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DEVELOPMENT OF CEMENT BONDED PARTICLE BOARD MAKING MACHINE

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ABSTRACT

The study involves careful consideration of the production process of ceiling board; design of hydraulic press; design of mould box; construction of press and box. The ceiling board making machine is made up of a frame consisting of four stands; machine cover which also carries the hydraulic cylinder; the moulding platform; hydraulic pump; hydraulic valve and electric motor. The machine was designed based on acceptable standards on structural design of machine elements. The choice of the flat structural support as well as the flat cover and base of the mould box where based on theory of deflection of plates using standard equations. The assembly and detail working drawing were made using the parameters obtained from the design calculations. The working drawing was used to construct the component parts of the machine as well as assembling the machine. The machine was then used to produce board samples from the mixture of cement, sawdust, waste paper and starch.

KEYWORDS: Assembly; Ceiling boards; Construction; Design; Machine

INTRODUCTION

Cement bonded wood composites (CBPB) have been on the market for over a century (Papadopulous, 2006). Most research in the field of cement bonded wood composites deals with cement bonded particle board (Fan et al., 2006; Okiro et al., 2005; Papadopolous, 2008). Production of dense cement board with good mechanical properties was achieved in 1962 in America and 1966 in Switzerland. Advanced research into Particle board led to a full scale commercial plant in Zurich in 1974 and Wunstoff, West Germany in 1974 (Dinwoodie & Paxton, 1983). Particle board bonded with cement was first discovered in Austria in 1914 (FAO, 1973). Portland cement was successfully used as a binder in 1928 in the production of wood cement board (Kollman, 1985). In Nigeria, research has been intensified into the possibility of using locally available materials for the production of Particle board. The forest product research division of the Forestry Research Institute of Nigeria has since 1978 been involved in testing tropical hard wood species, agricultural wastes and prolific grasses grown in the country for the production of cement bonded particle board (Ajueyitsi & Olumodeji 2007). Akpen and Tyagher (2006) produced ceiling boards from sawdust, cement, paper mash and starch which had satisfactory comparative properties to asbestos ceiling board with an added advantage of health and environmental friendliness. The machine developed here though could be tested with other materials was designed with this model in mind. The machine is made up of hydraulic press and mould box with bolt and nut fastener. It can press and hold mould materials (mixture of cement, sawdust, paper, water) under pressure for 24 hours setting time; after which the mould was opened to release the ceiling board which was now left for 28 days to cure.

MATERIALS AND METHODS

Material

Mild steel is chosen for the structural parts of the machine due to its availability, relative cost and strength.

Design Consideration and Analysis

The major considerations for the design of the machine components are:

i. strength
ii. external loads
iii. easy machinability, and
iv. nature of jobs to be carried out.

Other considerations are:

i. choice of structural materials for building the machine
ii. determination of the thickness of mould box materials
iii. determination of the size of frame component parts, and
iv. selection of the hydraulic system components.

Design calculation

Thickness and size of mould box

The production of standard ceiling board of dimension 600 x 600mm was achieved using a square mould box. The base plate of the square mould box was welded on all four edges (built - in plate) as shown in Figure 1. Deflection of the base plate of the box was calculated using Equation 1.

$$u_{3(\max)} = 0.00690622\frac{P_3 b^4 a^4}{D} \qquad 1$$

where,

$u_{3\,(\max)}$ is maximum deflection

a is half length of plate

b is half breadth of plate

$$D = \frac{Et^3}{12(1-\nu^2)}$$

where,

E is modulus of elasticity (E= 210×10^9 N/m^2 for mild steel)

ν is Poisson's ratio (we take ν = 0.3)

t is Plate thickness

For the square plate (base plate), length is equal to breadth (0.6 m). Recall (1)

$$u_{3(\max)} = 0.00690622\frac{P_3 b^4 a^4}{D}$$

Substituting for a and b (a= b=0.6/2=0.3m)

This problem falls under Buckling of Clamped–Clamped Column

The crippling load is given by eqn. 2

$$P_{cr} = \frac{4\pi^2 EI}{{L_s}^2} \qquad 2$$

Load carried by the four stands is given by eqn. 3

$$F = PA \qquad 3$$

where,

P is pressure of hydraulic press

A is area of mold box

$$A = LxB \qquad 4$$

where,

L is length of mould box

B is breadth of mould box

but $L = B$

Therefore,

$$A = L^2 \qquad 5$$

From the table of mechanical properties of standard angles, it can be deduced that:

$1\frac{1}{2}\times 1\frac{1}{2}\times\frac{1}{8}$ angle will do the job.

Other members of this machine that are not critical will be made with the combination of these chosen materials. This will enhance the strength of the machine.

Bolt design

Four sets of bolts and nuts are to be used to clamp the mould after ramming. The bolts shall be under tension after loading. The pressure inside the mould will put the bolts under tensile stress. For an Elastic material under tension:

$$\sigma = \frac{F}{Ab} \quad 6$$

$$\sigma = \epsilon E \quad 7$$

where,

F is force on the bolts,

Ab is the cross sectional area of the bolt

$$F = P \times A_m \quad 8$$

where,

P is pressure inside the mould ($P=1.23 \times 10^6$ N/m^2) and A_m is area of mould box ($A_m = 0.6 \times 0.6 = 0.36\ m^2$)

Equating 7 and 8, and substituting for ϵ (given ϵ is 0.01)

where,

Ab is the cross sectional area of the bolts

$$d = 0 \cdot 0082\ m$$

$$= 8 \cdot 2\ mm$$

Bolts of Nominal diameter 10 mm is selected.

Design considerations for the hydraulic system

The design considerations were made:

i. The mould is assumed to be confined, and the mould mixture is assumed to be a fluid, hence, Pascal principle applies.

ii. The size of ceiling board adopted is 600 × 600 × 20 mm

iii. A rectangular frame is adopted to suit the geometry of the mould box determined by the size of ceiling board adopted.

iv. The height of the machine frame is the midsection of an average height person.

v. The working Pressure in the mould box P_m is taken to be 1.23 N/mm^2 (Bamisaye, 2007; Erakhrumen et al., 2008).

Design theory and formulae of the hydraulic system

Pascal Principle: states that the pressure applied on a confined fluid at any point is transmitted equally throughout the entire fluid

$$P = \frac{F}{A} \quad 9$$

where,

P is pressure of fluid at any point in the container

F is force applied on the container

A is area on which the force is applied

The hydraulic cylinder

Cylinder of the following parameters were selected:

1. Bore diameter (D) – 80mm, 2. Rod diameter (d) – 40mm, and 3. Stroke - 120mm

Value of the area of pressure plate (Ap) was obtained using eqn.10

$$A_p = l_p x A_p \quad 10$$

where,

Ap is length of pressure plate =150mm

lp is width of pressure plate = 100mm

Value of the pressure of fluid in the cylinder plate (Ap) was obtained using Eqn.11

$$P_c = \frac{F_c}{A_c} \quad 11$$

where,

A_c is (surface area of piston) = $\pi \frac{D^2}{4}$

F_c is force exerted by the piston
Substituting for F_c and A_c
Assume Velocity of flow (v) = 3 mm/s
Flow Rate $Q = vA_c$
Fluid Power (F.P.) $= P_c Q$
F.P $= 3 \cdot 75 \times 10^6 \times 1 \cdot 509 \times 10^{-5}$ Watts
$= 56 \cdot 59\, W$
Overall Efficiency (η_o) is 0.81, shaft power (S.P) is obtained using Equation 12

$$\eta_o = \frac{F.P.}{S.P.} \quad (12)$$

where,

$$S.P. = 69 \cdot 86W$$

Analysis of the calculated parameters have shown that electric motor of 70 Watts rated power will be required to drive the pump of 40 bars. In addition, a directional valve was chosen to control the advance and the retract motion of the cylinder, with which the reservoir gave a complete hydraulic system.

Machine construction

The construction processes were carried out based on the design parameters.

Machine frame

Twelve pieces of length 810 were cut out of angle section 1½ x1½ x 1/8 to be used as horizontal members. Four pieces of the same section was cut to be used as stands of the machine using Measuring tape, Tri-square, Scriber, and Hacksaw (Figure 3b). The Machine Cover and the Moulding platform were cut from a metal plate of 3mm gauge into a square of size 810 using Guillotine (Figure 4). These cuttings were welded together by the arc welding process using gauge 12 electrode to form the machine frame.

Mould Box

The side walls of the Cope and the Drag of the mould box were formed from four pieces each of length 596 and 600 respectively, which is seen in Figure 5. Two cover plates of 598 and 600 square were cut out of 3mm plate using Guillotine and formed into cope and drag of the mould box by arc welding process (Figure 6).

Cleaning

Cleaning of the Frame and the Mould box was done using wire brush and chipping hammer.

Machine Assembly

The machine members were assembled using the assembly working drawing in Figure 7A. The constructed machine is shown in Figure 8.

Installation of the hydraulic system and painting

The hydraulic system was bought out according to design and mounted on the machine cover before the machine was painted and allowed to dry.

Bill of Engineering materials

Depicted in Table 1 is the engineering bill of quantity for the developed cement bonded particle board making machine.

Testing of the machine

The machine was used to produce ceiling boards from a mixture of cement, sawdust and paper.

CONCLUSIONS

A ceiling board making machine has been developed according to the objective of this work. The machine was used to produce ceiling boards from waste products (paper and sawdust) thus helping to reduce waste. The ceiling boards produced by this machine were tested and they met the standard requirement of CBPB as specified by EN and ASTM.

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Table 1: Bill of Engineering Materials

S/N	Name	Material/ Description	Qty	Cost Per Unit (₦)	Total Cost (₦)
1.	Angle bar	Mild steel	1	9,000	9,000
2.	Metal Sheet	Mild steel	1	10,000	10,000
3	Electrode	Guage 10	1pack	3,000	3,000
4	Grinding disc	Silicon oxide	2	500	1,000
5	Cutting disc	Silicon oxide	2	500	1,000
6	Bolts and Nut	Mild steel	4	30	120
7	Hydraulic cylinder		1	18,000	18,000
8	Hose	Rubber	4	1000	4000
9	Control valve		2	5000	10,000
10	Hydraulic fluid	Lubricating oil	10litres	500	5,000
11	Paint	Lead oxide	2tins	1000	2000
12	Hydraulic Pump		1	20000	20000
13	Electric Motor	1hp	1	15000	15000
14	Workmanship			30000	30000
15	Total				128,000

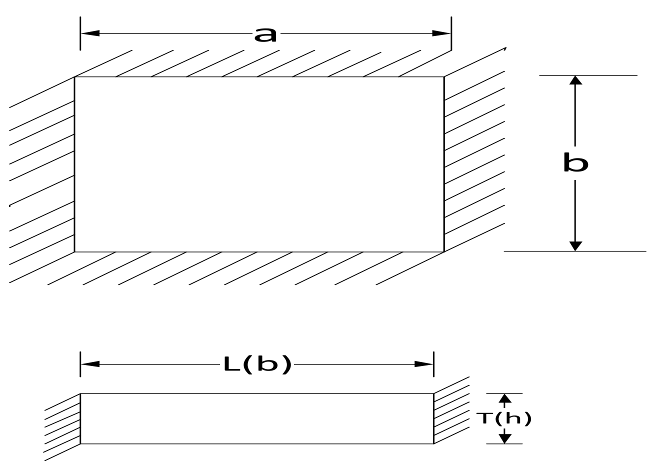

Figure 1. Schematic views (a) plan and (b) elevation of the of the mould base plate

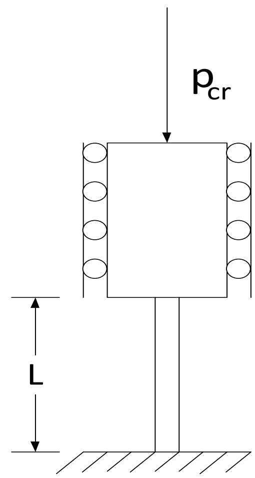

Figure 2. Schematic diagram of frame leg of machine

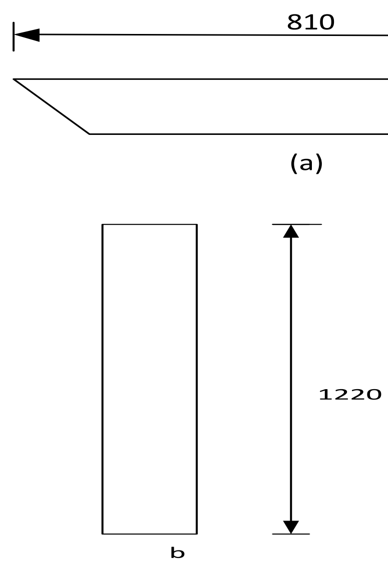

Figure 3. The machine frame (a) side wall and (b) stand

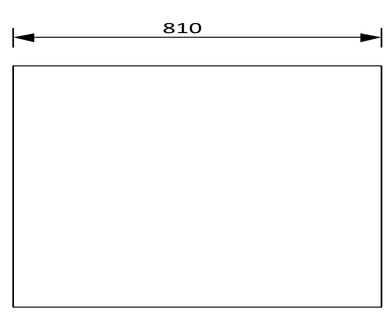

Figure 4. The machine frame cover

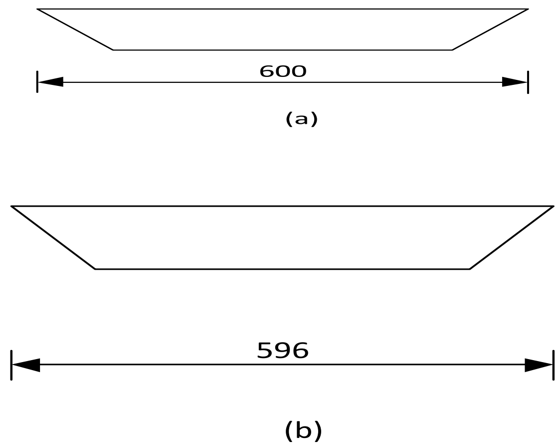

Figure 5. Side walls of the (a) cope and (b) drag of the mould box

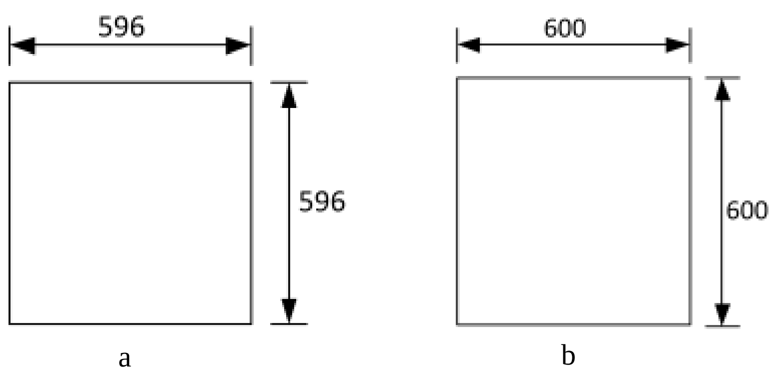

Figure 6. Side walls of the (a) cope and (b) drag of the mould box

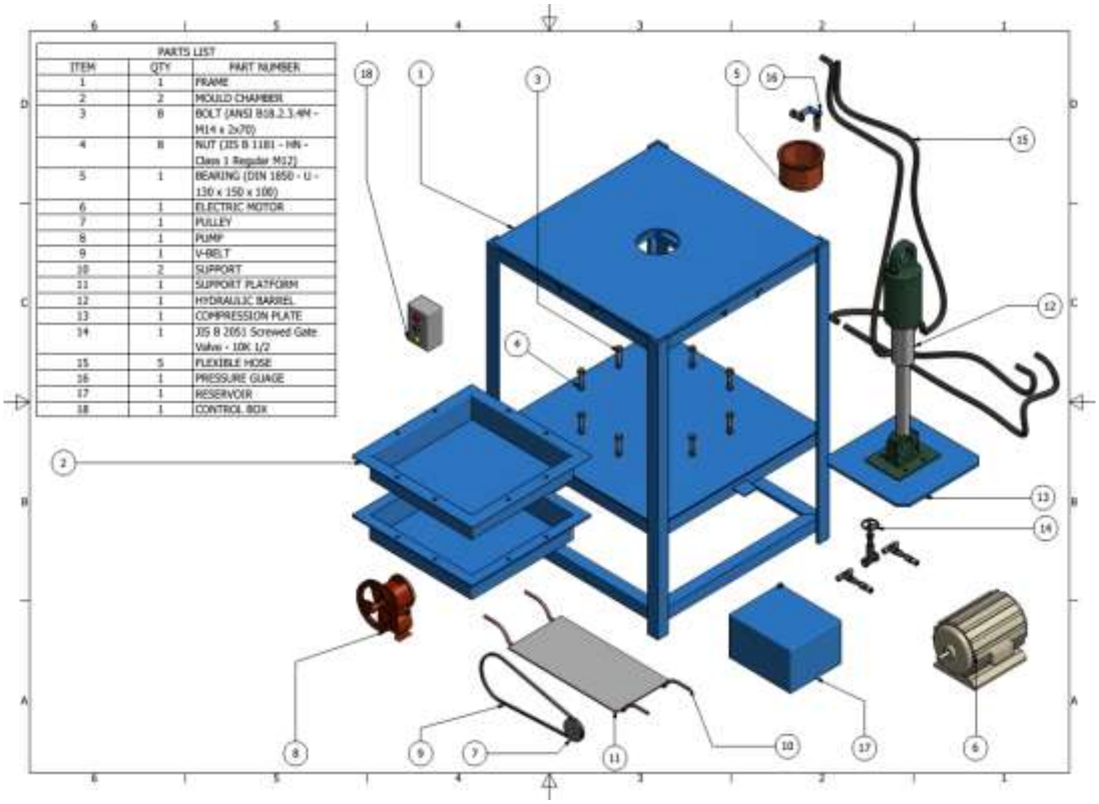

Figure 7. Assembly Working Drawing of Machine

Figure 8. The ceiling board making machine