Development and Performance Evaluation of Hydraulic Brick Moulding Machine

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Abstract

The pressing need for building materials in Nigeria and Africa in general, particularly for low-cost housing in rural areas, has now become a major issue of concern. Many naturally occurring substances, such as clay, sand, wood, and rocks are over 90% available in these rural areas. However, the cost of sophisticated modern brick moulding machines ranges between $2,500 and $3,000. Hence, there is a need to develop and evaluate the performance of a hydraulic brick moulding machine that can produce large quantities of bricks at an affordable cost by the people in the rural areas. The developed machine has several distinct parts: U-channel frame section made of mild steel (23.53 m^3 volume), angle plate (10.06 m^3 volume), hydraulic reservoir (1,000 m^3 volume), hydraulic cylinder, the pump (1.36 hp), pulleys (60 mm and 100 mm diameter; 125.68 rad/s and 209.47 rad/s angular velocity; 1,200 rpm and 200 rpm speed), and mould. The performance evaluation of the machine was carried out and a production of an average number of 86 bricks per hour was recorded, with machine efficiency of 75%. The machine is effective, easy to operate, relatively cheap with a production cost of $700 only.

Keywords: *Mould, brick, hydraulic moulding machine.*

Introduction

The rate at which structural defects or failures occur these days is alarming, and they usually come as a result of sub-standard cement blocks used in building construction, hence, there is a need to get highly compacted and strengthened bricks, which can be made from red soil mixed with some additives if needed. The quality of bricks is determined by the reliability and the efficiency of the brick machine, which will determine how strong the structure will be, which in turn will eventually determine the maintenance cost of said structure. The maintenance concept of the proposed machine is mainly focused on the three major parts of the machine: the U-channel frame section, the hydraulic section, and the mould section.

Maintenance in simple terms is defined as all operations that are conducted on a system in order to retain its components and keep it in good working condition (Meshkat *et al*. 2001).

Maintenance operations are categorized as corrective, preventive, and scheduled maintenance operations. As far as this proposed machine is concerned, all these maintenance operations have to be explored for effective and efficient quality assessment of brick production (Agbamu 1999).

A brick can be defined as a rectangular block of clay backed by the sun or in a kiln (an enclosed chamber in which heat is produced to fire, burn or dry materials), which is used as a building material or a paving material (Karnopp *et al*. 1990). Adobe bricks are a natural building material made from sand, clay, water, and some kind of fibrous material (sticks, straw, dung), which is shaped into bricks using frames and dried in the sun. Adobe structures are extremely durable and account for the oldest existing buildings on the planet. In dry climates, compared to wooden buildings adobe buildings offer significant advantages due to their greater thermal mass (Scott 1997).

Hydraulic machines are machines and tools which use fluid power to do work. In this type of machine, high pressure hydraulic fluid is transmitted throughout the machine to various hydraulic motors and hydraulic cylinders. The fluid is controlled directly or automatically by control valves and distributed through hoses and tubes. The popularity of hydraulic machinery is due to the very large amount of power that can be transferred through small tubes and flexible hoses, and the high power density and wide array of actuators that can make use of this power (Wolansky and Akers 1988, Akers *et al*. 2006).

However, the energy considerations compel the use of pressed mud blocks in place of the traditional burnt bricks. Usually bricks can be moulded manually by hand, but there is a need for a machine which would result in easier, faster and cheaper means of producing the bricks. Brick machines come in different designs, types, shapes and sizes, but this work considers a simple hydraulic brick machine which is powered by a hydraulic pump driven by a prime mover.

Methodology

The design considerations for the distinct parts of the proposed brick moulding machine are simple and straightforward.

Pump Design

Table 1 contains specifications of external gear pumps of three different classes, which can be used for the hydraulic section of the brick moulding machine.

Table 1. Specifications of external gear pumps.

Class	Speed (rpm)	Pressure (Psi)	Discharge (GPM)	Discharge (liter/min)
A	1800	2100 - 3000	0.8	3.028
B	3600	2100 - 3000	1.6	6.057
C	1200	2100 - 3000	0.7	2.650

Determination of Pump Displacement

The pump displacement is given by the following equation:

$$V_P = (Q_m \text{ x } 1{,}000) / (n_P \text{ x } \eta_{\text{vol.p}}), \qquad (1)$$

where:

V_P = pump displacement [cm³/rev];
Q_m = flow rate required by pump [liters/minute];
n_P = pump shaft speed [rpm];
$\eta_{\text{vol. p}}$ = pump volumetric efficiency (in the range 0.85 - 0.97).

Determination of Pump Power

The power rating of the pump depends on the pump displacement:

$$P_{\text{out}} = p \text{ x } (V_P \text{ x } n_P) / 600{,}000, \qquad (2)$$

where:

P_{out} = power [kW];
p = pressure [bar];
V_P = pump displacement [cm³/rev];
n_P = pump shaft speed [rpm].

Determination of Drive Power

The power rating of the prime mover is obtained accordingly:

$$P_{\text{in}} = p \text{ x } (V_P \text{ x } n_P) / (600{,}000 \text{ x } \eta_{t.\,p}), \quad (3)$$

where:

P_{in} = power [kW];
p = pressure [bar];
V_P = pump displacement [cm³/rev];
n_P = pump shaft speed [rpm];
$\eta_{t.\,p}$ = pump overall efficiency (0.8-0.9).

Determination of Velocity

The velocity is determined by the standard analytic expression:

$$v = Q \text{ x } 21.22 / D^2, \qquad (4)$$

where:

v = velocity in meters per second [m/sec];
Q = flow rate in liters per minute [liter/min];
D = inside diameter of pipe or hose in [mm].

Reservoir Design Considerations

***Sizing*:** Recommended reservoir fluid volume is 3 to 5 times the pump(s) output flow per minute with a 10% air cushion, expressed by the following formula:

$V = 3 \times Q \times 1.1,$ (5)

where:

V = reservoir volume [gallons or liters];
Q = flow rate of pump [gallons/ minute].

By choosing:
- length of tank to be 20 cm;
- width of tank to be 20 cm; and
- an assumed volume of 10 liters (10,000 cm^3);

the corresponding height can be calculated from:

$H = V / (L \times W),$ (6)

and the result is shown in Fig. 1.

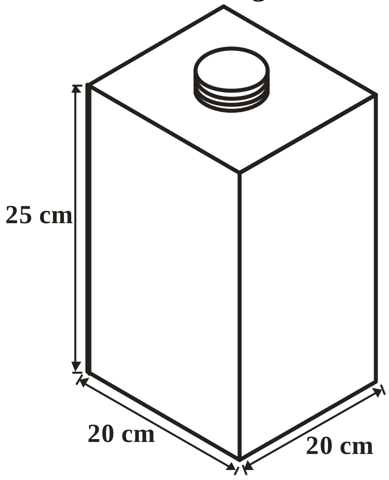

Fig. 1. Reservoir.

Design of the Frame of the Machine

The density of the material is given by the equation:

$\rho = m / V,$ (7)

where:

ρ = density of the material, [kg/m^3];
m = mass of the material, [kg];
V = volume of the material, [m^3].

U - Channel (Main Frame)

The main frame of the machine is shown in Fig. 2. The main frame is characterized by the following parameters:
- material used: mild steel; and
- density: 7.84 kg/m^3.

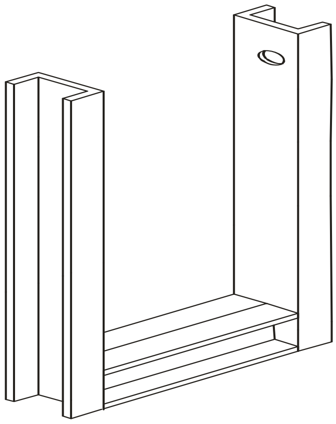

Fig. 2. The main frame of the machine.

The sectional view of the main frame and the dimensions of the U-section are shown in Fig. 3.

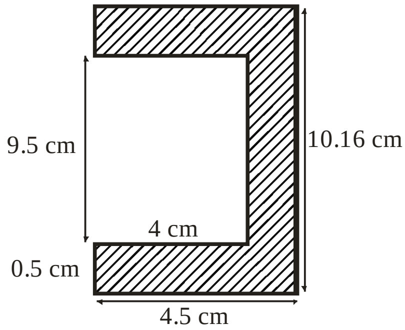

Fig. 3. Sectional view of the main frame.

Volume of U-Channel

The volume of the U-channel is given by:

$V = A \times L,$ (8)

where:

L = total length used;
A = cross-sectional area.

Angle Plate

The dimensions of the angle plate are shown in Fig. 4.

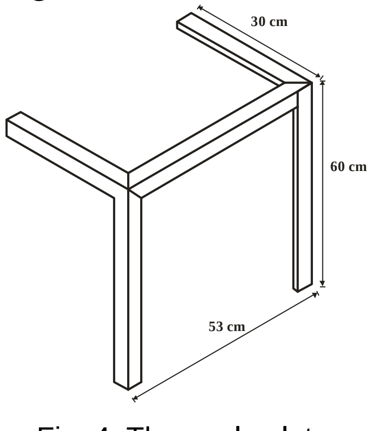

Fig. 4. The angle plate.

Design of the Mould and Brick

The brick designed in this research work is an interlocking brick such that the laying does not require mortar; it just needs to be aligned together. The mould was designed such that the shape of the brick has slots and protrusion. The mould for the brick is shown in Fig. 5.

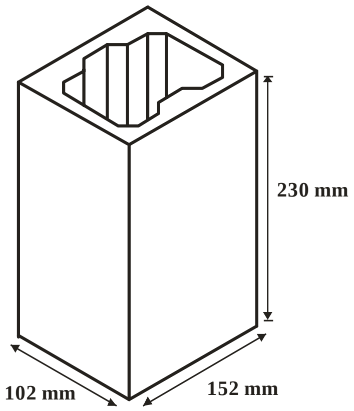

Fig. 5. Mould for the brick.

The volume of the brick is determined as follows:

$$V = L \times B \times H, \qquad (9)$$

where: L = length; B = breadth; H = height. The brick shape is shown in Fig. 6.

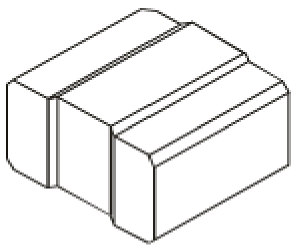

Fig. 6. Brick shape.

Results and Discussion

The isometric drawing of the machine is shown in Fig. 7. The fabricated hydraulic brick moulding machine is shown in Fig. 8.

The performance evaluation of the machine, as recorded by the author, is shown in Table 2.

Let:

Expected rate of production = 2 bricks per min.

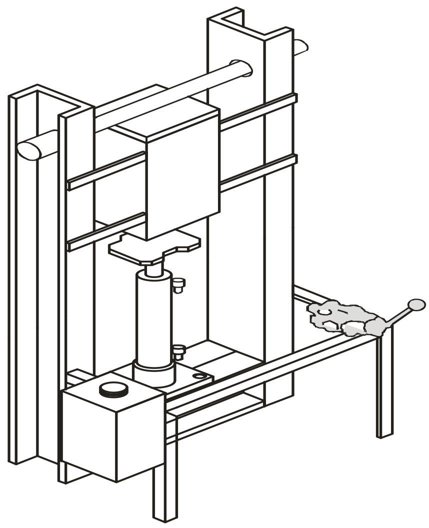

Fig. 7. Isometric drawing of the machine.

Fig. 8. The fabricated hydraulic brick moulding machine.

From Table 2, the following parameters are known:

Total bricks produced = 86 units;

Total time used = 60 minutes.

Therefore, the average rate of brick production is given by:

Average bricks produced per minute = 86/60 = 1.433 bricks per minute.

Table 2. Performance evaluation of the machine as recorded by the author.

Trial	Time (min.)	No. of bricks	Cumulative production	No. of workers
1	5	6	6	2
2	10	7	13	2
3	15	10	23	2
4	20	7	30	2
5	25	8	38	2
6	30	5	43	2
7	35	10	53	2
8	40	4	57	2
9	45	9	66	2
10	50	8	74	2
11	55	7	81	2
12	60	5	86	2
Total	60	86		

The efficiency (η) of the machine can be calculated as:

$$\eta = (\theta_o / \theta_i) \text{ x } 100, \qquad (10)$$

where: η = efficiency; θ_o = output; θ_i = input; resulting in:

$\eta \approx 75\%$.

This implies that if 1.433 bricks are produced per minute, then a total of 86 bricks will be produced in an hour. Hence, for a 7-hr day job the average number of bricks that will be produced per day is 602 bricks.

Conclusion

A hydraulic brick moulding machine was designed and fabricated. The various components were properly functioning while running. The machine can produce the reported average number of bricks per day, but this also depends on the performance of the operators involved in the production of bricks. The machine was designed in such a simple way that it requires little or no special training for the operators of the machine.

The intended maintenance operations for the three major parts of the machine, if implemented, will bring out good quality bricks and enhance the life span of the machine.

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