A Paint Mixer for Small Scale Paint Production

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ABSTRACT

A paint mixer (for small scale paint production) comprising of a stainless steel cylindrical tank, an agitator/stirrer, and a 2HP electric motor was developed and tested. V.-Belt and pulleys were used to transmit the torque from the electric motor to the shaft and stirrer through two vertically placed bearings. The pulleys used are one step each. One pulley is mounted on the motor while the other is mounted on the shaft. This is to enable the mixer to run at one single speed.

The performance test analysis conducted showed that the mixer has optimal capacity of 136 kg/hr, with an efficiency of 97.2% when producing emulsion paint with the stirrer running at 1430 rpm. The peripheral speed of the belt and current developed per sample case was measured using tachometer and clamp ammeter. Shaft speeds were calculated. Results showed that the mixer is capable of mixing the materials at various speeds. All materials used in the fabrication of this machine were sourced locally, and the estimated cost of producing one unit of the machine is seventy five thousand naira (N75, 000) only. The machine reduced drudgery and tedium in small scale paint production and also enhanced production quantity, quality and profit.

(Keywords: paint mixer, electric motor, production quality, fabrication)

INTRODUCTION

Paint is the term used to describe a group of substances that consist of a pigment suspended in a liquid or paste 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 the primary purpose is to protect the surface to which it is applied, paint also provides decoration. There is no doubt that the beauty of a house lies in the quality of paint used for its finishing. House paint adds value and beauty to both old and new buildings. House paints are of different types, which include emulsion, texture or texcote, flexcote, and marble trowel paints, etc.

Paints can be produced at the cottage, small-, medium-, and large-scale levels. Some of the machines required for operations include roller mills, sand mills, attrition mixers, etc. An electric manual mixer is one of the most important machines used in paint production (Adenekan, 2004).

The era we are into has witnessed an enormous increase in production and construction works using woods, stones, concrete and metals in which paints are used both for protection and appeal. This has resulted to great increase in demand for paint and paint production equipment such as industrial paint mixer/shaker. Between technology and increased output is the development of efficient machinery and equipment to drive production processes (Onwalu, 2011).

Statement of Problem

The industrial mixer being the most important machine in paint production, needs to be effective, affordable, and durable. Most mixers that are imported into developing nations like Nigeria, are too expensive and are not affordable to the cottage and small-scale paint producers. As the world becomes highly competitive, countries are persistently exploring ways to achieve low-cost and efficient production of products using affordable, less complex, culture friendly, cottage, small, and medium machines and equipment (Onwualu, 2011).

The industries in Nigeria as a developing country employ majority of the population belonging to the illiterate, low and middle literate classes. Therefore, the use of simple technology machines/equipment becomes the only panacea to for cheap and high-quality competitive goods towards reducing the high dependence on imports (Onwulau, 2011).

To this effect, there is a need to design and fabricate an indigenous industrial paint mixer with local raw materials to meet the demands of our local paint industries, which this work advocates.

Aim

The aim of this project is to design and fabricate a paint mixer (with rotary and vertically reciprocating moving impeller).

Objectives of the Project

- To design and construct a low-cost mixer fabricated with locally sourced raw materials.
- To encourage the establishment of cottage and small-scale paint industries.
- To fabricate a less complex, culture friendly mixer that can be operated with little or no skill.
- To contribute in the actualization of Nigeria vision 20:2020 by producing a production machine which can enhance industrialization, generate wealth and improve the standard of living for many.
- To increase the productivity in the paint industry by producing a low-cost mixer with a high-quality output.

These and many other things are the reasons the electrical mixing machines are developed and it is considered that this project will make life easier for the user.

Justification of the Project

Using this mixer in paint production will go a long way to encourage cottage and small-scale paint producers to adequately produce quality paints at low cost.

The production of processing/production machines is vital towards increasing the number of small and medium scale industries, generating employment as well as increasing the value addition and exports (Onwualu, 2011). This no doubt will encourage our young graduates to go into paint production since the cost of starting the business will be highly reduced as the equipment can be fabricated locally.

To those in rural areas where electricity is a limiting factor who as a result of this have stayed out of business, they can use low cost electric generator to power the mixer. Different capacities of the mixer can be fabricated, hence the mixer is designed and fabricated with the consideration of the maximum weight of the materials the mixer can mix; the speed of the motor that will produce the required rotary motion (force), the calculation of the factor of safety of the belt for the maximum load, the efficiency and reliability of the mixer. The materials that will withstand the forces were used. Furthermore, lubrication and proper alignment of the part were adhered to control noise.

HISTORICAL BACKGROUND AND LITERATURE REVIEW

Humans have seen the need to leave a mark on the world in the form of painted images since prehistory. If we look at how art evolved over the years, we can know a number of things about the people that created painted images and the societies they lived in. At some point, early man figured out that by mixing color giving particles known as pigments into a medium like water or saliva, paint could be created.

Historical Dates

Paint was first used as a protective coating by the Egyptians and Hebrews; who applied pitches and balsams to the exposed woods of their ships in ancient times. Early artists relied on easily available natural resources to make paints such as natural earth pigments, charcoal, berry juice, blood milkweed sap, etc. Later, the ancient Chinese, Egyptians, Hebrews, Greeks, and Romans used more sophisticated materials to produce paint for limited decoration such as painting walls.

The earliest American paint mill was built by Thomas Child (around 1700). The mill used a granite trough within which a granite ball rolled, grinding the pigment. Later (1869), patented by J. W. and H. Hyatt in USA, when they improved Parkesine as Celluloid, being the first commercial plastic that modern users would recognize. In 1905, paint and coatings research starts at North Dakota Agricultural College, now North Dakota

State University. Phenol-formaldehyde resins ("Novolac" resin) made by Leo Hendrik Baekeland, was patented in 1907 as a "Method of Making Insoluble Products of Phenol and Formaldehyde". These are better known as Bakelite.

During that same year, A.H. Munsell, a painter and art teacher, publishes his color notation system; the first useful description of a color space.

In 1912, dispersion polymerization of isoprene was patented in Germany by Kurt Gottlob (German patents 254 & 255). This used egg albumin or starch as emulsifier. Acrylic resins were also patented.

In 1913, Rosin-modified phenolic resins polyvinyl acetate were patented by Klatte and Rollet.

In 1914-18 First synthetic detergents developed in Germany during World War I. They were short chain alkyl naphthalene sulphonates. Similar materials are still used.

In 1916 Joel H. Hildebrand made strides in solubility theory for non-electrolytes.

In 1917 Staudinger presents the macromolecular concept at a meeting of the Swiss Chemical Society. He received the Nobel prize for this discovery in 1953. Stuart Croll NDSU 2009 6 1920 Staudinger publishes macromolecular concept: Staudinger, H. Ber. Deut. Chem. Ges.1920, 53, 1073.

During that same year, DuPont scientists made a fast-drying lacquer from nitrocellulose. Dupont had a background with nitrocellulose since it had been making it for explosives since the 1890s.

A patent applied for use of Aluminum and Zinc Stearates as pigment stabilizers in oil paints (US 1,421,625 in 1922). Metal soaps had been known to help stabilize pigments for some time before this.

In 1922 DuPont patents nitrocellulose lacquers. and in 1923 Cellulose nitrate lacquers were first used on cars ("Duco" from DuPont). The use came because a low viscosity resin (sprayable at useful solids) was discovered by DuPont in 1920 (see above), as opposed to the very high molecular weight resins that been investigated prior to that. This was taken up by many of the companies that later became General Motors, Chrysler, and Ford. Ford most famously used it as one of the enablers for assembly line production. Previously, the oil paints had needed 3–6 weeks to cure and be dry to the touch on the vehicle.

In 1925, BASF (Glasurit-Werke) introduced nitrocellulose car paints in Europe. The "Tamol" name was first used for compounds in dying, tanning, and textile industries (see 1968).

From 1921 – 1925 Alkyd resins were introduced but they were slow drying, even when baked. Note: one can trace polyesters back to Berzelius who condensed glycerol tartrate in 1847. Maleated rosin varnish gums were also introduced. In the 1920s, spray guns were developed. R.H. Kienle of GE develops unsaturated alkyds.

In 1926 the Paint Research Station was founded in the UK, GE introduced Glyptal resins (glycerol phthalate), and DuPont introduce alkyd resin (glycerol/phthalic anhydride/linseed oil). Alkyd modified oil paints and then alkyd paints were eventually used on cars and household appliances.

In 1927, R. Kienle et al. of G.E. patents alkyds, but the patent is ruled invalid in 1935 due to prior art, which enables other companies to make and sell alkyds (after 1935). Stuart Croll NDSU 2009 was probably responsible for the combination of the word alkyd – from the condensation of alcohols and acids.

In 1928, R.H. Kienle and C.S. Ferguson present a paper at an ACS meeting in September, entitled "Alkyd Resins as Film-Forming Materials.

In 1930, Paul Flory starts work on molecular weight distributions (experimentally and theoretically) and shows that step-growth polymerizations follow the Gaussian distribution for molecular weight. Rehbinder, Lagutkina, and Wenstrom, gain first insights into steric stabilization of colloidal particles, Z. Physik. Chem. (1930).

In 1931 Commission Internationale de l‟ Éclairage, CIE, meets in Cambridge and defines the primary stimuli for color vision to be red (700 nm), green (546.1 nm), and blue (435.8 nm). The paint roller was also invented by Norman Breakey of Toronto in that year.

In the 1940s, Styrene-Butadiene synthetic rubber latex developed as the "Mutual Recipe" in the USA (75% butadiene, 25% styrene with a rosin soap and a little mercaptan) since isoprene did not give a useful material. Production started in

1943. This era also saw the use of Urethane Oils and alkyds, thermoplastic acrylics for lacquers, thermosetting acrylics for enamels, silicone copolymers [1]. Crosslinking latexes were also introduced.

In 1957, George Brewer developed anodic electrophoretic coatings at the Ford Motor Company. A 1960 US patent 2930775, was issued for composition of a dispersing aid for pigments etc., maleic acidisobutylene copolymer ~ 1:1, corresponds to Tamol 731.

From 1961–1965, Fluoropolymers were first introduced (Teflon).

In 1962 Texanol was registered as a trademark by Eastman Chemicals and found use as a coalescing aid for latex paints by Eastman together with several customers and other resin suppliers (Del Rector, Eastman Chemical Company, private communication). The discovery of the compound was somewhat accidental.

Early 1960s-1970 saw the patents of the first polyurethane dispersions (in water) (D. Dieterich), "Aqueous Emulsions, Dispersions And Solutions Of Polyurethanes; Synthesis and Properties," Progress in Organic Coatings, 9 p. 281 – 340, (1981); Dr. R. Roesler, Bayer Chemicals, private Communication] Stuart Croll NDSU 2009 12 1964. Epoxy, acrylic and other resins were used for anodic electrophoretic primers – pioneered by Ford Motor Company (Brewer, 1964). The first electrophoretic (otherwise known as electrodeposition) paint tank filled at Ford Wixom works by PPG was completed during this period and Eastman built the first plant producing Texanol as a commercial chemical. This coalescing additive made the application of latex paints possible over a much broader range of environmental conditions. [Del Rector, Eastman Chemical Company, private communication] 1966–1970 Ultraviolet and electron-beam cured polymer coatings appear for very fast cure requirements with low solvent emissions. Non-aqueous dispersions of acrylics are developed.

In 1967, Los Angeles County invoked EPA Rule 66(5) that regulated the use of potentially harmful solvents in industrial coatings. This was to restrict photo-chemically (helped by UV) reactive solvents that combine with nitric oxide from automobiles and industrial processes to produce the well-known "smog" (smoke/fog). Calculations quickly showed that high solids coatings would be necessary. The world changed for coatings in the US. High Solids means ~ 60% solids by weight or higher (DiCarlo et al., 2010).

RECENT ADVANCEMENT IN PAINT PRODUCTION

Until modern age, paint was made mostly by the artist themselves. Water color became popular when art became a hobby of the wealthy. In 1776, William Reeves began a company that produced cakes of water color. In his process he realized that the cakes of color he produced could be kept from cracking by adding small amount of honey into the formula.

By the early 1700s producing paint became a profession. The first of the two modern day Pigments was Prussian blue, derived from iron. It is important because it tends not to fade, unlike those made from lapis lazuli.

The second pigments of the modern age are cobalt green. An interesting fact about cobalt is that only recently scientist discovered that what people have been using to make pigment for century has magnetic properties that are ideal for the computer age.

Industrialization changed the world of color completely with the paint-tube. Paint companies figured out a way of suspending pigments in linseed oil, and also keeping the paint from drying too quickly. Till today the advances in science and technology aid the development of paint sand pigments that can be applied better, and last for a lifetime for generations to appreciate.

CONTRIBUTIONS TO KNOWLEDGE

This work introduces a number of contributions to the knowledge base that are summarized as follows:

a. We propose a better method of paint making in local paint production.
b. We suggested the optimization of condition required to maximize the output gain for paint production.
c. We propose a new technological technique to improve the level of productivity.
d. We suggested the optimization of performance characteristics when used for household beatification, environmental design, interior and exterior decoration.

PAINT MAKING

There are four most important components in paint making:

The Resin: The resin is the main part of the paint which forms a film on the surface. It is typically a non-hazardous component like linseed or acrylic.

Solvent: Solvent keeps the paint a liquid state until the solvent evaporates after painting. In oil-based paint, the solvent is derived from a petroleum distillate and can include hazardous ingredients like mineral spirits, toluene, and xylene. The solvent in latex paint is water.

Pigments: Pigments provide the color and covering power. The major pigments used presently are relatively nontoxic. Some highly colored pigments may contain heavy metals such as chromium, cadmium or arsenic. Older paints may contain lead.

Additives: Paint may also have additives. Some types of additives include stabilizers, dryers, thickeners, and preservatives. Some latex paints contain a mercury-based fungicide preservative.

Here are some tips for using paint. Avoid having leftover paint by buying only the amount you need for the job. Use up any leftover paint. If you cannot use it up, see if a friend or neighbor is willing to use it. If paint is unusable, dispose of it properly. Never put liquid paint in the trash or pour it in a drain or storm drain. Small amount of paint can be solidified. If you choose to solidify paint, be sure to do so in a well-ventilated area. Make sure there are no possible sources of spark or fire and wear protective gloves.

To solidify small quantities, such as an inch or two in the bottom of a can, simply remove the lid, add non-flammable absorbent and stir until all the liquid is absorbed. Then the paint is solidified, place the absorbent and paint cans inside a garbage bag, seal the bag tightly and dispose of it in the trash can.

METHODS OF PAINT MIXING

There are two methods of paint mixing:

Traditional Paint Mixing: This method involves the use of wooden ladle and bucket. When the chemicals required for the paint are poured in a bucket, a wooden ladle is then used by the mixer to mix the paint to the required mixture. This method is not efficient since it is not only very laborious but also results in the waste of materials for the paint. This method is less expensive, but it is tedious and time consuming. It is possible that during the mixing of the chemicals, some are spilled cause a loss of materials for production.

Modern Method of Paint Mixing: The work of the paint mixing machine is to mix paint without the use of a wooden ladle. It is a mechanized method that replaces the use of wooden ladle to mix paint. The machine can be operated manually or electrically.

***Manually Operated Mixing* -** is done by fixing a handle on the top of the machine on the shaft to rotate it. This can be used anywhere in the rural areas where there is no electricity, thereby encouraging paint production in large scale.

***Electrically Operated Mixing* -** can be operated using an electric motor. The electric motor is fixed at the extreme of the machine, with a pulley on it; there is also a pulley on the shaft that connects the motor to the shaft through a belt transmission (v-belt), which then turns the stirrer that mixes the paint. This method is fast but requires electricity. When the required chemicals is poured into the stainless steel containers, the motor rotates and through the belt transmission it turns the shaft that in turn, moves the stirrer and mixes the chemicals for the paint to the required mixing time. After the required mixing time, the switch is put OFF and the tap can be opened for the mixture to be poured.

***Machine Maintenance* -** The machine has a very simple approach to its maintenance. This is because, it has few parts to be taken care of:

1. The bearing only needs to be lubricated regularly with grease, this increase the life span of the component
2. The bolt and nuts should be adequately tight.
3. The correct position of all its components should be maintained.
4. Retouch any rusting part of the machine with oil paint.
5. Safety measures should be put into consideration while working in the machine.
6. Do not expose the machine to rain.
7. Always clean the inside of the stainless-steel container, the shaft and stirrer immediately after use.

Safety Measures - Safety measures should be highly considered when using a mixing machine. The safety measures are given as:

a. The correct requirement should be used of the electric motor.
b. When the machine is working, the opening must be locked.

MATERIALS AND METHOD

Design Analysis

The constructed industrial paint mixer is operated with electric motor which transmits torque to the shaft (stirrer) through the belt. It has two pulleys. These are to enhance speed performance. Water is introduced into the tank before the machine is put on. Other materials can be added as the stirrer is rotating. As the stirrer rotates, it agitates the materials and when the desired mixture is obtained, it will be discharged through the tap provided at the base of the tank.

Parts of the Machine

The machine consists of:

1. Mixing vessel
2. Impeller / Rotating metal plate
3. Shaft
4. Belts/ Pulleys
5. Bearings
6. The metal stand
7. Opening and locking tap
8. Bolts and nuts

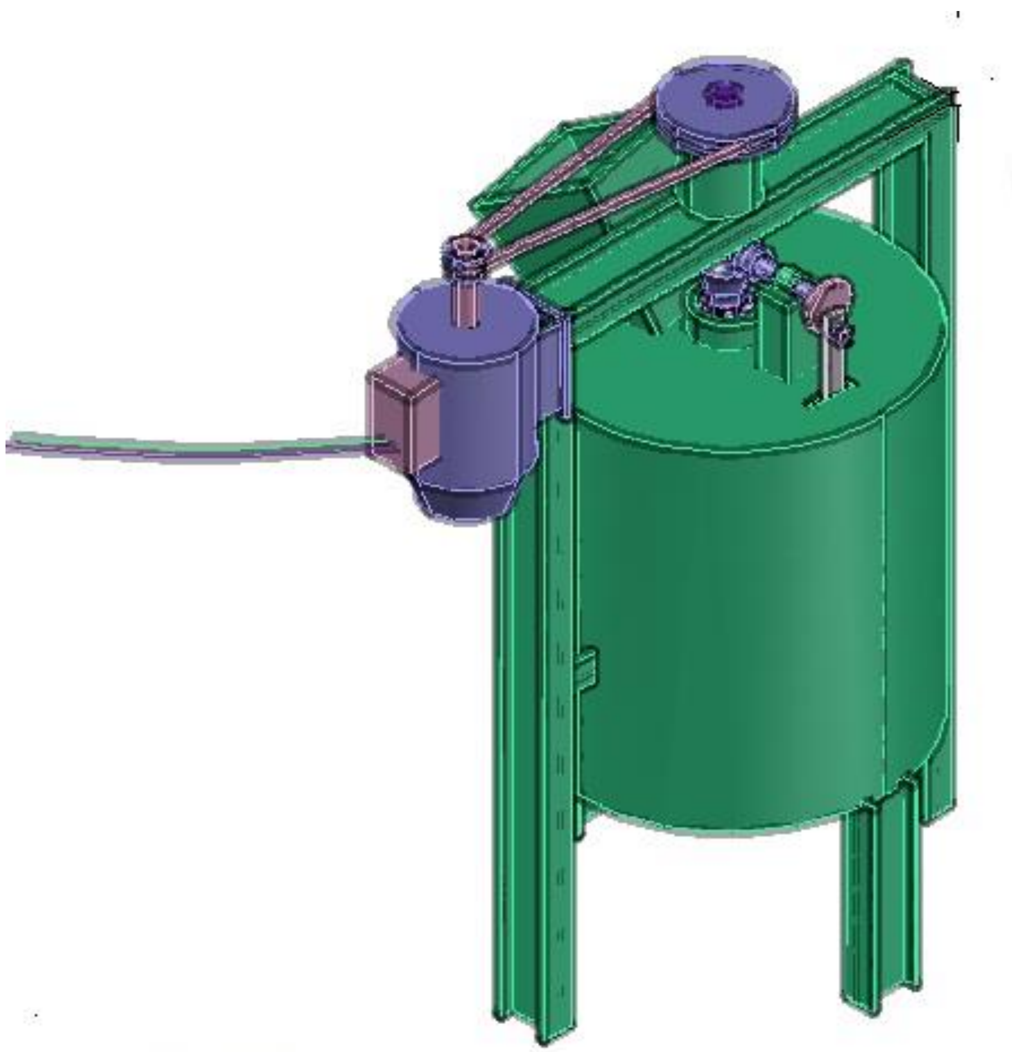

Figure 1: The Front Solid View.

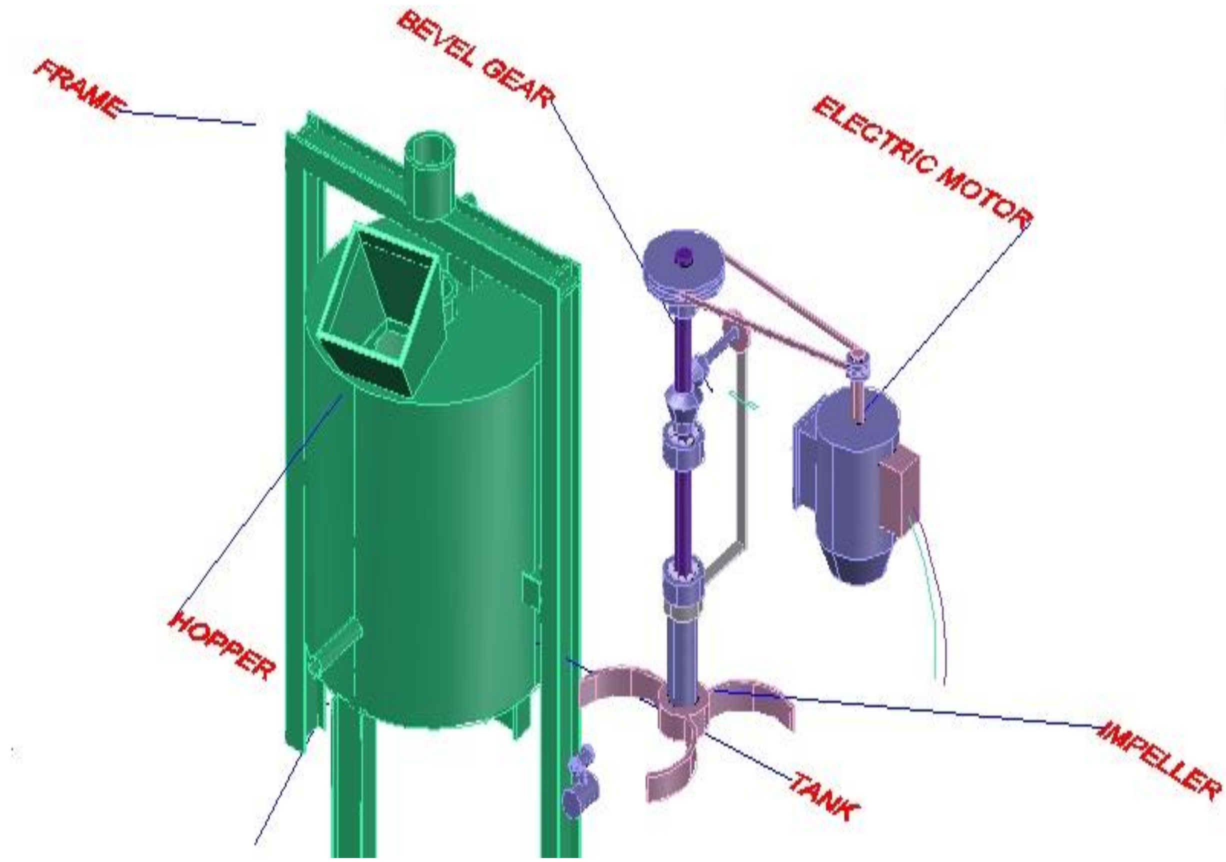

Figure 2: Part Listing of the Machine.

Mixing Vessel

For Producing White Paint:
1. 50kg of calcium carbonate
2. 12.5kg of titanium
3. 11kg of Tickner
4. 5kg of ammonium
5. 3kg of Kerosene
6. 5kg of Anticides
7. 2 bucket of binder (i.e., 50kg)

Total mass of liquid = 50 kg

Mass of the paint to be stirred in the tank is assumed to be 50kg. According to Input data: (Ref.www. engineering toolbox.com)

Specific gravity of paint = 1.59kg/l

Density of paint = sp.g density of water.
= 1.59 x 1000 = 1590 kg/m^3

Now, volume of paint stirred / time in the mixing vessel,

Density = mass / volume

Volume = mass /density

Paint volume = = 0.031 m^3

This implies that 0.03 m^3 of paint is stirred = 31 litters

Volume of cylinder containing the paint = $\pi r^2 h$

Assumed diameter of cylindrical = 690mm

Assumed height of mixing vessel = 710mm

Volume = $\pi \times (0.315)^2 \times 0.71$
= 0.06m^3

This implies that the mixing volume is 60 liters (i.e., capacity of mixing vessel).

Weight of paint = mg
= 490.5 kg m/s^2 = 136 kg/ hr

Impeller and Blades

Impeller is a mechanical agitator use for mixing.

There are two types of impellers:

- Axial impeller
- Radial impeller

Radial impellers impose essentially shear stress to the fluid, and are used to mix immiscible fluids and also viscous fluids.

Axial impellers impose essentially bulk motion, and are used on homogenization process, in which bits important of increase fluid volumetric flow rate. Therefore, axial impellers are used in paint mixers.

For thorough mixing, impellers can be designed to perform both axial and vertical movement, it is related to wave motion on bodies of water which can only occur at an unbounded circulation and turbulence both consumes energy and time. Hence an important consideration in the design of an agitated vessel is the power required to drive the impeller.

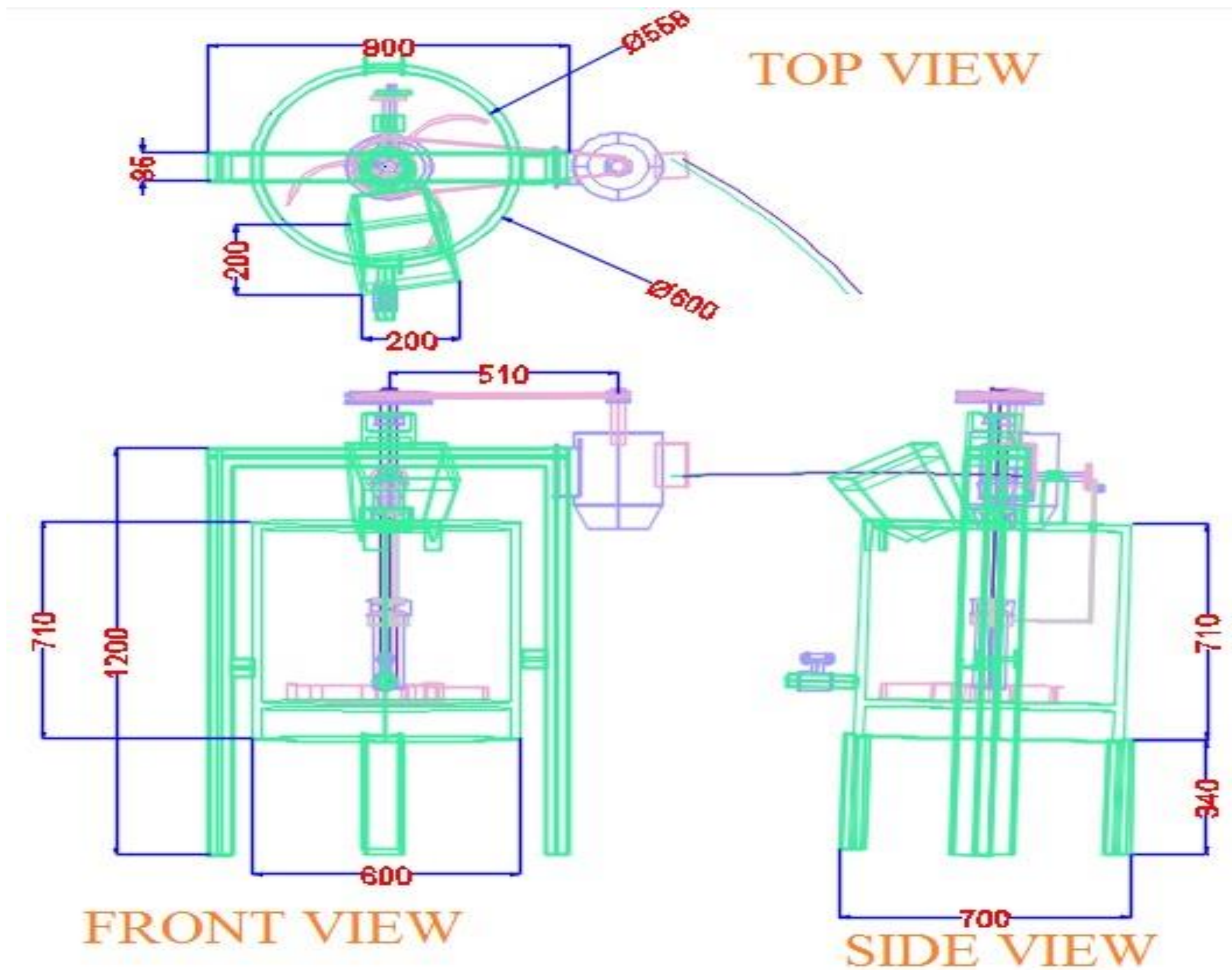

Figure 3: Orthographic View.

Input Data: (Ref.www. engineering toolbar)

1. Kinetic viscosity of paint = 2.4 Poise
   = 2.4/0.01 centi poise
   = 240 centi poise.

2. Specific gravity of paint = 1.59kg/lit in design of spatial agitation, the approach to design would be to calculate the torque required at the output shaft for stirring and based on this torque selecting an appropriate motor, after incorporating a suitable factor of safety. The torque calculation will be based on two analogies namely, torque required to overcome the viscous force by virtue of the fluid viscosity and the secondly the torque required to overcome the static total pressure on each blade owing to the stationary fluid i.e. paint.

Calculation of Torque Owing to Viscous Force at Periphery of Blades

In calculation of the viscous force we use the following analogy. The blade tip traces a loci of points which is a circle, hence motion of the bracket due to oscillation of the output shaft can be considered to be a cylinder (assuming blade angle = 0), which is making against another cylinder i.e. the container both separated by a fluid film of thickness.

Putting up the above problems internal diameter of cylinder container = 57.5mm

Diameter of impeller = $\frac{690}{2}$

= 330 mm.

The diameter of the second cylinder i.e. the diameter of impeller blades forming a loci circumference = 330 x 2 = 660 mm.

The thickness of the film = diameter of the cylinder container- diameter of the impeller blades.

Film thickness = 30mm

μ=2.4 poise = 1 x $\frac{2.4}{10}$ = 0.24 N/Sml^2

Assuming a shaft speed of 70 rpm

Tangential speed of shaft = $\frac{\pi DN}{60}$

= 2.42m/sec.

Now, τ=μ du/dy

Where,

τ = shears stress (N/m^2)

du= change in speed = U-0 = 2.42m/s

dy = distance between shaft and journal = 0.34m

τ = μ du/dy

= 1.71N/m2

Area of the cylinder that is exposed to this shear intensity will be circumferential area; (assuming width of the blade = 10mm)

A= π x D x W

A= 0.021 m^2

Shear force (F) = shear stress x shear area = 1.71 x 0.021= 0.036N

Power = F x U = 0.087 W

Calculation of Torque Owing to Viscous Force at Top and Bottom Ends of Blades

In calculation of the viscous force we use the following features:

The blades along the length when rotated along with bracket will trace an annular ring at the either ends of blade putting up the above problem:

Given U = 2.4 poise = 1 x 2.4 = 0.24 NS/m^2

Speed of plate = 2.42m/sec

Now, τ= μ du/dy

Where,

τ = shear stress (N/m^2)

du = change in speed = U-0= 2.42 m/sec

dy = distance between shaft and journal = 0.34m

τ = μ du/dy = 1.71 N/m^2

Area of the cylinder that is exposed to this shear intensity will be A= L x B

Assume length of shaft = 330mm and breadth = 10mm

Finding the force and power required to move a plate of width and length against a stationary plate extending infinitely, separately by a fluid of kinetic viscosity.

Area (A) = 0.33 x 0.01 = 3.3 x10 -3m^2

Shear force (F) = shear stress x shear Area = 1.711 x3.3 x 10 -3 = 5.64 x 10-3 N

Total shear force = 3xF

For 3 blades = 3x5.64x10 -3 = 0.0169N

Power = F.U
= 0.04 W

Calculation of Torque Owing to Static Total Pressure Acting on the Blades by Virtue of the Stationary Fluid

In calculation of torque due to specific static force exerted by the fluid, we use the following analogy.

Given specific gravity = 1.59kg/lit.

Density of water= 1000kg/m^3

$$\text{Sp. Gravity} = \frac{\text{density of paint } (\rho p)}{\text{Density of equal of water } (\rho)}$$

$$\text{Sp.gr} = \frac{\rho(p)}{\rho} = \frac{\rho(p)}{1000}$$

s.(p) = 1590 kglm^3

Total pressure is given by:
P= F/A

But pressure in a cylinder container with point fluid = ρgh

(i.e., F = PgAh)
Total height of cylinder = 710mm

The plate is placed vertically at a distance below the free surface of fluid of specific gravity.

Height of plate from the free surface of fluid h = 510mm = 500mm

F = ρAh

F= 25.74N

Since there are 3 such blades:
F=3 x 25.74 = 77.29N = total force.

The Torque that Each Blade Has to Overcome to Rotate About its Own Axis

T=F.R

T= 77.29 x 0.165

Ts = 12.75 N-M

Power required at output shaft to overcome the static resistance of fluid is:

$$Ps = \frac{2\pi NT}{60}$$

Ps= 93.471W

Thus, the net power required at the output shaft is the summation of the above three powers.

Power = 93.47 + 0.04 + 0.087 ≈ 93.6W

The Shaft

The shaft is made from a mild steel rod measuring 30 mm diameter. It is being fixed inside the tank with the head projecting out for the driven pulley to be mounted on it.

A bearing is fitted between the shaft and the tank so that the shaft can rotate freely without any rubbing contact between the tank and the shaft. There is also a support on the shaft welded to the frame. This is the stability of the shaft. The impeller is mounted at the end of the shaft. The power impact on the shaft is being transmitted to the impeller blades, which in turn transmit it to the fluid particles as it rotates in the fluid.

Moment of Inertia and Torque on the Shaft
(For circular solid shaft)

$$J = \frac{\pi D^4}{32}$$

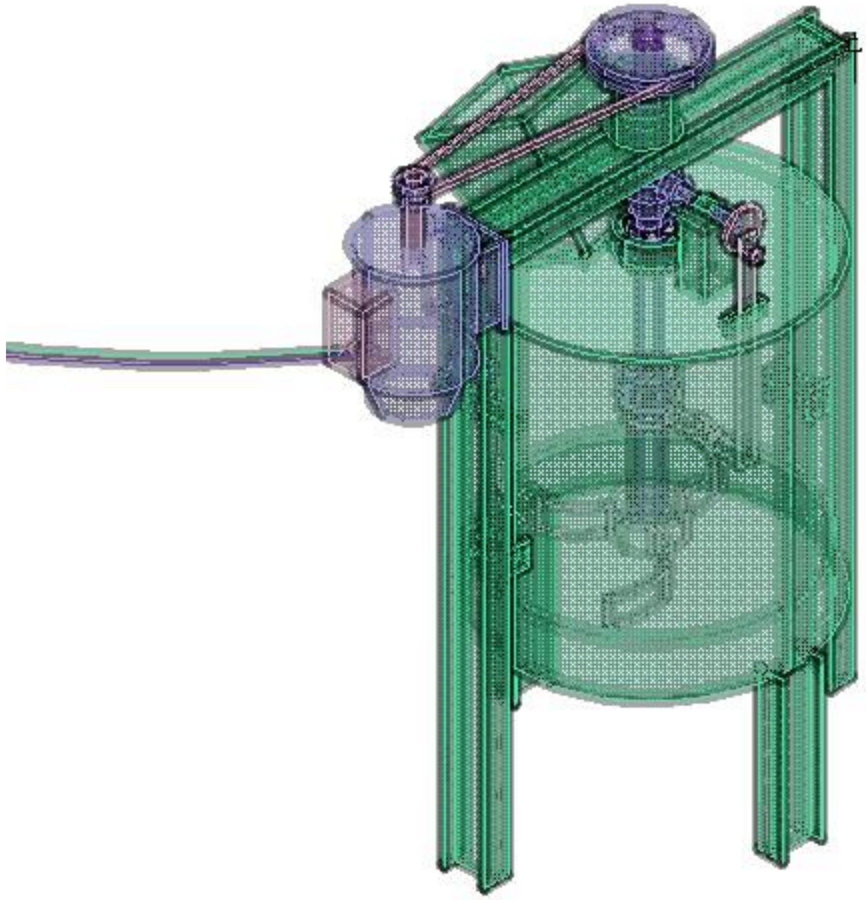

Figure 4: Exploded View.

T = twisting moment on the shaft

J = Polar moment of inertia of the shaft about the axis of rotation

R =D/2 (R & D) = radii and diameter of the shaft, respectively.

$J = \frac{\pi(0.03)^4}{32} = 7.95 \times 10^{-8}$ N

Torque

$T = \tau \times \frac{\pi}{32} \times d^4 \times \frac{2}{d} = \frac{\pi}{16} \times \tau \times d^3$

Total shear stress τ acting on the output shaft = 3.4 N/m

$= \frac{\pi}{16} \times 3.4 \times (0.03)^3$

$T = 1.803 \times 10^{-5}$ N-m

Moment of Inertia and Torque on the Shaft
(For Hollow Shaft)

The hollow shaft making vertical reciprocating motion with external diameter (D_o) and internal diameter D_i.

Polar Moment of Inertia

$J = \frac{\pi}{32}((D_o)^4 - (D_i)^4)$

Note D_O = 40mm =0.04

D_i= 35mm = 0.035

= 1.08021 x10^{-7}

Torque on Hollow Shaft

T = $\frac{\pi}{16}$ x τ$(D_O)^4(1 - K^4)$

K = $\frac{D_I}{D_O}$

K = 0.88

T = $\frac{\pi}{16}$ x 3.4 $(0.04)^4(1 - 0.88^4)$

= 1.713 X 10^{-5} N /M

Equating round solid shaft and hollow shaft to make them equal in strength, i.e.

= 1. 803 x10^{-5} + 1.713 X 10^{-5}

Tmax = 3.516 x10^{-5} N/m

Speed of the Shaft

⇨ $N_2 = \frac{N_1 D_1}{N_2}$

= 414 rpm

Power on the Shaft

P = $\frac{2\pi NT}{60}$

P = 1.5 X 10^{-3} W

Belt and Pulley

The belt is a device used to transmit power from one source (motor) to another (shaft/stirrer). In this case, v-belts were selected because of its advantages over other belts which include the following:

a. The reasonable attainable tension ratio T_1/T_2 is greater for v-belt than flat belts.

b. It gives a positive drive because it has a negligible slip.

c. Because of the wedging action, v-belt has belt tension when compared to flat belts and therefore, a large tangential (transmitted) force is obtainable for some coefficient of friction.

d. Because of wedging action, v-belt do well on short center distance without frequent adjustments for initial tension. The size of v-belt selected is size B-55, with degree = 36^o and the center to center distance is between 60mm to 150mm.

e. It gives compactness.

f. It can be installed and removed easily.

g. It is durable.

Velocity Ratio of Belt Drive

This is the ratio between the velocity of the belt and the driven pulleys:

Let : D_1 = Diameter of driver = 55mm =0.55

D_2 = Diameter of Driver= 190mm =0.19

N_1 = speed of driver = 414

N_2 = speed of driven =1430

Therefore, length of belt that passes over the driver in one minute = π$D_1 N_1$.

Length of belt that passes over the driven in one minute = π. $D_2 N_2$

π$D_1 N_1$ = π. $D_2 N_2$

: - $\frac{N_2}{N_1} = \frac{D_1}{D_2}$

Alternatively, we know that the peripheral velocity of the belt pulley,

$V_1 = \frac{\pi D_1 N_1}{60}$

V_1 = 41.41m/s

And peripheral velocity of the belt and driven pulley:

$V_2 = \frac{\pi D_2 N_2}{60}$

= 41.41m/s

If there is no slip, then $V_1 = V_2$

Where B is the width of the pulley.

The width of pulley used for this mixer is 13mm. therefore, belt width,

b= 13 ~ 10mm

- **Length of belt**

L = 2C + 1.57$+ (\mathbf{D} - \mathbf{d}) + \frac{(\mathbf{D}-\mathbf{d})^2}{46}$

(Khurmi Gupta, 2005)

Where C = Center to center distance of the pulley = 185

D = diameter of big pulley

d = diameter of small pulley

L = 978.15m

- **Weight of belt**

Mass of full length of belt = M x L

= 105.624kg

- **Belt tension**

T_1 = Tension on the tight side

T_2 = tension on the slack side

Where M = mass of the belt = 105.624

N_1 Here is the electric motor speed which is 1430 rpm, and N_2 is the speed of the stirrer shaft. With these, when the belt is fixed at the step of the pulley, then the stirrer shaft speed.

$N_2 = \frac{D_1}{N_1 D_2}$ = 414m/s

Belt Design

- **Belt width (b)**

It is given as b = B/ 1.25 (Khurmi and Gupta, 2005).

V = peripheral speed of the belt = 41.19

T_c = centrifugal tension on the belt, which is given as:

T_c = MV^2
435065.3N

Maximum tension, $T = T_1 + T_C$

$T_1 = T_{max} - T_c$

T_{max} = δ x A,

A = $\frac{\pi(D)^2}{4}$ = 751 m^2

T_{max} = 15778N

T_1= 1143N/M

Tension Ratio

$T_2 = \frac{T_1}{e^{\mu\Theta}}$

T_2 = 1.2 x 10^{16} N/M

P = (T_1-T_2)V

P= 4703/1000 = 4.703kw.

Gears

The type of gears used wear bevel gears.
torque transmitted by the shaft

$$T = \frac{P\ X\ 60}{2\pi N}$$

T = 3.46N/M

Maximum Bending Moment

Maximum bending moment of a simple supported load carrying a central load on gear.

$$M = \frac{W\ X\ L}{4}$$

= 100

The equivalent twisting moment:

$$T_e = \sqrt{M^2 + T^2}$$

$$= \sqrt{100^2 + 11.972^2} \qquad = 100$$

Bearing

A bearing is a support or guide that is used to support a shaft with the other shaft of the mechanism where reciprocating and rotary motion are required. In this case two bearings in diameter mainly to reduce the speed transmitted by the electric motor and increase the torque and efficiency.

The Metal Stand (Frame)

This consists of angle bar and galvanized flat bar, that are welded together to archive the major aim, which carries the weight of the mixture, resist rotary motion to torque from the electric motor, fastens the drum to the system (frame), etc.

Bolts and Nuts

Bolts and nuts used are of different sizes but majorly the aim of holding parts together (e.g. bolts and nuts) are used to fasten the electric motor to the frame, etc.

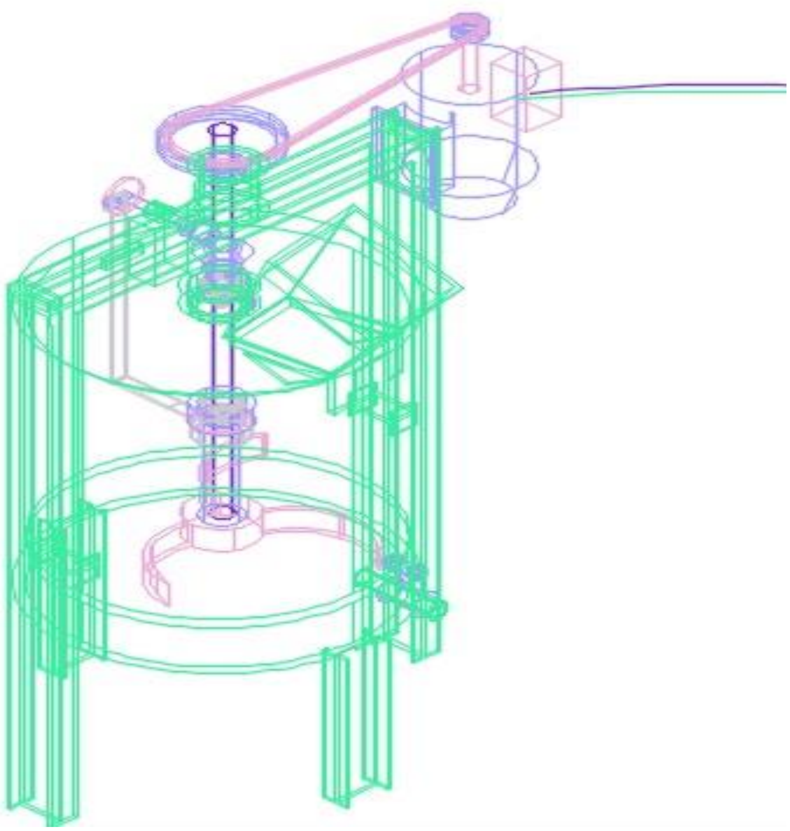

Figure 5: The Internal View.

RESULTS AND DISCUSSION

In accordance with Cornish guides for design and selection of components of engineering systems; the design, material selection, and fabrication of the electric paint mixing machine was based on the following considerations:

The following considerations were made while designing the machine:

i. **Mechanical Strength:** This includes the toughness and corrosion resistance characteristics of the materials to be used (i.e., this should be considered depending on the service requirement).

ii. **Cost:** The cost of any material involves; raw materials, fabrication, and installation costs, in terms of replacements due to failure. If the cost is not considered, the expenses while undergoing repair or replacement should be considered which in absence of that may lead to economic damage and production losses.

iii. **Service Requirements:** These include the dimensional stability, strength, and toughness, etc.

iv. **Design:** In selection of materials, design is closely related to the strength and ductility. However, there are several cases in which the search for a substitute material lead to feasible design modification which should be much more advantages than a change in alloy composition.

v. **Availability:** If a material is not available, irrespective of the advantages of the material, it is not reasonable to base a design on it. This involves availability of material at an appropriate cost and availability in desired form.

vi. **Fabricability:** There is a close relationship between fabricability and availability. One of the most challenging tasks of an engineer is proper selection of the material for a particular job. An engineer must be in position to choose the optimum combination of properties in a material at the lowest possible cost without compromising the quality (i.e., the material that will be easy to fabricate should be selected).

vii. **Stability:** Stability of materials should be putting in consideration, the materials in service which is related to temperature; fluctuations in temperature and length of time at temperatures, stability also have to do with the reaction of the material in failure.

viii. **Ductility:** This related to strength, considerable ductility is generally obtained at a sacrifice of strengths during cold working of metals. However, the more ductility obtainable without great loss in strength, the better, at the same time, appreciable ductility is required for fabrication by rolling and mechanical working processes.

DESIGN PROCEDURE

Generally, a number of factors were considered during the design state of the machine before the most suitable material selection was achieved. These designs considered, most of the areas in which the previous challenges were experienced. Several designs were produced and castigated upon due to one factor or the other being consider deficient. Among these factors are:

1. It does not include excessive mechanisms as these could make the machine cumbersome. The versatility of its movement or mechanism is of paramount importance.

2. Portability is more assured if it can be dismantled and assembled. It makes use of bolt and nut attachments for its coupling instead of the obsolete existing models that were completely welded together.

3. The design is simplified in such a way that the motion transmitted is rational and limits damage that would occur if the machine were be imposed to a high amount of load.

Frictional Properties

Suitability for forming and shaping operation determined by the material properties such as malleability, ductility, and the many available methods for joining. The importance of properties desired in this project includes hardness, strength, and resistance to corrosion.

Shear Force and Bending Moment

Stresses set up in bars due to axially applied force of tension or compression formed the subject of the designed. The two important effect of lateral loading are: shear force and bending moment.

Consider a simply supported beam AB. Carrying uniformly distributed load, 50kg/m over the entire span AB by symmetry, each support reactions is that RA=RB=w/2.

Basic Concept of the Machine

The average power produced by a man approximately 75W (0.1hp), If they work continuously (Modak et al., 1998). Therefore, human power may be used for the process if the power requirement is more than 75W and if the process can be of an intermittent nature without affecting the end product, a human-powered machine system can be employed.

Essentially, the machine consists of three sub systems:

a. The energy unit
b. The transmission mechanism
c. The process unit.

The energy unit consists of an electric motor, the transmission unit consists of belt drive, a belt drive connecting the electric motor and the shaft through the pulley, and the process unit is a mild steel vessel where impeller blades stirs and blends the paint mixture.

The machine should principally have efficient velocity ratio obtained by maximizing gear ratios in order to minimize the energy requirement on the effort end will have a low center of gravity for increase stability.

CALCULATIONS

This machine, when compared to the previously existing design was fabricated putting into consideration the fact that the force required to overcome the pressing operation should be large irrespective of the high amount of load to be placed on it. Under static equilibrium, the muscular capacity of force exerted can be measured using external device attached to areas sensitive to the applied force. This force depends on the intrinsic muscular strength of the individual operating the machine.

However, after considering all these factors, research was carried out and found out that by applying torque to the drive train of the machine through an electric motor, the maximum force required to overcome turning on the machine at ground state.

Electric Motor

The radial electric motor was used in this work is rated 2 hp. The choice of our type of electric motor is its ability to transmit the required power effectively. Furthermore, the radial motor is rated with a speed of 1400 rpm which is efficiently enough to drive the impeller (blades) of the stirrer.

Drive Train

To propel an electric motor, it is connected to an electric source. It is powered ON, the motor rotates and turns the pulley via a v-belt drive which transmits rotary energy to drive the shaft attached to the impeller blades in the mixing vessel.

The Mixing Vessel

The mixing vessel is subjected to the paint weight and circumferential pressure generated during mixing and corrosion from the composition of paint. A vessel with sloping or dished bottom is often recommended, although tanks whose sides have a right angle are also commonly used. Square tanks or others having corners hinders the fluid motion (Gray et al, 1987).

A cylindrical vessel having a flat bottom was used in the work. The vessel is provided with a discharge tap which penetrates into the main vessel. The tap is made in such a way to give effective and adequate discharge of the mixed ingredient that will be poured. The maximum pressure acting on the base of the vessel and consequently, that is the region that must be well considered in designing. Since little or no pressure act on the top of the vessel, there is therefore no longitudinal stress at any point in the vessel is given by:

$C = Pr/t$

r = is the radius of the vessel, t is the thickness and p is the pressure on the plate of the vessel.

The Mechanical Advantage of the Machine

To determine the mechanical advantage of the machine, the applied load to be obtained by weighing the quantity of paint (N) is to be divided by the average effort required to overcome the pressing load of the quantity of paint solution.

Then, mechanical advantage = total load/required torque. = 14.2207 .

The Efficiency of the Machine

The efficiency of the machine can be obtained by using the formula:

Efficiency (E) =Mechanical adv./velocity ratio*100%. = 97.2%

Shear Stress on the Machine

The area of the machine can be calculated as follows:

Area = length * breath (L*B), Also, total force action on the machine when the paint in it has no force applied on it is equal to (n*I) (P.N. Okeke, 1989).

Where n = quantity of paint solution, L = load per quantity

The shear stress at this instance = n*I/A

Also, when effort e, is applied to the load, the total force acting on the machine becomes an application of the effort (Roeenerg, 1968).

Therefore, shear stress at this instance = e*n*I/A (N/m^2) = 1.711

Volume of the Machine

The volume of the machine can be calculated as follows:

Volume = pir^2h (m^3) = $\pi \times (0.315)^2 \times 0.71$
= $0.06m^3$

Where r = is the radius of the drum, h = is the height of the drum.

Table 2: Bill of Engineering Measurement and Evaluation (BEME).

S/N	ITEM	QUANTITY	AMOUNT (₦)
1	Ball bearing	2	1,600
2	Bolts and nuts	15 paint or more	2,700
3	Angle bar	2 full length	2,600
4	3mm thick mild steel	2 full length	11,800
5	Flat bar	½ sheet	1,100
6	Iron rod	½ length	1,600
7	Electric motor	1 hp (radial type)	14,000
8	Pulleys	½ length	2,500
9	v-belt	1	700
10	Cable	2 ½ length	900
11	Filling and cutting stone	4 (2 each)	2,000
12	Filler		2,800
13	Grease and auto base paint		3,700
14	Transport		5000
15	Workmanship		22,000
	TOTAL		75,000

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

The study discussed the problem of local production in Africa, especially in Nigeria, and how this problem has affected those in the rural areas. This work highlighted the effect of those problems in the industrial sector of the Nigerian economy and the level of unemployment among youths as a result of the slow pace of paint production.

The study also reviews the operation of various mixing operations by different mixing machines that have similar working principles and operations. The study also talked about the mechanism for the operation of the operation of the machine, the choice of material selected as well as the design and operation procedures.

The art of producing the electric motor driven paint mixer, involve a series of complex activities which include welding, drilling of holes of various sizes and also cutting of some metal into different shapes. Finishing and machining were accomplished by lathe machine; wire brush, sprayer and filling materials. Finally, the researchers encountered a number of problems which includes in consistent power supply in the workshop, unavailability of working materials, high cost of materials in the market, etc.

Conclusion

As the need for paint production is on the increase in the country, this then acts as a reason for the use of electric motor driven paint mixer in order to ease the problem of rural dwellers in Nigeria and Africa at large in producing local paint mixing machine and quick further mixing paint solutions. It is the believe of the researchers that the locally manufactured machines can be improved and modernized into highly-efficient machines like the modern mixing machine produced in this work. If only the necessary encouragement and environment can be given by the appropriate authorities, it is of the belief that in no due time the level of technological advancement in the country will change drastically in a short period.

Recommendations

Considering that large scale production of electric motor–driven paint mixers can be achieved in the next few years, the researchers therefore recommended that the following should be put in to consideration:

- Technological awareness should be made known to the rural areas by the government and also by advertising the product.
- If local materials are used for manufacturing of the products, the cost price should be low, so as to encourage people to buy the local products.
- Government should encourage and finance the local industries that will go a long way, subsiding the cost price of the product, hence the producer can now produce most machines easily and the consumers can be able to purchase the product.
- Government should use the taxing method to encourage the local producers, by imposing higher tax on foreign products and lower tax on the local products.

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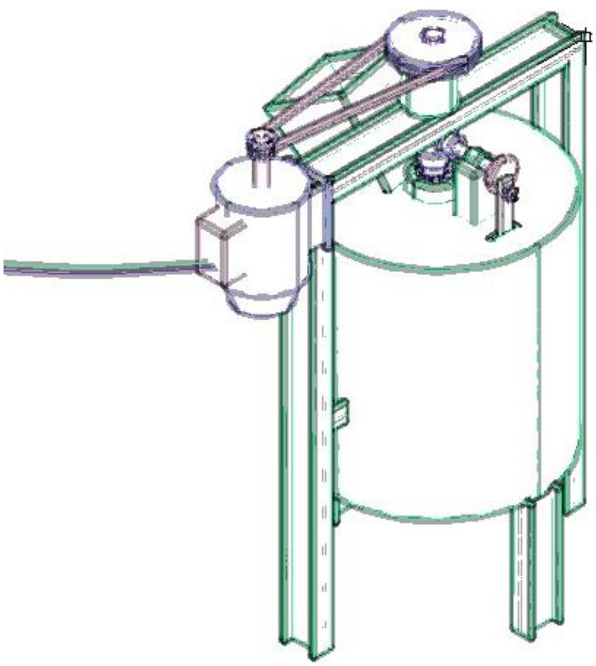
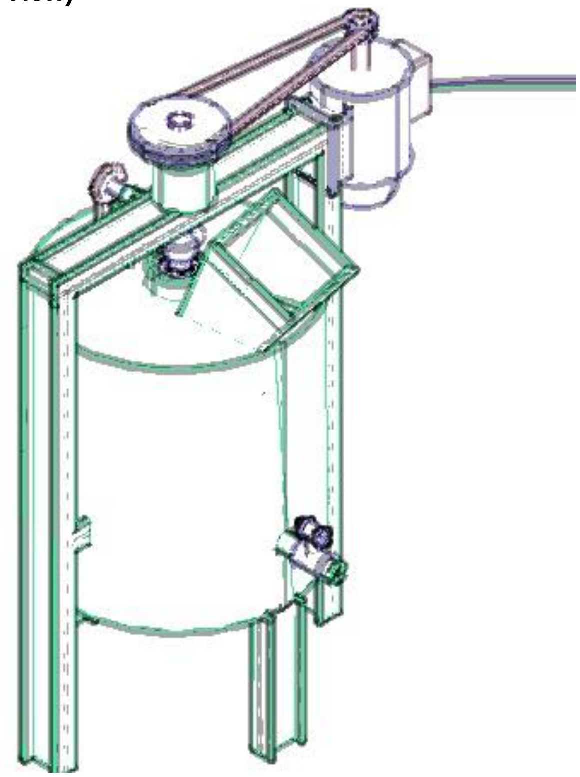
APPENDIX

Illustrations of the Mixer
(Back View)



(Front View)



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