega^2}{8MR^2} \quad \text{...................................(13)}$$

Thus Eq.(13) expresses the kinetic energy of the piece of plank as it leaves the saw blade. In this equation, rotational kinetic energy is neglected because the rotational speeds of the plank pieces were observed to be small compared to the linear velocities. Air resistance would normally reduce this energy as the piece of plank flies away from the saw – blade. However, if the piece of plank strikes the operator or bystander in close vicinity of the saw table, the reduction in the kinetic energy is assumed negligible and hence equation (13) can be used to predict the energy with which the piece of plank strikes the operator or bystander.

In order to make a numerical study of this energy with which a piece of plank is likely to strike an operator or bystander, the densities of six commonly sawn woods were obtained as shown in appendix 1. Three types of wood, AKAMA, ABURA (Stipulosa mitragyna), and IROKO (Excelsia milicia) [3] were then chosen for the study. From each of these woods, three different sizes in the neighborhood of the size that killed a man by piercing through him were cut into rectangular shapes and their masses calculated as shown in table 3.

TABLE 3: PLANK SIZES AND THEIR MASSES

Type of Wood	Sizes and Masses		
	52x2,8x2.7 M1 (kg)	**32.3x3.1x2.6 M2 (kg)**	**15.8x2,7x2.6 M3 (kg)**
AKAMA	0.163	0.103	0.046
ABURA (Stipulosa mitragyna)	0.204	0.129	0.057
IROKO (Excelsia milicia)	0.312	0.197	0.087

Three saw systems and their speeds were also chosen from table 2 in order to complete the study as shown in the tables 4,5and 6.

TABLE 4: KINETIC ENERGY FOR AKAMA WOOD

Prime Mover	Cutting Speed (rps)[1]	System moment of Inertia ($kg.m^2$)	Blade Radius (m)	Kinetic Energy of Plank Pieces		
				M1 (KJ)	**M2 (KJ)**	**M3 (KJ)**
Ruston Diesel Engine (850rpm)	89.01	0.248	0.280	4.766	7.543	16.889
Electric Motor (2000rpm)	209.44	0.0734	0.203	4.398	6.960	15.584
Hatz Diesel Engine (6200rpm)	649.26	0.0487	0.175	25.035	39.618	88.710

1 Rps means radians per second.

TABLE 5: KINETIC ENERGY FOR ABURA (Stipulosa mitragyna) **WOOD**

Prime Mover	**Cutting Speed (rps)[1]**	**System moment of Inertia (kg.m^2)**	**Blade Radius (m)**	**Kinetic Energy of Plank Pieces**		
				M1 (KJ)	**M2 (KJ)**	**M3 (KJ)**
Ruston Diesel Engine (850rpm)	89.01	0.248	0.280	3.808	6.023	13.630
Electric Motor (2000rpm)	209.44	0.0734	0.203	3.514	5.557	12.576
Hatz Diesel Engine (6200rpm)	649.26	0.0487	0.175	20.003	31.633	71.590

TABLE 6: KINETIC ENERGY FOR IROKO (Excelsia milicia) **WOOD**

Prime Mover	**Cutting Speed (rps)[1]**	**System moment of Inertia (kg.m^2)**	**Blade Radius (m)**	**Kinetic Energy of Plank Pieces**		
				M1 (KJ)	**M2 (KJ)**	**M3 (KJ)**
Ruston Diesel Engine (850rpm)	89.01	0.248	0.280	2.490	3.944	8.930
Electric Motor (2000rpm)	209.44	0.0734	0.203	2.298	3.639	8.240
Hatz Diesel Engine (6200rpm)	649.26	0.0487	0.175	13.079	20.714	46.904

For completeness of the study, eight (8) standard sizes of plank were analyzed for each of the three types of wood, Akama, Abura and Iroko. The masses of the standard planks were calculated from their respective densities as obtained from the measurements of the sizes and masses of the pieces of plank (see appendix). The results of this analysis are shown in tables 7, 8 and 9. Since for each mass in tables 4,5 and 6, the saw system with the Hatz Diesel engine as prime mover produced the highest kinetic energy, only that system was used for this analysis

TABLE 7 KINETIC ENERGY OF STANDARD PLANK SIZES FOR AKAMA

Standard Metric Plank Sizes (mm)	**Mass (kg)**	**Kinetic Energy (J)**
50x50x3600	387.7	10.52
50x100x3600	776.23	5.26
75x75x3600	873.26	4.67
75x100x3600	1164.35	3.50
75x150x3600	1746.52	2.34
100x100x3600	1552.46	2.63
25x300x3600	1164.35	3.50
6.35X50X3600	48.51	84.12

TABLE 8: KINETIC ENERGY OF STANDARD PLANK SIZES FOR ABURA (Stipulosa mitragyna)

Standard Metric Plank Sizes (mm)	**Mass (kg)**	**Kinetic Energy (J)**
50x50x3600	477.38	8.55
50x100x3600	1090.27	3.74
75x75x3600	1453.69	2.81
75x100x3600	1938.26	2.10
75x150x3600	969.13	4.21
100x100x3600	2180.54	1.87
25x300x3600	1453.69	2.81
6.35X50X3600	60.57	67.37

TABLE 9 KINETIC ENERGY OF STANDARD PLANK SIZES FOR IROKO (Excelsia milicia)

Standard Metric Plank Sizes (mm)	Mass (kg)	Kinetic Energy (J)
50x50x3600	741.99	5.50
50x100x3600	1671.25	2.44
75x75x3600	2228.33	1.83
75x100x3600	2971.11	1.37
75x150x3600	1485.55	2.75
100x100x3600	3342.50	1.22
25x300x3600	2228.33	1.83
6.35X50X3600	92.85	43.95

4.0 DISCUSSION OF RESULTS

The results of the energy analysis of plank pieces are shown in tables 4,5,6,7,8 and 9. As indicated in equation (10), the kinetic energy of plank pieces increased with speed of the saw system and decreased with increase in their masses. The kinetic energies as seen in tables 4,5,and 6 are in the order of several kilojoules. These energies are dissipated as the plank pieces are brought to rest when they hit an operator or bystander. Although the plank pieces used for the study have blunt ends, actual pieces of plank usually have pointed ends and sharp edges. Thus if a pieces of plank having such high energies hit a human being, it can cause serious injuries which in some cases can cause death.

The general consequences would be either or a combination of

(i) The infliction of major injury on the human victim.
(ii) The maiming of the victim.
(iii) The death of the victim.

The kinetic energies of standard plank sizes are shown in tables 7,8 and 9 are generally small and would therefore not cause serious injuries if they hit the operator. Secondly, the operators in most cases have enough time to dodge the planks as their speeds are slow.

5.0 CONCLUSION

From the results of both the interview and theoretical analysis, the following conclusions were be made.

(i) Plank shoot – back from table saws is a phenomenon that actually occurs in the plank industry. Its causes and the effects have been established. If a piece of plank flakes off from the main piece and comes in contact with the rotating blade it acquires kinetic energy and is ejected with high velocity. Even the main piece of plank if handled inappropriately and it comes of the saw blade and later comes in contact it can acquire some kinetic energy and move backward towards the operator.
(ii) From the energy analysis, it was observed that small pieces of plank (as shown in tables 4,5 and6) travel with high kinetic energies as they leave the saw blade and can cause serious injuries.
(iii) Standard plank sizes and heavy pieces of plank do not travel with high kinetic energies and hence their velocities are low and therefore may not cause severe injuries but can knock an operator and cause swellings.
(iv) It is very necessary to provide appropriate safety devices to protect the operator and bystanders.

6.0 REFERENCES

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ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.6, No.4, 2015

APPENDIX
DENSITY OF VARIOUS WOODS

Types of Wood	***Mass (Kg)**	**Length (m)**	**Width (m)**	**Thickness (m)**	**Density (Kgm^{-3})**
AKAMA	0.020	0.069	0.047	0.015	411.14
ABURA (Stipulosa mitragyna)	0.052	0.0134	0.028	0.027	513.31
ACHIGUM	0.056	0.323	0.044	0.007	562.91
ACHIPUTAUGO	0.018	0.062	0.045	0.011	586.51
MAHOGANY (Swietinia macrophyla)	0.023	0.0163	0.040	0.005	705.52
IROKO (Excelsia milicia)	0.0565	0.0223	0.046	0.007	786.84

The various masses were obtained by weighing the pieces of wood on a scale. The names of three of the woods are in Igbo (a Nigerian language) because their botanical names could not be ascertained. However, the names do not have any effect on the objectives and results of the study.

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