**International Journal of Academic Engineering Research (IJAER)**
**ISSN: 2000-001X**
**Vol. 2 Issue 4, April – 2018, Pages: 9-16**

# Development of a Paint Mixing Machine

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***Abstract****: Paint production is an important process which has wide applications in several fields. The report entails the development of a paint production machine. The machine essentially comprises of a 3 kW variable speed electric motor, a ball valve, a pillow bearing, 3 mm thick stainless steel cylindrical tank and a stirrer assembly that rotates in the tank with four baffles to control the splashing. Performance evaluation of the developed paint production machine was carried out with the production of emulsion paint at different stir speed ranging from 100-500 rpm. From the result obtained, increase in stir speed beyond 300 rpm leads to decrease in paint viscosity as well as production time. In conclusion the machine has a fast production time than conventional machine while also being environmentally friendly and cost effective.*

**Keywords:** Emulsion, paint, stir speed viscosity

## 1. INTRODUCTION

Paint production is an important process which has wide applications in several fields. Paint is a term used to describe a number of substances that consist of a pigment suspended in a liquid or paste vehicle such as oil or water. With a brush, a roller, or a spray gun, paint is applied in a thin coat to various surfaces such as wood, metal, or stone. Although its primary purpose is to protect the surface to which it is applied, paint also provides decoration. Under adverse conditions, the surfaces of materials tend to rust, disintegrate, corrode and crack resulting in wear. However, these effects can be prevented or managed with various surface coating medium such as wallpapers, plastic sheet, chrome, silver plating and paint which have being identified and applied to decorate and smooth out any surface roughness or irregularities (Jonathan, 2009). According to Adamu *et al.* (2014), a paint is composed of pigments, solvents, resins, and various additives. The pigments give the paint colour; solvents make it easier to apply; resins help it dry; and additives serve as everything from fillers to ant fungicidal agents. Today, paints are used for interior and exterior house paintings, boats, automobiles, planes, appliances, furniture, and many other places where protection and appeal are desired.

Paint is defined as an engineered material made of several ingredients such as resin, solvent, pigments and additives that are mixed together to create a specific product with its own unique properties (Rodger, 2008). It is classified based on purposes and area of applications. A paint whose diluent of formulation and medium of cleanliness is solvent is refers to as „gloss paint. This type of paint can be formulated for car surface coating, refinery equipment coating, road marking purposes, varnishes and so on (Rodger, 2008; Alireza et al., 2009). While a water base paint is term as an emulsion paint which can be applied for architectural building (Michael, 2005; Rodger, 2008). It can be formulated from four major components, be it solvent base or water base type (Michael, 2005). These components are resin (binder), pigments (sometimes in conjunction with extenders), solvent and additives (Rodger, 2008).

However, it has been established that, mixing binder, solvent, pigments and additives in random proportion will result to paint product, but its certified quality depends on its ability to meet standard specification test, where its best performance after application tells and differentiate it from low quality product (Turner, 1999; DuPont, 2010; Shawn, 2011; PAN, 2013). Thus, having knowledge of the appropriate proportions of each component of the paint to be added during formulation will give rise to a desired quality product as may be proved from analysis of its physico-chemical/physico-mechanical test before and after application (Alireza et al., 2009).

In general, the manufacturing process of solvent based, high solids and water based products is similar in all paint production plants and includes the following process steps: dissolution of solid materials, mixing of different liquids or of liquids with solid materials, further mixing to fulfil required specifications regarding viscosity, colour and other characteristics, sieving and filtering of base materials, intermediate and end products.

Some of the problems bedevilling developing countries are the problem of unemployment, decline in Gross Domestic Products (GDP) etc. In recent times, there have been agitation for local contents to develop indigenous capacity in the production or manufacturing industries. With the abundant human manpower and the relatively simple technology of paint production, resources (time and money) can be effectively geared into paint production thereby leading to increase in GDP. As such, Nigerian economy, would have immense capacity to generate the much desired huge, stable and predictable revenue. This will also solve the problem of paint availability to the medium and low class earners.

The aim of the project is to develop a small scale paint production machine. The design and fabrication of the paint production machine is feasible, sustainable and cost effective due to the fact that that most of the materials for its development are locally sourced. Also, the design and fabrication of a small scale machine capable of high quality paint at optimum cost, attained from the collection of locally sourced materials that are easy and cheaper to procure. The advantages of this novel is the reduction of unemployment and development of indigenous capacity because smaller cells of individuals will be able to produce their own paint without reliance on large companies for their services. Furthermore, importation of some these products will be reduced, subsequently improving the economy in the long run. There will also be reduction in waste produced since material are sourced locally scrap metal and other useful materials can be recycled and reused in the fabrication process or maintenance of already existing models. The work contributes to knowledge as via the development of a small scale machine for paint production and analysis and performance evaluation of the paint production machine.

## 2. Materials and methods

For the design of the small scale paint production machine, the following factors were taken into consideration in the development of all parts of the machine:

i. Minimum energy requirement

ii. Simplicity in design to ease fabrication

iii. Cheap source of raw materials.

### 2.1 Materials selection

Materials selection one of the critical issues faced by designers. Materials are selected for the purpose of ease of machining, serviceability with all other mechanical inclusive of the design consideration. To identify the best material for the job, it must serve its use with the consideration bearing the most minimum cost. The following were considered for material selection during design and fabrication so as to obtain high efficiency and reliability of the machine; availability, cost consideration, favourable mechanical and chemical properties, non-corrosiveness to avoid contamination, sustainability of material for the application, good weld-ability and size and weight of materials.

The material used for the fabrication were selected after careful study of its physical, mechanical, chemical and aesthetic characteristics. For the purpose of this work, due to economic considerations, and material availability as well as the type of paint the machine will be required to produce which is emulsion paint (water based paint), stainless steel were mostly used for the container and the shaft due to its corrosion resistance properties.

The following machine components were employed in the construction of the small scale paint production machine:

i. Cylindrical container/tank
ii. A variable speed electric motor
iii. Bearing support
iv. Machine frame
v. The control system
vi. Shaft
vii. The leg and stand orientation
viii. Outlet incorporated with a filter/sieve.

Details of the different components of the paint mixing machine is presented in Table 1.

**Table 1: Component Description**

| S/N | Component | Function | Material | Selection Criteria |
|---|---|---|---|---|
| 1 | Cylindrical Container/Tank | It holds the paint ingredients for the mixing process | Stainless steel | Corrosion resistance<br>Attractive appearance<br>Lower maintenance<br>Higher strength and hardness |
| 2 | Shaft | It transmits torque and motion from the electric motor to mix the ingredient in the container | Stainless steel | Corrosion resistance<br>Lower maintenance<br>Higher strength and hardness |
| 3 | Filter/Sieve | It filters out clogged paint and foreign contaminants from final product | Stainless steel | Corrosion resistance<br>Lower maintenance |
| 4 | Stand | It supports the machine firmly | Angle iron | Low cost<br>High strength<br>Durability |
| 5 | Pillow bearing | It holds the bearing into position | Stainless | Low cost |

| | | | | |
|---|---|---|---|---|
| | | | steel | Firm support<br>Better wear resistance |
| 6 | Bearing | To allow free movement of the shaft | Stainless steel | Stability<br>Suitability<br>Not easily damaged and available |
| 7 | Motor stand | To support motor and absorb vibrations | Mild steel | High strength<br>Durability |
| 8 | Outlet | For drainage of the paint | Stainless steel | Corrosion resistance<br>Attractive appearance<br>Lower maintenance |

The design drawing of the paint production machine is shown in Figure 1.

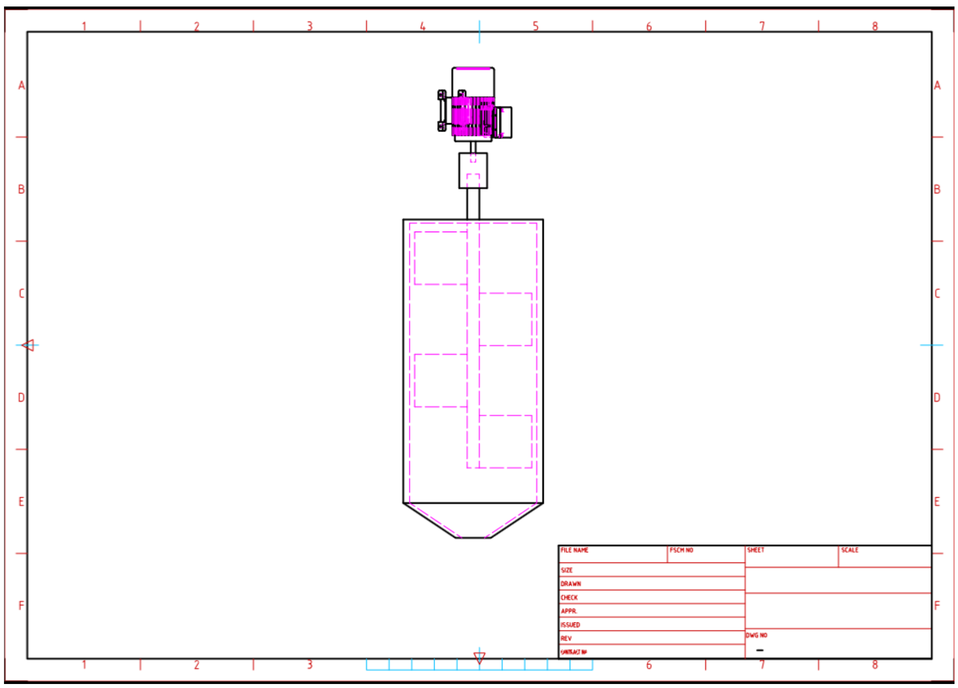

Figure 1: Design Drawing

### 2.2 Design calculations

This comprises of the following parameters

i. Volume and capacity
ii. Thickness of the wall of cylindrical tank
iii. Speed of the electric motor
iv. Torque transmitted by the electric motor.
v. Diameter of the shaft

#### 2.2.1 Volume and Capacity

Since the tank is cylindrical, the volume is given by equation 1

$$V = \pi r^2 h \qquad (1)$$

Where;

v is volume, r is radius given as 0.2 m and h is height of the tank given as 0.8 m

Therefore $V = \pi \times O.2^2 \times 0.8$

$$V = 0.10053\ m^3$$

This means the volume of the cylindrical tank is approximately 100 litres

#### 2.2.2 Thickness of the Wall of Cylindrical Tank

The thickness of the cylindrical tank (T) is given as equation 2

$$T = \frac{P \times d}{2 \times \sigma \times \eta} \qquad (2)$$

Where

P is the internal pressure ($0.5\, N/mm^2$); $\eta$ is the joint efficiency (0.95); $\sigma$ is the circumference stress (5.26 $N/mm^2$)
d is the diameter of tank (40 mm)
Therefore

$$t = \frac{0.5 \times 40}{2 \times 5.26 \times 0.95}$$

$t = 2\, mm$, designed as 3 mm using a safety factor of 1.5 mm

### 2.2.3 Speed of the Electric Motor

According to Powers, (1990), the density of emulsion paint is about 1200 $kg/m^3$. Hence Srivastara and Prasad (2000) noted that a 3 kW electric motor is adequate to stir fluid whose density falls between (1000-1500) $kg/m^3$ at a speed of (100-500) rpm. Therefore a 3 kW motor should be employed.

### 2.2.4 Torque Transmitted by the Electric Motor

According to Shigley and Mischke, (1996), the torque transmitted by an electric motor can be given by equation 3;

$$T = 9.55 \frac{p}{n} \qquad (3)$$

Where:
$T$ is the torque transmitted (Nm); $p$ is the power of the electric motor (watt); $n$ is the number of revolution per minute of the electric motor (rpm)
For the operation of the machine, a 3 kW electric motor is required;
Using equation 3, the developed torque is calculated as

$$T = 9.55 \frac{3000}{250}$$

$$T = 114.6\, Nm$$

### 2.2.5 Diameter of the Shaft

The shaft is a solid shaft having little or no axial loading. According to Hall *et al.*, (1980), the diameter of a shaft is given by the equation 4.

$$d^3 = \frac{16}{\pi s_s} \sqrt{(k_b\, m_b)^2 + (k_t m_t)^2} \qquad (4)$$

Where
$m_t$ is the torsional moment (Nm); $m_b$ is the bending moment (Nm); $k_b$ is the combined shock and fatigue factor applied to the bending moment
$k_t$ is the combined shock and fatigue factor applied to the torsional moment
$s_s$ is the allowance shear stress ($N/m^2$)
For this type of vertical shaft bending moment is zero i.e. $m_b$= 0
Therefore the first equation reduces to equation 5

$$d^3 = \frac{16}{\pi s_s} \sqrt{(k_t\, m_t)^2} \qquad (5)$$

According to Hall *et al.* (1980), the shear stress $s_s$ for the stainless steel material used for shaft is $55 MN/m^2$ and for the rotating shaft with minor shock load $k_t$= 1.0
Also torsional moment $m_t$ is given by equation 6

$$m_t = \frac{P}{2\pi N} \qquad (6)$$

Using a 3 kW, 400 rpm electric motor, the torsional moment in the shaft is calculated as

$$m_t = \frac{3 \times 10^3 \times 60}{2 \times \pi \times 250}$$

$$m_t = 114.57\, Nm$$

Therefore diameter of the shaft will be given as

$$d^3 = \frac{16}{\pi \times 55 \times 10^6} \sqrt{(1.0 \times\ 114.57)^2}$$

$$d^3 = 1.0607 \times 10^{-5}$$

$$d = 0.0219m$$

20 mm diameter shaft is selected to the nearest standard size

## 2.3 Fabrication

Some of the materials required for the fabrication were bought out while some were purchased.
Since the design entails that the electric motor will be placed on the cover of the container, which will also hold the stainless steel shaft via the pillow bearing. A stainless steel sheet with thickness of 3 mm was acquired, marked out with a compass and cut out into a circular shape of 420 mm in diameter with the aid of a cutting disk. After wards, four point were marked out, which signified where the bolts will be inserted to hold the pillow bearing in place. These four points surrounded a central point marked out at a diameter of 24 mm for the passage of the shaft. The next stage was the punching of the holes, which was then taken to a vertical drilling machine to be drilled. Hinges were then welded to the side of the cover to enable easy accessibility to the shaft for maintenance purposes.
The mixer comprises of the shaft and the blades, first of all the shaft was operated on a lathe machine to bring it to 20 mm in diameter so it could fit into the drilled hole in the cover as well as the pillow bearing and then stainless steel sheets were cut into 4 rectangular pieces with a length of 150 mm and a width of 100 mm. The stainless steel sheet were welded to the shaft, two at each side for balance. The stirrer assembly comprising of the stirrer blades and shaft is shown in Figure 2.

**International Journal of Academic Engineering Research (IJAER)**
**ISSN: 2000-001X**
**Vol. 2 Issue 4, April – 2018, Pages: 9-16**

Figure 2: Diagram of the Stirrer Assembly

### 2.4 Final assembly

After all the components for the machine were designed and fabricated, it was then assembled as a unit. Angle iron were cut to 600 mm and made into a tripod stand to support the cylindrical container, a rectangular beam was welded across the top of the cylindrical container to support the cover and the electric motor. The shaft and the pillow bearing were coupled together on the cover and a motor stand was also put in place to support the electric motor on the cover of the container. The filter mesh was incorporated into the outlet and then it was screwed onto an already threaded cylindrical metal piece at the bottom of the container. This is done to ensure that the outlet can be removed for cleaning of the filter mesh as well as to pave way for any other maintenance task required to be carried out on the machine.

The paint mixer at the developmental stage is shown in Figure 3.

Figure 3: The paint mixer at the developmental stage

The developed machine is shown in Figure

Figure 4: The developed paint production machine

### 2.5 Performance Evaluation of the Paint Production Machine

The performance evaluation of the paint production machine was carried by the production of emulsion paint using the chemicals listed in Table 2.

**Table 2: Table of Paint chemicals used and their functions**

| S/N | Chemicals | Functions |
|---|---|---|
| 1 | Calgon | Disperses particles and make them dissolve properly |
| 2 | Titanium-dioxide | Adds coverage to the paint when it is applied<br>Makes the paint brighter |
| 3 | Nitrocellulose | It acts as a thickener |
| 4 | Formalin | It is a liquid preservative |
| 5 | Butyl glycol | Enables paint to dry fast |

International Journal of Academic Engineering Research (IJAER)
ISSN: 2000-001X
Vol. 2 Issue 4, April – 2018, Pages: 9-16

| | | |
|---|---|---|
| 6 | Anti-fungal paste | It acts as an anti-fungal agent |
| 7 | Acrylic | Holds the paint on surface, without it paint will run off the surfaces |
| 8 | Calcium carbonate | It acts as the base or foundation of the paint |
| 9 | Ammonia | It acts as a preservative |
| 10 | Pigment paste | Gives colour to the paint<br>Used for interior painting |
| 11 | Pigment oxides | Gives the paint colour<br>Used for exterior painting |
| 12 | Deformer | Used for preventing foaming in paints |

## 2.6 Production of emulsion paint

For the production of 30 litres of paint, 30 litres of water was measured and poured into the drum. 130 g of titanium-dioxide, formalin and anti-fungal paste was poured into the water and it was dispersed in the water with calgon (dispersant) then the machine was run for about 1 minute to prevent caching of the ingredients. The next phase was the addition of ¼ of the bag of calcium carbonate and acrylic before the machine was run for another 20 minutes. The final phase was the addition of 130 g each of pigment (oxide or paste depending on the application) nitrocellulose, butyl glycol and liquid ammonia respectively to the mixture and running the machine for another 10 minutes before drainage, subsequent filtration and canning.

## 3. Results and discussion

The total time for the production of the 20 litres emulsion paint was 40 minutes, this comprised of a combined mixing to of 30 minutes with loading and unloading time of 10 minutes. Conventional paint production machines have a similar mixing time of 30 minutes but their loading and unloading time is 30 minutes, due to the fact that they have to manually filter the paint. This takes total production time to 1 hour for conventional method.

The emulsion paint produced is Figure 5.

Figure 5: Emulsion paint produced

Using a variable speed motor, it was observed that increases in speed of the mixer led to decrease in the viscosity of the paint as shown in Table 2.

**Table 2: Effect of Stir Speed on Paint Viscosity**

| S/N | Stir Speed (rpm) | Paint Viscosity ($m^2$/sec) |
|---|---|---|
| **1** | 100 | 0.0018 |
| **2** | 200 | 0.0016 |
| **3** | 300 | 0.0012 |
| **4** | 400 | 0.00009 |
| **5** | 500 | 0.00007 |

Figure 6 studies the effect of stir speed on paint viscosity. Increase in stir speed decreases the viscosity. Hence the optimum stir speed was found to be 300 rpm which sufficient for the required service condition to give the paint a corresponding kinematic viscosity of 0.0012 m2/sec.

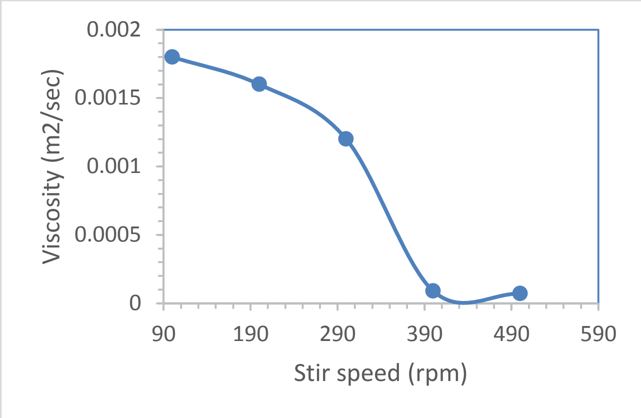


Figure 6: Effect of stir speed on paint viscosity

The effect of stir speed on production time was also studied and presented in Table 4.

**Table 4.: Effect of Stir Speed on Production time**

| S/N | Stir Speed (rpm) | Production time (mins) |
|---|---|---|
| **1** | 100 | 70 |
| **2** | 200 | 60 |
| **3** | 300 | 40 |
| **4** | 400 | 40 |
| **5** | 500 | 38 |

Figure 7 explains the effect of stir speed on production time. Increase in stir speed decreases the production time. This is due to the fact that increase in the stir speed increases the collision rate of the reacting particles thus driving the reaction to completion. The optimum stir speed was found to be between 300-400 rpm. Further increase in speed beyond this decreases the paint yield due to excessive agitation that leads to splashing of the reacting particles.

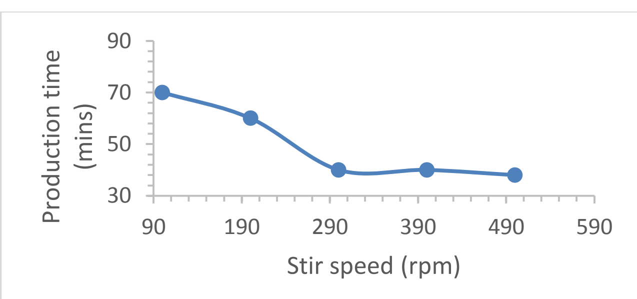


Figure 7: Effect of Stir Speed on Production time

Since it takes my paint production machine 40 minutes to produce 20 litres of paint, this means that its takes 2 minutes to produce a litre of paint. Conventional machine takes an hour to produce the same amount, which mean that it takes them 3 minutes to produce a litre of paint. Which means my machine produces paint at a faster rate than the conventional paint mixing machine. The increase in speed of the mixer led to decrease in the viscosity of the paint because paint falls under the category of shear thinning fluids that exhibit pseudo plastic behaviour, which entails that as increase in rotational speed of the mixer will lead to an increase in shear stress of the fluid which decreases the viscosity temporarily. As soon as the speed drops and shear stress is reduced, this viscosity starts to increase systematically and the fluid thickens back. Pseudo plastic behaviour allows paint to be applied to a wall using a brush which imparts shear stress on the paint after which paint thickens and solidifies on the wall.

## 4. Conclusion

In conclusion, design and fabrication of a paint mixing machine with a capacity of 100 litres was achieved, performance evaluation was carried out on the machine by the production of emulsion paint and it was observed that the machine had a faster production time than conventional machine while also being environmentally friendly and cost effective.

### 4.2 Recommendations

The following are recommended:

i. More locally sourced materials should be used to develop more paint production machine.
ii. Adequate measurement of the mixing ratio should be made to enhance mass production.
iii. Future designs of the paint production machine should include a viscometer for monitoring the viscosity, as well as a heating element so that the machine will be able to produce other forms of paint aside from emulsion paint
iv. An automatic feeder system can be put in place to improve speed and efficiency of the production process especially on a large scale.

## REFERENCES

Adamu, A. K., Yakubu, M. K. and Olufemi Kassim Sunmonu (2014). Characterization of Emulsion Paints Formulated using Reactive-Dyed Starch as a Pigment. International Conference on Biological, Chemical and Environmental Sciences (BCES-2014) June 14-15, 2014 Penang (Malaysia).

Alireza, A., Rosiyah, Y., and Sengweon, G. (2009). Alkyd resins are still of major important binders in organic coatings. Malaysia Polymer International Conference (MPIC, 2009). Malaysia.

DuPont (2010). DuPont Refinish Product Reference Guide and Specifications (2010). E.I. DuPont de Nemours and company. PP. 23 and 40.

Jonathan, F. (2009). Paint, heal thyself: Chemicals in the shells of shrimps may lead to coatings that can heal themselves. Retrieved from http://www.forbes.com/fdc/welcome_mix.shtm on 10-06-2017.

Michael, D.T Clark. (2005). X-polymer-D-paint and pigment. Retrieved from http://www.paint-quality.com/media_centre/paint publications/edu/module.pdf on May 20, 2017.

PAN (2013). Peugeot Automobile Nigeria (PAN) Ltd standard test specifications. PAN paint data sheet. Retrieved from PAN laboratory data file on May 20, 2017.

Rodger, T. (2008). Paint technology handbook. CRC press Tailor and Francis group. Boca Raton, London. pp. 79-222.

Shawn, C. (2011). Latex paint and oil paint. Via www.colerepair.com/latexvs oil/paint Retrieved on May 20, 2017.

Turner, G.P.A (1999). Introduction to Paint Chemistry and Principles of Paint Technology. 2ndedition, ICI paints division, Slough, London. pp. 56-57