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Design Modification of Candle Making Machine

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ABSTRACT

A candle making machine is designed, which is cost effective to bridge the gap between candle production from large scale and small scale enterprises in Nigeria A computer simulation model of the designed candle making machine was also developed to determine the technical and economic viability of the machine. A survey of candle making machines currently used in the local industries was carried out to establish their cost and source, Data to this effect was also obtained. From the survey, it was discovered that most of the candles making machines currently in use in Nigeria were imported either from USA, China or India and at a cost range of N180000 to N300000. This machine can only be afford by large scale industries leaving out the small scale entrepreneurs who cannot afford it. A design of a candle making machine using our local standard material was therefore designed to accommodate small and medium scale enterprises interested in candle production. AutoCAD design software was an important tool used. A technical and economic evaluation of the design was carried out in terms of performance, environmental factors, maintenance, aesthetics/ergonomics, size and weight, safety and cost. The cost of production will be N80, 000.

Keywords : Aesthetics, Ergonomics, AutoCAD, Candle Making Machine

I. INTRODUCTION

Norma Coney (1999) defined a candle is an ignitable wick embedded in a wax or another flammable substance such as tallow that provides light and in some cases, a fragrance. It can also be used to provide heat, or as a method of keeping time. A candle manufacturer is traditionally known as a chandler.

There are various ways of candle making. According to Wikipedia encyclopedia (2015), the methods include press method, single mould method and machine candle making process. The most popular candle making process is the use of machine. This process involves:

a) Wick centering

The first step of the machine candle making process is to fix the wicks at the bobbing from where it is made to pass through the ejectors to the catch board. The wick is set to be on tension by proper adjustment of the screw on the catch board.

b) Melting and additives adding

The petroleum wax is heated externally until it melts. Stearic acid, colour and perfume can be added to the molten wax at calculated quantity to improve quality and have particular characteristic.

c) Cooling and finishing

The molten wax is poured into the mould where it is cooled and solidified. Excess wax is cut out and the candles ejected out.

The candle making machine is made up of two main parts namely

a) The mould which is designed to be housed by the cooling chamber
b) The ejection system which is used to extract the solidified candles from the mould. The machine is made of mild steel because mild steel is cheaper and has good properties such as toughness, has good tensile strength and

thermal conductivity. However the machine has to be painted to prevent rusting since mild steel has weak resistance to corrosion. **JK Gupta (2014)**

II. MATERIALS AND METHOD

The main material chosen for the candle making machine is mild steel also known as plain carbon steel It is the most common type of steel because its price is relatively small while it provides material properties that are acceptable for many applications. Mild steel is used for the housing and frame structures.

I. In mild steel composition, other than mild maximum limit of 0.02 carbons in the manufacture of carbon steel, the proportions of copper and silicon are fixed while the proportions of cobalt and chromium are not.
II. A high amount of Carbon makes mild steel stronger and stiffer.
III. Carbon atoms get affixed in the interstitial sites of the iron lattice and make it stronger.
IV. Density is $7850 kg/m^3$
V. Young's modulus is 207 GPa. **PC Sharma (2004)**
VI. These factors make carbon steel to be suitable as the main material of the candle making machine .For the moulds, the most preferred material is copper. This is chosen due to the following properties,
   I. Tensile strength – this is about 483Mpa.
   II. High resistance to corrosion
   III. Good heat conduction ability **PC Sharma (2004)**

2.0. DESCRIPTION OF PARTS OF DESIGNED CANDLE MAKING MACHINE

The design of the candle making machine has major systems:

i. The power and Extrusion system
ii. Cooling and system
iii. The frame

Other operations like heating and feeding is to be externally done.

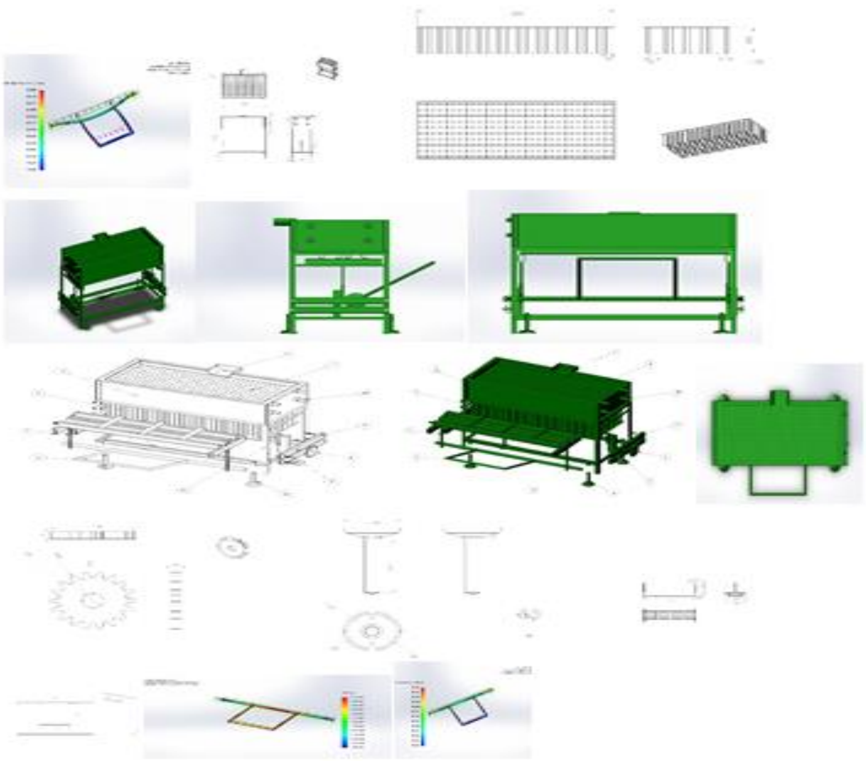

Figure 1

2.1. DESIGN ANALYSIS OF THE CANDLE MAKING MACHINE.

2.1.2 Weight capacity of the wax.

The effective weight capacity of this system depends on the volume of the molds and that of the shaft with solid candles in the molds.(Nwankwojike B. Nduka, 2012).

The molds are cylindrical.

The length and diameter of the molds are 0.3m and 0.03m respectively.

Therefore the effective weight capacity of wax to be used is given in this equation.

$$W = g \times \rho_w \times V_m$$

Where ρ_w = density of paraffin wax which is given as $920 kg/m^3$ (Stephen tambara 2015)

$$V_m = n_m(\pi r^2 l) \qquad (1)$$

Where n_b = total number of moulds

l_m = Length of the moulds

Therefore the effective weight capacity wax per operation was determined as 574.23N using this equation. $W = g \times \rho_w \times V_m$

g= acceleration due to gravity. =9.81m/s^2

2..1.3. Weight capacity of ejecting pins assembly

Length of pin is 0.3m.

Diameter of pin is 0.02m

$$V_p = n_p(\pi r^2 l) \qquad (1)$$

Where n_p = total number of moulds

$$Wp = g \times \rho_s \times V_p$$

Where ρ_s = density of steel which is given as $7850 kg/m^3$ (Stephen tambara 2015)

Weight of pins is 2199.85N from the equation

Volume of steel plate = lbt

Length is 1.2m,

Breath is 0.6m, thickness is 0.003m

Weight of steel plate, w by the formula

$$Wp = g \times \rho_s \times V_p$$

is **116.33N.**

Therefore the effective weight of ejection pin assembly Wp = $2366.2N$

2.1.4 Rack/pinion parameters

Rack and pinion is used to convert a rotary motion to translating motion or vice versa (either the pinion drives the rack or the rack drives the pinion). Fig. 4.1 shows a rack in mesh with a pinion. Rack can be imagined as a spur gear having an infinitely large diameter. Therefore the rack has an infinite number of teeth and a base circle which is infinite distance from the pitch point. With infinite diameter of base circle, the involute outline of teeth on rack becomes straight lines.

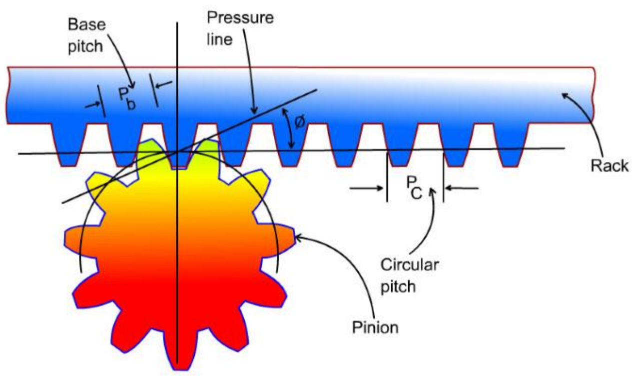

Figure 2.1. Rack and pinion

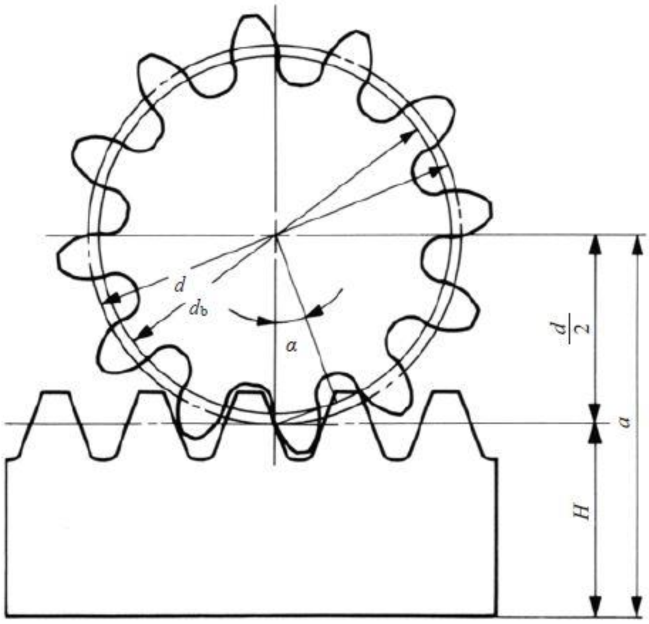

Figure 2.2. Rack and pinion

The effective weight capacity of this system at the gear/pinion arrangement depends on the size of the gear selected, considering the fact that different sizes of gear have different weight. (Nwankwojike B. Nduka, 2012)

The design of the rack/pinion has the following parameters.

Table 1

No.	Item	Symbol	Formula	value Spur gear	Rack
1	Module ,	m		3	
2	Reference pressure angle,	a		20 deg	
3	Number of teeth	z		42	–
4	Profile shift coefficient	x		0.6	
5	Height of pitch line	H		–	32.000
6	Working pressure angle	α_w		20 deg	
7	Mounting distance	a	zm/2 + H +xm	96.3	
8	Reference diameter	d	zm	126–	
9	Base diameter	d_b	d cos α	118.401	
10	Working pitch diameter	d_w	db/cos α_w	126	
11	Addendum	h_a	m (1 + x)	4.800	3.000
12	Tooth depth	h	2.25m	6.750	
13	Tip diameter	d_a	d + 2h_a	45.600	–
14	Root diameter	d_f	d_a – 2h	32.100	

One rotation of the spur gear will displace the rack l one circumferential length of the gear's reference circle, per the formula

l = $\pi m z$

(α = 20°, z = 42, x = + 0.6)

KH Kelvin (1998)

The rack displacement l = 395.892mm

The machine requires two rack/pinion assemblies. Standard spur gear (steel) with 20 degree pressure angle were selected due to simplicity in the design, availability/economy of maintenance, absence of end thrust on bearing and suitability for heavy loads features of this kind of gear. The length of the rack is 600mm.

2.1.5 To Determine The Shaft Diameter Of The Shaft.

The shafts were designed for appropriate load and torque, which is being transmitted, and therefore have ample strength and rigidity. Considering availability, a mild steel shaft was used for the fabrication, the shaft diameters, d of the shaft of this machine was determined using the equation below

$$d = \left[\frac{16}{\pi\tau} \sqrt{(k_b m_b)^2 + (k_t m_t)^2} \right]^{1/3} \qquad (9)$$

Where τ = 42 N/mm². The maximum twisting moment acting on the shaft.

M_t = Maximum Twisting Moment on the shafts, N-mm.

M_b = Maximum Bending Moment on the shafts, N-mm.

K_b = Combined shock and fatigue factor for bending.

The allowable shear stress for steel shaft with provision for keyway, τ is given as 42N/mm^2 (Khurmi and Gupta, 2005)

Where σ = maximum safe stress

2.2.0 Determination of The Shafts Bending Moment.

The bending moment on the shaft was determined using fig 3.3

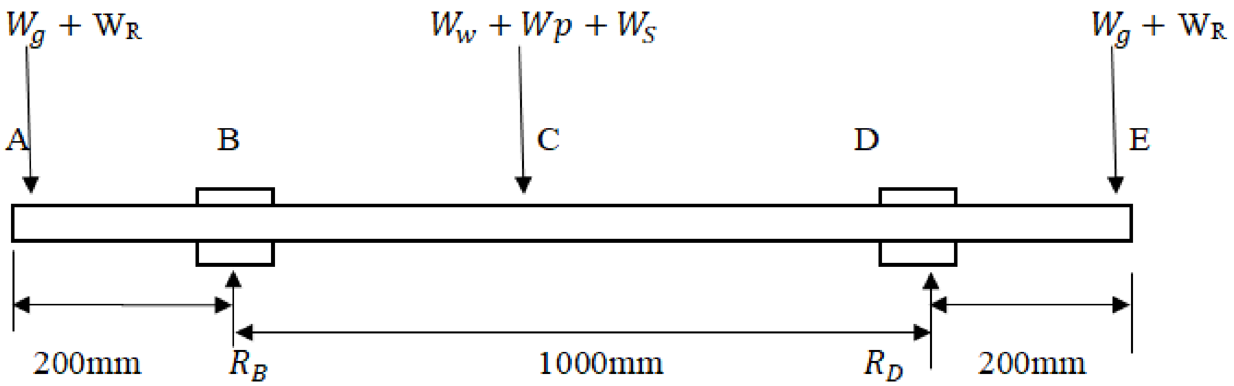

Figure 2.3. The bending moment on the shaft

Where W_w = Weight of the wax in moulds = 574.23N

W_g = Weight of the gear =14.92N

W_S= Weight of the shaft =16.68N

Wp = weight of rack / ejection pin assembly = 2366.2N

Resultant weight on shaft due to pinion according to Nwankwojike B. Nduka, (2012) is given by

$W_R = [W_n^2+W_g^2+2W_n+W_g\cos\varnothing]^{1/2}$

Where W_a is weight of gear =14.92N

Ø is pressure angle of gear

Wn is normal load

Wn =F/cosØ

where F = τA = 4040N

Wn = 4299.28N

The resultant weight due to the pinion,

W_R = 4300N

Total force at point A= $W_R + W_g$=4300N + 14.92 = 4314.92

Total load at point C= $W_w + Wp + W_S$= 2957.11N

Total force at point E = Total force at point A

The reactions of bearing R_B and R_D were determined by taking the moment about B.

$\sum M_D = 0$;

R_B (1000) + 4314.92(200) -4314.92(1200) – 2957.11(500)

$R_B = 5793.473N$

Also $\sum F_y = 0$

$-4314.92 + R_D + 5793.57 - 2957.11 - 4314.92 = 0$

$R_D = 4793.47N$

Taking downward forces to be negative (-) and upward forces to be positive (+), the shear forces acting on this shaft were computed as follows:

$F_{A-B} = -4314.92N$

$F_{B-C} = -4314.92 + 5793.47 = 1478.55N$

$F_{C-D} = -4314.92 + 5793.47 - 2957.11 = -1478.55N$

$F_{D-E} = -4314.92 + 5793.47 - 2957.11 + 5793.47 = 4314.91N.$

Thus the bending moments on this shaft are calculated as follows

$M_A = 0Nmm$

$M_B = -862984Nmm$

$M_C = -123709Nmm$

$M_D = -862984Nmm$

$M_E = 0\ Nmm$

Thus the maximum bending moment on the shaft is −123709Nmm. The maximum twisting moment of the shaft is 323200Nmm from equation (7). Since the turning of the shaft is gradual and steady, K_b = 1.5, K_t = 1.0 (Khurmi and Gupta 2013) the shaft diameter was determined using equation (6) as 25.01mm. Therefore a standard 25mm diameter solid mild steel shaft was selected.

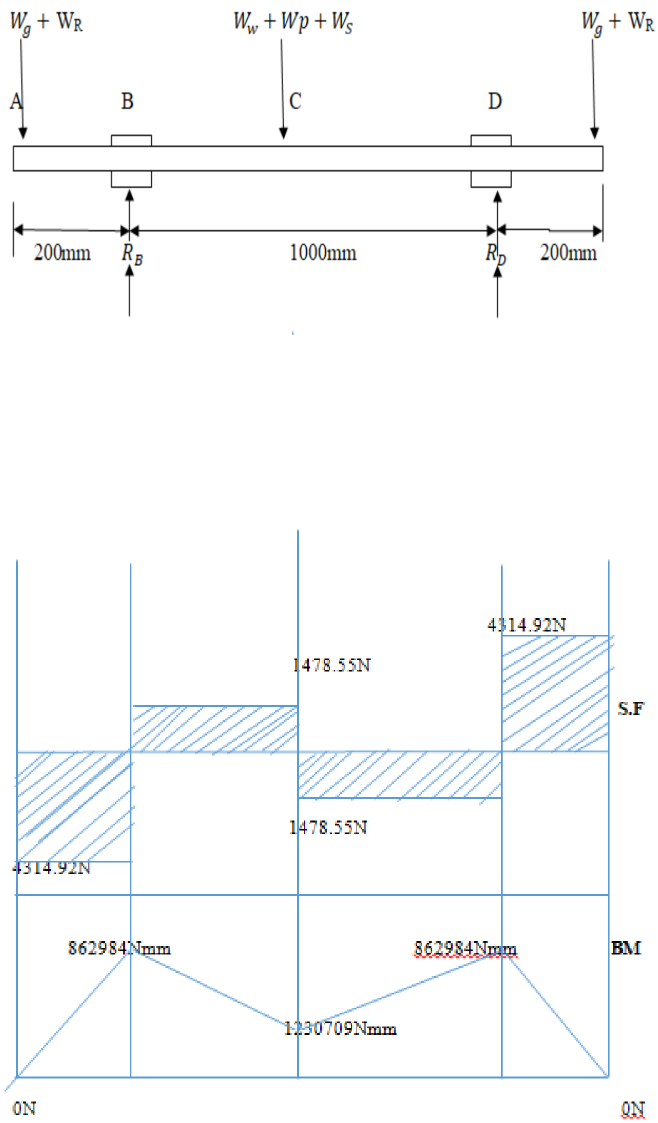

Figure 2.4. Shear Force And Bending Moment Diagram Of The Shaft.

2.2.3 VOLUME OF MOLTEN WAX REQUIRED PER OPERATION

Maximum length of candle = length of mould= 300mm

Diameter = 30mm

Maximum volume of candles =212,057.5mm³

Volume of wax required = 300 X 212,057.5 = 63,617,251.24 mm³

2.3 COOLING SYSTEM

The cooling system is basically water around the mid-section of the extrusion shaft. A water bath is fitted around the extrusion shaft but without it coming into contact with the shaft or the candle

Water is contained in a tank with inlet and outlet pipes where cold water from a tank (reservoir) placed at a higher level enters and warm water leaves through the exit pipe fixed at the bottom of the container.

Heat from the molten wax is conducted to the cold water since the material making the housing of the extrusion shaft is mild steel which has good thermal conductivity properties and then transferred out.
The cooling tank is made of a 2mm steel plate because of it good thermal conductivity properties.
Height of tank = length of mold =300mm
Desired length of machine =1400mm
Width =650mm
Volume of cooling tank = 300X 1400 X 650 — nVm
Where n= number of molds
Vm = volume of mould
Capacity of cooling tank =**232,285 mm³**

III. EXIT SYSTEM

This system is composed of a rectangular plate on which is fixed three hundred push rods. The design is such that has provision for free passage of the wick. Therefore hollow shafts of 25mm diameter are used. A rubber seal is fixed at the end of each rod to serve as stop for molten wax.

The rectangular plate is welded to the rack at its equilibrium position. The turning of the shaft brought about by the handle bar upward or downward movement opens the moulds for pouring or ejects the solidified candles.

3.1.1. Performance

In Nigeria, electrical power supply is unreliable. The candle making machine will be completely manually operated. From this the machine will operate at a rate

depending on power of the user. At 30rev/min, minimum of 1800 candles will be ejected every hour.
The candle making machine is designed to run continually for 12 hours. The bearing is well lubricated to reduce friction. With adequate lubrication, there is minimal friction on the components leading to minimum heat generation. The candle making machine is designed to produce a cylindrical shaped candle whose standard length is 18cm. The length can be adjusted on the mold.

3.1.2. Environment

The candle making machine can operate indoors and outdoors under normal working conditions. Keeping the machine on a flat surface will reduce vibration and prolong life.

3.1.3. Maintenance

Frequent lubrication of the candle making machine should be carried out. In addition to this general observation should be made to ensure that all the joints, bolts and nuts are well secured.
For the above candle making machine innovation, maintenance takes a short time since it is smaller and most parts can be easily accessed.

3.1.4. Aesthetics

The candle making machine is painted in blue to give it a fine finish. The color can also change according to customer specification.

3.1.5. Safety

All metal edges are also blunted out to prevent cuts and bruises.

3.2. ECONOMIC VIABILITY OF THE CANDLE MAKING MACHINE

With the objective of designing a candle making machine suitable for the candle industry in Nigeria, it is of paramount importance to get a machine which can be fabricated locally. From the available materials and manufacturing methods, cheap but appropriate combinations in order to get the most economically viable design.

Considerations put in place in the design and choice of materials for the various parts of the candle making machine included the type, direction and operating speed, machinability and cast ability of the part material, cost of material and fabrication, material property and aesthetics

IV. CONCLUSION

The current design of the candle making machine has overall dimensions of 1400mm length, 650mm width and the total height 1100mm. Focus is laid on the reduction of the bulk and overall price of the machine without compromising on the quality of the candle produced.

To achieve this, the working mechanism of the candle making machine is designed so that the total number of moving parts is reduced to a necessary few. All motion of the candle plodder is conveyed from the handle bar to the extrusion shaft through the pinion/rack arrangement. This modification aided by sufficient lubrication of the machine has also rendered the machine to be adequately water cooled.

Careful selection of materials observed while considering their availability without compromising on the durability of the candle making machine once it is fabricated. On the subsequent implementation of the above design, the industry will tend to develop having introduced a business opportunity. This is a blue ocean venture that will enable not only the creation of jobs but will also, in line with vision 2020, boost the Nigerian economy. This would also come by way of reducing the cost of candle.

This project is also aimed at cutting down the prices of candle making machines which are imported. By introducing this cheap and economical candle making machine into the Nigerian market, there would be competition with the imported machines and this would eventually lead to the reduction of candle prices. As is evident from the cost analysis of the candle making machine, it is much cheaper than the existing candle making machines and can be manufactured locally from the available materials.

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