Design, Construction And Commissioning Of A Chalk Extrusion Machine

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Abstract: A chalk extrusion machine has been designed, fabricated and commissioned in the Department of Mechanical Engineering University of Maiduguri as part of the campaign in the local sourcing of educational consumables. The presence of large gypsum deposits (a major raw material for chalk production) in the North Eastern part of Nigeria is a justification for going into the project for utilizing available raw materials rather than imports that result in the country's foreign exchange. The machine requires one operator and is capable of producing 20,000 pieces of high quality chalk per day (for six hour working per day) which translates into $6000 (six thousand USD) turnover per day. The chalk is tapered with dimensions of 12mm X 9 mm in diameter and 81mm overall length and was tested on a blackboard and found to be non-toxic, dustless, easily erased, smooth writing and does not scratch the board. Arrangement for patenting the machine is in progress.

Keywords: Chalk, Construction, Design, Extrusion, Gypsum, Machine, Mould, Slurry.

1.0 INTRODUCTION

Manufacturing technology is the art and science of making hard ware of a specified quality on a planned production scale with the minimum consumption of material and maximum productivity of labour (Ibhadode, 2001).Chalk-making machine with moulds made of the seamless red copper tubes was produced by Xuguan (2005). It has to be noted that copper is very expensive, thus calls for another material that is less expensive and will be used to achieve the desired goal. In this country, small scale chalk plants such as model KM-5200 are imported at the rate of over two million naira by August 1988 (Butu Ventures, 2005). This work is aimed at producing chalk making machine using locally available materials for self reliance and a boost for small scale industries.

2.0 DESIGN OF CHALK AND MACHINE

For the manufacture of good quality plaster of Paris, good quality gypsum (more than 94% $CaSO_4.2H_2O$) is crushed in jaw crushers, washed with water, dried and finely ground using micro-pulverizer. The finely ground gypsum is then calcined at 130 – 150oC in a coal fired furnace. The water content of the product is checked from time to time by drawing samples from the furnace. A product of uniform size is obtained by adjusting the moisture contents.

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After cooling for 24 hours the product is then mixed with potassium bisulphate in a ribbon blender. The function of potassium bisulphate is to accelerate and control the time of setting of the plaster of Paris, which is then packed in polyethene line jute bags (Sharma, 2000). The procured plaster of Paris is mixed with water in a bucket to form thick slurry. For preparing crystal white crayons, small amount of ultramarine blue is also added to the slurry. The resulting slurry is then fed into the cavities of the aluminium or iron moulds of about 100 cavities each lubricated with a mixture of kerosene and groundnut oil (at a ratio of 4:1 respectively) for easy removal of the chalk crayons form the cavities. After about 10 minutes, the set chalk crayons or chalk sticks are removed from the cavities, allowed to dry in sunlight and packed in boxes made of hard paper. If colored crayons are required, suitable pigment may be added to the slurry before feeding into the cavities. Colored chalk fades in sunlight and should be dried under shades (Sharma, 2000).

3.0 DESIGN OF CHALK MAKING MACHINE PARTS

3.1 The Shaft

Shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. For a solid shaft having little or no axial loading the code equation reduces to;

$$d_3 = \sqrt{\frac{16}{\pi s}\left(K_b M_b\right)^2 + \left(K_t M_t\right)^2} \qquad (1)$$

where,

τxy = torsional shear stress, N/m2

Mt = torsional moment, N.m

Mb = bending moment, N.m

Kb = combines shock and fatigue factor applied to bending moment

Kt = Combined shock and fatigue factor applied to torsional moment

Rack and Pinion

A pinion is the smaller of two mating gears, the larger being often called the gear. The rack has an infinite number of teeth and a base circle which is an infinite distance form the pitch point. The sides of involute teeth on a rack are straight lines making an angle to the line of centers equal to the pressure angle. Figure 1 shows an involute rack which mesh with a pinion. Corresponding sides on involute teeth are parallel curves; the base pitch is the constant and fundamental distance between them along a common normal as shown in the figure. The base pitch is related to the circular pitch by an equation due to Joseph and Charles (2001).

$$Pb = Pc \cos \phi \qquad (2)$$

where

Pb is the base pitch, Pc is circular pitch and ϕ = Pressure angle

The pinion diameter D, was obtained from the equation due to Kurmi and Gupta (2005) given as

$$D = 360\ L / \theta\ \pi \qquad (3)$$

Where

the distance moved by the piston or length of the mould = L, and θ is the angle of turn of handle.

3.3 Gear

For the gear the module is given by

M = d/t (Schaum's series, 2002), where

d = diameter of gear and t is the number of teeth. Other dimensions were taken from Khurmi, 2001) as shown in table 1 below.

Table 1: Gear parameters used in this work (Khurmi, 2001)

Addendum	1
Dedendum	1.25
Working depth	2
Minimum total depth	2.25
Tooth thickness	1.5708
Minimum clearance	0.25
Fillet radius at root	0.4

The Tangential force on gear is given by FtTt / RG (Schaum's series, 2002) and the

Radial Force is = Ft tan ϕ.

Determination of the Total Load Acting on the Shaft (WT) This total operational load of the machine is made up of the weights of the piston, the piston carrier, the racks and the chalk computed as follows:

3.3.1 Weight of piston (Wp)

Wp = total mass of piston × acceleration due to gravity

= Mp × g

$$\frac{\pi d_1^{\ 2}}{4} L_1 + \frac{\pi d_2^{\ 2}}{4} L_2) \times \mathrm{B} \times np \times g$$

3.3.2 Load of Piston Carrier (Wpc)

Wpc = mass of carrier × acceleration due to gravity

= Mpc × g

= volume × ϑ volume of holes (78ϕ 6mm)

$$= (Lbt - \pi \frac{d^2}{4} t)\rho g x 78 \qquad (4)$$

where,

L = length of plate

b = breath of plate

t = thickness of plate

d = diameter of hole

3.3.3 Weight of Rack (WR)

WR = Mass of 2 racks × g

= Vol. of 2 racks × ρ × g

$$= 2\pi \frac{d^2}{4} \rho g \qquad (5)$$

3.3.4 Weight of 78 Chalks (Wch)

Wch (78) = mass of chalk × Mch × g (6)

Determination of the Load on the Mould Box (Wmb)

The mould box comprises of

Chalk moulds (78), W1

Upper and lower plates sandwiching the moulds, W2

Two side guides, W3

Mould handle, W4

Collecting tray and casing W5

Wmb = W1+ W2 + W3 + W4 + W5 (7)

Where,

W1 = weight of chalk moulds (78)

= volume × density × g

$$= \frac{\pi}{4}\left[\left(D_o^2 L_o + 2D_1^2 L_1\right) - d^2 L\right]\rho g$$

W2 = Weight of mould plate

= 2 (volume of plates with 78 holes) × density ×g

$$= 2\left(Lb - 78A\frac{D^2}{4}\right)t\rho g$$

Weight of mould carrier (W3)

W3 = 2 (volume of mould carrier) × density × g

= [½ (a+b1) h + L × b2] t × ρ × g (8)

Weight of mould handles (W4)

W4 = π/4 (D2 – d2) L × density × g (9)

The weight of collecting tray and casing (W5) is given by The volume of frame + volume of trays × ρ × g , that is,

W5 = [2(L1b1 + 2L2b1) t1 + 6 (L1b1 + L1b2) t2] × ρ × g (10)

W_{mb} = W1 + W2 + W3 + W4 + W5

4.0 FABRICATION AND ASSEMBLY OF COMPONENT PARTS

The various components were fabricated in the workshop by casting, cutting and machining according to the design specifications. The machine was finally assembled and tested. The plates of appendix 1 show various assembling stages.

5.0 TESTING THE MACHINE

The procedure for operation of the machine is as follows: First clean the machine with kerosene to remove all the dust, grease and oil. Apply fresh lubricant oil to the rack, gear and moving parts of the machine. Apply mixture of Kerosene and groundnut oil (ratio 1:1) at the upper part of the mould using brush to ensure that the oil goes down the entire mould. Stir the mixture of plaster of Paris and water thoroughly with a stick. Mix just enough quantity of plaster of Paris and water that may be required for one charge of the mould, as the mixture sets very fast, and once set becomes unusable. Also ensure that the quantity of mixture is sufficient for one charge of the mould, since delayed mix causes breakage of chalks. Pour this mixture from the top of the mould (i.e. from the side where the hole diameter is larger) and allow the mixture to settle down. After 4 to 5minutes of pouring mixture into mould, remove the excess mixture from the top of the mould with the aid of the steel knife or otherwise Turn the mould box to 90o, fit the collecting tray with its aluminium trays to the mould box, and roll the handle to push out the chalk for drying of the chalk sticks in sunlight or an electric oven. Turn the box to the initial position for the next operation.

CONCLUSION

A chalk extrusion machine has been designed, fabricated and commissioned using local materials. This machine would help in job creation and self reliance in educational consumables. It would save foreign exchange and if properly managed could produce 20,000 pieces of chalk per day which translates into about N60, 000.00 turnover per day. The chalk is non-toxic, dustless, easily erased, smooth writing and does not scratch the board. It is tapered between 12 and 9 mm in diameter and 81 mm in length.

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