

Design and Manufacture of Plank Shoot – Back Containment Structure

Dienagha, A.R.S[1] Naenwi[2] Yiinu, Opuene – Amalagha, Patience[3]
1.Department of Mechanical Engineering,Niger Delta University,Amassoma, Bayelsa State, Nigeria
2.Federal Ministry of Labor, Abuja, Nigeria
3.Nembe Local Government Area Council, Nembe City, Bayelsa State, Nigeria

Abstract
When the causes and effects of the plank shoot – back phenomenon were established, the need for a safety device was also established. A plank shoot – back containment structure has therefore been designed, manufactured and tested. The results of the test have shown that the structure can trap about one hundred percent (100%) of plank pieces that shoot out from the saw blade before they can harm operators or by standers. Table saw operators have accepted the structure as a good safety device they can use with their saw mills.
Keywords: Plank, Shoot –Back, Containment, Structure.

1.0 INTRODUCTION:

The plank shoot – back phenomenon has been described as the undesirable backward movement of a piece of plank from a table saw, [1]. The causes of plank shoot – back have been established 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 or any time any part of the plank being sawn is raised above and then lowered on to the rotating saw blade.

The effects or general consequences of plank shoot – back were found to 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.

It was also found that the table – saw is the most widely used sawing machine in Nigeria due to its relatively low cost. This machine constitutes about two – thirds of plank sawing machines used in the local saw – mills. Band saw accounts for the one third of the sawing machines. This implies that due to plank shoot – back, the lives of about two – thirds of saw machine operators and bystanders are in danger. [1] In the conclusion of his plank shoot – back analysis, Dienagha recommended the provision of an appropriate safety device to protect saw operators and bystanders. Thus it became necessary to design, manufacture and test a plank shoot – back containment structure.

2.0 DESIGN OF THE CONTAINMENT STRUCTURE:

2.1 SPECIFIC DESIGN OBJECTIVES:

The specific objectives to be satisfied by the design are,

(i) The structure must be able to trap all the pieces of plank flying out from the saw blade before they can come in contact with the operator or by – stander,

(ii) The structure must not obstruct the smooth sawing operations and,

(iii) The structure must not constitute another source of injuries to people.

2.2 SHOOT – BACK TRAJECTORY:

In order to design a structure that will trap all pieces of plank that shoot – back or fly out from the saw blade, a theoretical study of the trajectory of some plank pieces was made.

As shown in Fig. 1, as the piece of plank leaves the saw blade, it has a velocity V_0 in the direction that makes an angle of θ with the horizontal.

The initial velocity V_0 is given by the equation, [1]

$$V_0 = V = \frac{I\omega}{2MR} \quad \text{......(1)}$$

where I is the mass moment of inertia of the saw system,
ω is the angular speed of the saw system (cutting speed),
M is the mass of the plank piece and
R is the radius of the saw blade

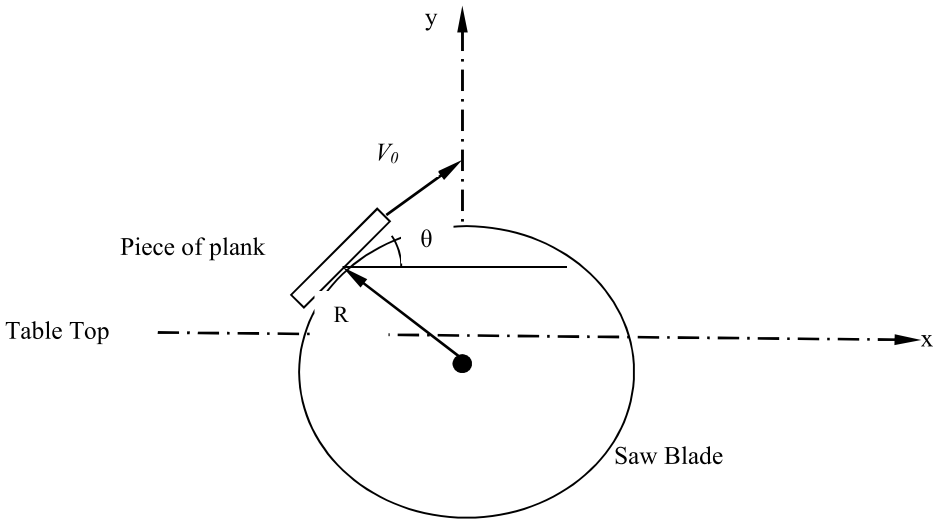

Fig. 1: PIECE OF PLANK IN CONTACT WITH SAW BLADE

Thus its velocity component in the horizontal direction is [2]

$$(V_x)_0 = V_0 \cos\theta \quad \text{......(2)}$$

and its component in the vertical direction is,

$$(V_y)_0 = V_0 \sin\theta \quad \text{......(3)}$$

The initial projectile angle θ was chosen to be 45^0 because it is known to produce the longest range of any projectile. In the vertical direction, the velocity at any time t is given by the equation [2]

$$V_y = (V_y)_0 - gt \quad \text{......(4)}$$

where g is the acceleration due to gravity equal to $9.81m^{-2}$

When the piece of plank attains the highest possible position, its vertical velocity becomes zero and therefore,

$$t = \frac{(V_y)_0}{g} = \frac{V_0 \sin\theta}{g} = \frac{I\omega \sin 45^0}{2MRg} \quad \text{......(5)}$$

Substituting for g into Eq. 5 yields,

$$t = \frac{0.036 I\omega}{MR} \quad \text{......(6)}$$

The distances moved by the piece of plank after the impact with the saw blade in the x and y directions at any time t are, [2]

$$X = X_0 + (Vx)_0 t \quad \text{.........(7)}$$

and

$$Y = Y_0 + (V_y)_0 t - \frac{1}{2} g t^2 \quad \text{.........(8)}$$

where X_0 *is the initial position coordinate of the plank piece in the x direction,*
t is the time taken for the plank piece to travel,
Y_0 *is the initial position coordinate of the plank piece in the y direction,*
g is the acceleration due to gravity.

With the 45^0 angular orientation of the piece of plank,

$$X_0 = -R\cos 45^0 = -0.7071R \quad \text{.........(9)}$$

and $$Y_0 = 0.7071R \quad \text{.........(10)}$$

TABLE. 1: SAW SYSTEM WITH PRIME MOVER COMBINATION

S/#	Prime Mover	Saw Blade Radius (m)	System Angular Speed ω (rs^{-1})	System Mass Moment of Inertia (Kgm^2)
1.	Hatz Diesel Engine (6200rpm)	0.175	649.26	0.0487
2.	Ruston Diesel Engine (850rpm)	0.28	89.01	0.248
3.	Electric Motor (18.5KW – 2000rpm)	0.205	209.44	0.0734

To complete the trajectory analysis, three saw systems and their parameters where chosen from the work of Dienagha [1]. They are the systems with Hatz diesel engine, Ruston diesel engine and Electric motor (18.5KW – 2000rpm) (table 1). Three types of wood, AKAMA, ABURA (Stipulosa mitragyna), IROKO (Excelsia milicia) (table 2) [3] were also chosen. Then each saw system in combination with the three types of wood was used to determine the possible maximum heights Y_{max} and corresponding horizontal distances X attained by the pieces of wood. Equations 1,2,3,6, 9 and 10 were appropriately substituted with numerical values into equations 7 and 8 to calculate the values of Y_{max} and X as shown in table 3.

TABLE 2: PLANK PIECES AND THEIR MASSES

S/#	Type of Wood	Mass (Kg)
1.	AKAMA	0.046
2.	ABURA (*Stipulosa mitragyna*)	0.057
3.	IROKO (*Excelsia melicia*)	0.087

An observation of the last three columns of table 3 shows that the initial speeds of the plank pieces are high and consequently the maximum height Y_{max} and the corresponding horizontal distances X are very large. However, it was practically observed that the pieces of plank that shot back did not go far. This was due to the high wind resistance which is a function of the cube of the high speeds. Some of the plank pieces were seen to sway to the sides after leaving the saw blade depending on their orientation during contact with the saw blade. These pieces are the ones that can strike and injure a by stander and must be contained by the design.

TABLE 3: MAXIMUM HEIGHT AND CORRESPONDING HORIZONTAL DISTANCE OF THE TRAJECTORY

S/#	Prime Mover	Type of Wood	Initial velocity V_0 (ms^{-1})	X (ms^{-1})	Y_{max} (m)
		AKAMA	1,963.91	196,296.52	98,291.39
	Hatz Diesel Engine (6200rpm)	ABURA (*Stipulosa mitragyna*)	1,584.91	127,885.77	64,011.96
		IROKO (*Excelsia melicia*)	1,038.40	54,895.54	27,478.53
		AKAMA	856.93	37,385.71	18713.60
	Ruston Diesel Engine (850rpm)	ABURA (*Stipulosa mitragyna*)	691.56	24348.22	12187.90
		IROKO (*Excelsia melicia*)	453.09	12989.59	7769.99
		AKAMA	815.11	33825.30	16931.61
	Electric Motor (18.5KW – 2000rpm)	ABURA (*Stipulosa mitragyna*)	657.80	22029.33	11026.95
		IROKO (*Excelsia melicia*)	430.96	9455.75	4733.14

2.2 THE CONTAINMENT STRUCTURE

The structure designed to contain all the flying pieces of plank is made up of four (4) screens – a back screen, two (2) side screens and a bottom screen (see appendix). Each screen is framed with 2cm galvanized iron pipe, a 0.5cm galvanized wire mess laid over the frame, a 2cm galvanized iron strap (aluminum strap could be used) placed on the wire mess over the frame and these are held together with aluminum rivets. As seen in the appendix, the back screen is held vertical while the side screens are welded to it at angles of 30^0. The bottom screen is also welded to the bottom of the back screen at an incline angle of 52^0. Two 2mm galvanized anchor pipes are bolted to the top member of the back screen and their other ends are to be bolted to the cross beam of the roof trusses. Two bolt holes are provided on each pipe.[4]

3.0 MANUFACTURE OF THE STRUCTURE

All the materials were purchased from the local markets and gathered in the mechanical engineering workshop. The parts were then prepared. Thereafter, each screen was assembled. Next the side screens were welded to the back screen at 30^0 to the back screen. Finally, the bottom screen was welded to the back screen at the 52^0 angle. The anchor pipes were not assembled in the workshop but at the saw mill as they would have created transportation challenges.

4.0 INSTALLATION AND TESTING

The plank shoot – back containment structure was taken to one of the plank centers in Port Harcourt where there were a reasonable number of saw mills for testing. It was installed over a pre – arranged saw mill. [5]

The operator of the saw mill then cut some wood and it was observed that all the sawdust and small pieces of plank that came out from the saw blade were trapped by the containment structure. In order to confirm the observation, several pieces of plank close to the sizes that were used for the previous simulations were thrown on the saw blade and they were all trapped by the structure. Figure 2 shows three pictures from some photographs that were taken immediately after the tests.

FIG. 2: PHOTOGRAPHS OF PLANK SHOOT – BACK CONTAINMENT STRUCTURE WITH TRAPPED WOO PARTICLES.

4.2 ACCEPTANCE TEST

After the physical test, a number of other table - saw operators in the plank center gathered to appreciate the structure. Then the operators were interviewed to show whether they would like to use the structure for the purpose of safety, number of plank shoot – back cases each operator had seen or experienced, and the degree of injuries each operator had seen. All the operators interviewed were exited and accepted to have one for their table – saws.

Table 4 shows the result of the interviews.

TABLE 4:TABLE – SAW OPERATORS INTERVIEW RESPONSES.

OPERATORS	YEARS OF EXPERINCE	FREQUENCY OF SHOOT – BACK SEEN OR EXPERIENCED	NUMBER OF SERIOUS INJURIES	DEATH	ACCEPT
1.	12	7	4	1	Yes
2.	4	1	1	0	Yes
3.	4	3	3	0	Yes
4.	3	2	2	0	Yes
5.	6	3	3	0	Yes
6.	2	1	1	0	Yes
7.	14	8	5	2	Yes
8.	8	3	2	0	Yes
9.	5	2	1	1	Yes
10.	3	1	1	0	Yes

5.0 CONCLUSION

It was established that plank shoot – back from table saws causes serious injuries and in some cases the death of the victims. the protective device – plank shoot – back containment structure was designed. This protective structure has been manufactured and tested on the saws mills.

The test results have shown that the structure trapped all pieces of plank that shot back from the saw blade. Therefore it can be concluded that the plank shoot – back containment structure can give the operators and by standers about a one hundred percent (100%) protection during the table saw operations.

During the testing, the shoot – back containment structure did not obstruct the smooth sawing operations and was seen not to constitute another source of injuries to people.

Table saw operators accepted the structure as a safety and life saving device. Thus the design objectives have been achieved.

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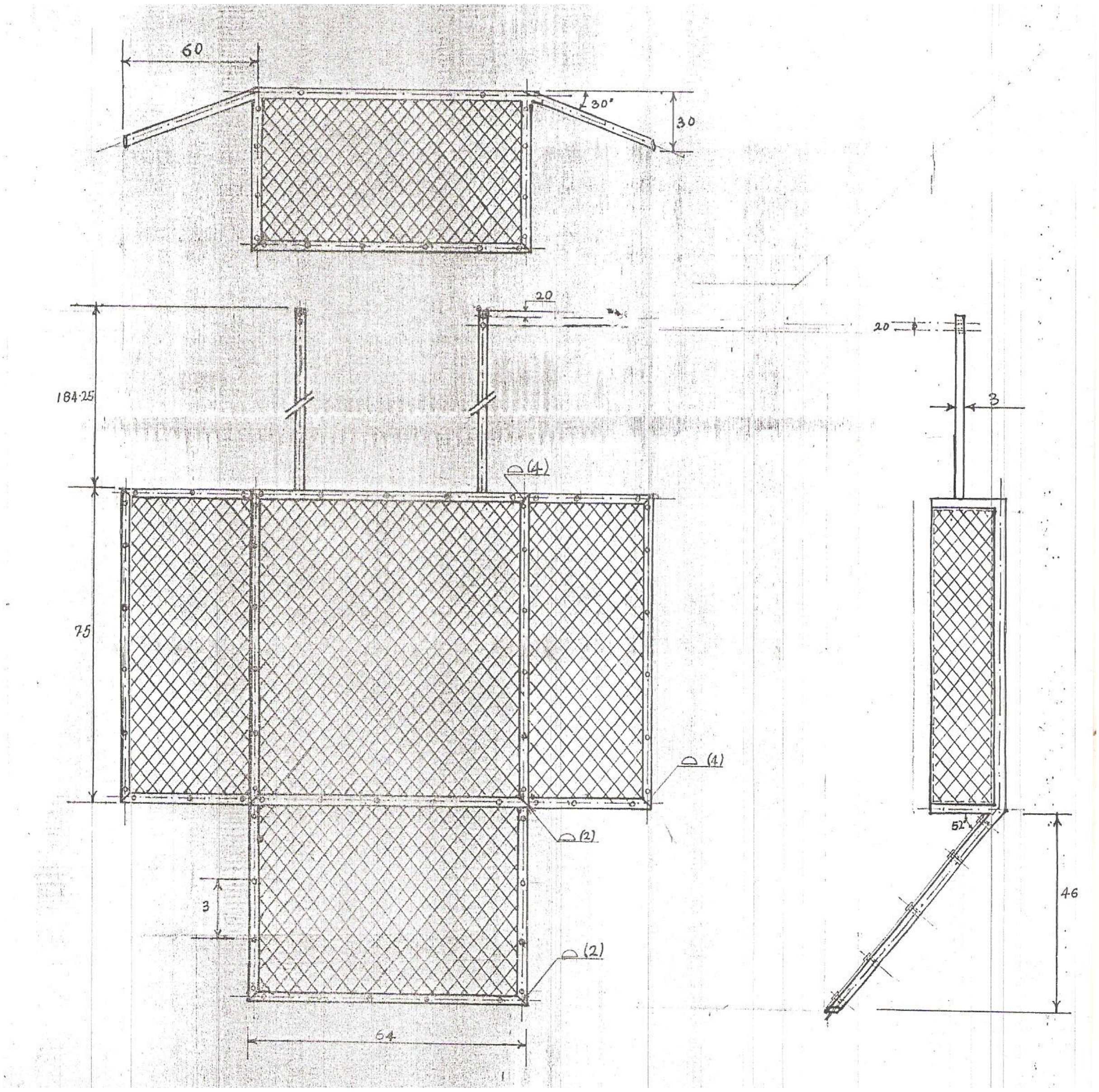
APPENDIX

ASSEMBLY DRAWING OF PLANK SHOOT – BACK CONTAINMENT STRUCTURE



All dimensions in cm