Design And Fabrication Of A Detergent Mixing Machine

Musilim A.A[1], Nwagwo A[2], Olaleye H.A[3], Adesowon S.E[4]

[1,3,4]Mechanical Engineering Department, Yaba College of Technology, Yaba, Lagos, Nigeria
[2]Mathematics Department, Yaba College of Technology, Yaba, Lagos, Nigeria.
[2]naxander2000@yahoo.com, [1]abbeymuz@yahoo.co.uk

Abstract: The aim of this paper is to design and fabricate a detergent mixing machine that will be easy and economical to maintain, and cost effective. Mild steel is used in fabrication of the bowl mixer (pan), frame, spaddle and shaft. The machine is to ensure even mixture of detergent constituents during operation and a smooth discharge of the detergent at the base. The performance evaluation of the mixing machine was carried out using detergent and liquid ingredients/constituents. Various volumes of samples containing detergent and liquid ingredients were first prepared and were ensured that the same quantities of each of the samples were mixed by the mixing machine and the conventional mixer (manually operated). The results obtained for mixing machine were compared with the performance of the conventional mixer under the same conditions. The efficiency of the mixing machine was found to be 80.7%. This study shows that where mixing of detergent and liquid soap is involved, the conventional mixer takes longer time of operation and consume more man power whilst the mixing machine yield at a shorter time of operation and at a reduce cost.
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1. Introduction

In industrial engineering, mixing is a unit operation that involves manipulation of a heterogeneous physical system with the intent to make it more homogeneous. Familiar examples include pumping of the water in a swimming pool to homogenize the water temperature, and the stirring of pancake batter to eliminate lumps (deagglomeration). (Edward, 2004). Mixing is performed to allow heat and/or mass transfer to occur between one or more streams, components or phases. Modern industrial processing almost always involves some form of mixing. Some classes of chemical reactors are also mixers. With the right equipment, it is possible to mix a solid, liquid or gas into another solid, liquid or gas. Mixing machine are used to aid the performance and to quality output of the mixable constituents. Example, you would mix tea after adding milk and sugar to your daily cup of coffee or at pouring hot water into a tub to reduce the temperature of water that is too hot. This very mixing action of adjusting the taste of coffee or equalizing the temperature of hot water is what called mixing.

Thus, detergent mixing machine is a mechanical device/equipment used in agitating different raw materials and ingredients properly. The mixing machine can be used to manufacture powder, liquid detergent and any other mixable materials.

Most locally made soaps (bar, liquid or detergent) are being produce with the use of stirrer (stick) which consume much time to produce and man power. It is obvious that mixing of two or more liquid constituent cannot be perfectly homogenize manually but can be with the use of machine.

This led to invention of mixer machine to eliminate human labour involved. The purchase of the equipment is outrageous to small and medium scale business vendor. However, the design of this machine will reduce human labour to the bear rest minimum and make affordable to the end users.

The mixing machine is of two types, the detergent powder mixer machine and detergent cake mixer machine. The designs are available in mild steel and stainless steel construction.

In this paper, mild steel is used for the construction, gear reduction motor is used in reducing the speed generated by the electric motor to allow proper and thorough mixture of the constituents. The impeller used in this course is counter rotating type.

2. Materials and Methodology

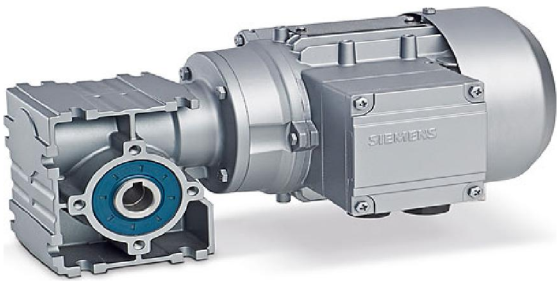
A mixing machine consists of several element which can easily be used to explain the basic principles involved in mixing of detergent by a mixer. (Sharma and Aggawal, 2010)

2.1. Materials

2.1.1. Gear Reducer Motor (Worm Gear motor)

This is the prime mover that supplies the needed motion in a detergent mixer and it is strictly electrical in some designs. Worm gear arrangement is attached to the top of the motor at 90^0 to reduce direct speed from the motor to a very low speed as design. It is smooth and almost without sound, as well as allowing large transmission ratio. The reduction ratio can reach 1/100.

Plate 1: Gear Reduction Motor Shaft



This is a steel rod that receives the motion generated by the motor via the use of gears. This is to maintain element of the machine. It consist of a small length and parts with some provision for the bearings mounted on both sides of the shaft. A 1hp, 3 phase gear motor running at speed1400rpm is use. Reduction gear with gear reduction ratio of 20:1 is procured to reduce speed (in rpm) of the gear motor.

2.1.2. Agitator (Impeller)

A part attached to the shaft with the sole purpose of transmitting the rotational movement of the shaft imposes on it into energy input needed in stretching and deforming the detergent ingredients between itself and the mixing bowl (Pan).

2.1.3. Mixing bowl (pan)

This is the container or tank into which soap ingredients are mixed. The bowl comes in different sizes but always of a smooth surface and sometimes curved base so that no ingredient is excluded in the mixing process.

2.1.4. Bearing

These are used to reduce friction and ensure accurate alignment between the moving parts.

Factors that determine the appropriate selection and life of a bearing is as follow;

- ✓ Bearing Housing
- ✓ Selection of Bearings
- ✓ Bearing Life
- ✓ Bearing Materials
- ✓ Bearing and Load Relationship

Empirical calculations and experimental data point to a predictable relationship between bearing load and life. This relationship may be expressed by formulae. In this empirical formulae, the bearing life is fond to vary inversely as the applied to an exponential power. The assigned value of the exponent depends upon the basic type of a rolling element. For all type of rolling bearings the formulae is given below:

$$Life = \frac{Basic\ Dynamic\ Capacity}{Load} \times 3.33 \times 10^6\ revolution \qquad \text{Eq. (1)}$$

For all types of ball bearings the formulae is as given below:

$$Life = \frac{Basic\ Dynamic\ Capacity}{Load} \times 3 \times 10^6\ revolutions \qquad \text{Eq. (2)}$$

2.1.5. Shaft Materials

The most common material for shafting is mild steel, but for high – strength requirements, an alloy steel such as nickel, nickel- chromium or chrome vanadium steel are used. Low-carbon steel similar to SAE 1015 is usually used for commercial shafting, sizes of shafting and for special purposes they may be forged (Edward, 2004).

2.2. Methodology

2.2.1. Shaft Design

The design of a shaft generally requires the interrelated considerations of number of factors namely: materials and heat treatment, strength for power and loading requirement, stiffness as affecting for instance bearing performance, gear operation timing and critical speeds, weight and space limitations; and stress concentration. All rotating shafts, even in the absence of external load deflect during rotation. However, the magnitude of the deflection depends upon the characteristics properties of the shaft as well as the amount of damping in the system. Shaft design consist 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. Shaft are usually circular in cross section, and may be either hollow or solid.

2.2.1.1 Shaft design considerations

The size of the shaft for a particular application may be determine on the basis of strength or both strength and rigidity. Designing a shaft on the basis of strength, it is necessary to consider the type of loading, the weakening effect at point of stress concentration due to key wheel and shoulder and the combination of loading. The size of the shaft must be sufficient to prevent the induce stresses from exceeding the allowable stress for the material. At times, the rigidity of the shaft is the important feature. The twisting of the shaft may be limited to in order to provide accurate prescribe timing or motions, as in the camshaft of an internal combustion engine. Transverse deflections may be limited for instance to maintain proper bearing clearance or gear-tooth alignment. Both torsional and transverse rigidity are important in vibration. For the allowable stresses in the design of shafts, these are based on.

- ➢ The yield stress of the material if the loading is static.

- The endurance limit of the material if the loading is cyclic.

2.2.2. Determination of shaft size on the bases of strength.

The action of the load on a shaft is generally one of the following;

- Torsional loads
- Bending loads
- Axial load

For torsional loads, the torsional stress is express as:

$\tau_s = \frac{16T}{\pi D^3}\ N/m^2$, for solid shafts……………Eq. (3)

For bending loads, the bending stress is express as:

$\sigma_B = \frac{32\ M}{\pi D^3}\ N/m^2$, for solid shafts…………Eq. (4)

For axial loads, the direct stress is expressed as:

$\sigma_D = \frac{4\ P}{\pi D^2}\ N/m^2$, for solid shafts……………Eq. (5)

P = the applied load axial load (N)

D = diameter of shaft (m)

M = the applied maximum bending moment in the shaft (Nm)

T = the applied maximum torque on the shaft (Nm)

By the maximum shear stress consideration in the maximum shear stress, a shaft is express as;

$\tau_{max} = \frac{16}{D^3}\sqrt{\gamma^3 + M^3}\ N/m^2$,……………….Eq. (6)

$= \frac{16}{\pi D^3}\sqrt{M\gamma^3 + M\ M^3}\ N/m^2$,…………….Eq. (6a)

The term $\sqrt{\gamma^3 + M^3}\ N/m^2$ is the equivalent twisting moment and defined as the fictitious twisting movement that will induce the same maximum stress in the shaft as the combined action of the actual twisting moment and actual bending moment.

2.2.3. Determination of the shaft size on the basis of the rigidity.

In many machines the sizes of shaft are determined by the limits that are placed on the deflections. Two kinds of rigidity must be considered namely; torsional and lateral.

For torsional rigidity, the total angle of twist, in radians, for a circular shaft of a uniform cross-section is expressed as;

$\theta = \frac{TL}{JG}\ radians$,………………….Eq. (7)

For a solid circular shaft of diameter D, equation (7) reduces to:

$\theta = \frac{584\ TL}{GD^2}\ radians$,……………..Eq. (8)

θ = angle of twist of shaft (radian)

T = the torque on shaft (Nm)

L = length of shaft (m)

G = the rigidity of the shaft (N/m^2)

D = diameter of shaft (m)

The permissible amount of twist depends on the particular application. In drive shaft of machine tools, the twist should not exceed 0.08^0. In line shaft, 0.75^0 to 1.0^0 may be used as limiting values. The maximum permissible stress, or working stress is usually determined taking into account the social and economic consequence of failure and factor of safety is normally defined as a ratio between ultimate tensile, stress and the working stress. Based on this definition, values used in most engineering design will vary from 3 for dead loads accurately determined to 12 for shock loads of indefinite magnitude. The factor of safety is expressed as given in equation 9 below;

Factor of safety = $\frac{Ultimate\ Stress}{Working\ Stress} = \frac{\sigma_U}{\sigma_W}$……Eq. (9)

For lateral rigidity, the diameter of shaft may be determined by permissible lateral deflections as required, for instance, to maintain proper bearing clearance, gear teeth alignment, and vibration characteristics. The deflections of a shaft of uniform section may be readily fund by the use of appropriate equation foe mechanics of materials. If the shaft of variable cross-section, the deflection may be determined from the fundamental equation (10) below:

$\frac{d^2y}{dx^2} = \frac{M}{EI}$…………………………..Eq. (10)

Two integration of equation (10) will normally yield the deflection, y of the shaft.

3. Design Analysis

3.1. Volume of mixing bowl (pan)

The mixing pan is cylindrical in shape; its material is of 2mm thickness. The volume V_p is determine using:

$V_P = \frac{\pi D_P^2 H_P}{4}$..................................Eq. (11)

With D_p = 370mm and H_P = 623mm

$V_P = \frac{\pi \times 370^2 \times 623}{4} = 0.067m^2$

Mass of liquid detergent is given by:

$M_S = \rho_D \times V_P$……………………Eq. (12)

The variable ρ_D of liquid detergent is 1320kg/m^3

M_S=1320×0.067=88.4m^2.

3.2. The paddle

This is a pole with a flat wide part at one or both ends used for mixing which can be controlled manually or the use of electric motor. The straight length from the end of one paddle to another through the centre of the shaft is 520mm.

3.3. Shaft

For detergent mixer, the shaft supports the rotating mixing paddle and is subjected to transverse or axial loads.

Gear motor power supply = 1hp

Rotating Speed = 1400rpm

Gear reduction ratio = 20:1

Using gear speed ratio, the speed of the shaft in rpm is determined using:

$\frac{N_1}{N_2} = \frac{20}{1}$…………………………..Eq. (13)

Where N_1 = 1400rpm

$N_2 = \frac{N_1 \times 1}{20} = \frac{1400 \times 1}{20} = 70$ rpm.

Recall from design consideration that the angular velocity, ω_S of the shaft is determines using:

$$\omega_S = \frac{2\pi N_2}{60} \text{.........................Eq. (14)}$$

$$\omega_S = \frac{2 \times \pi \times 70}{60} = 7.33\ rad/sec$$

Also, the torque on the shaft is given as:

$$5T_S = r_b \times F_s \text{..................Eq. (15)}$$

Where, $r_b = \frac{d_b}{2}$ the force F_S acting on the shaft is determined using:

$$r_b = \frac{0.1895}{2} = 0.09475\ m.$$

$$F_S = M_S \times g \text{.......................Eq. (16)}$$

$$F_S = 88.4 \times 9.81 = 867.204.\ N$$

This is the maximum force that can act on the paddle connected to the rotation shaft.

Also, the power P, require can be determine using:

$$\boldsymbol{P = T_S \times \omega_S} \text{.......................Eq. (17)}$$

Where $\boldsymbol{T_S = r_P \times F_S}$

$$T_S = 0.09475 \times 867.204 = 82.16\ Nm.$$

Hence, $P = 82.16 \times 7.33 = 602.23\ W$

Again, the diameter of the shaft is determined using:

$$d_s = \sqrt[3]{\frac{16\,T_S}{\pi\,S_S}} \text{.......................Eq. (18)}$$

The shear stress of mild steel is about 0.04KN/mm^2

$$\boldsymbol{d_s} = \sqrt[3]{\frac{16 \times 82.16}{\pi \times 40}} = 0.021\ m.$$

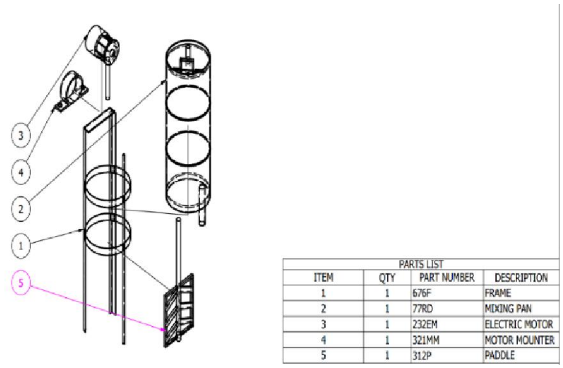


Figure 1: Part drawing of detergent mixing machine

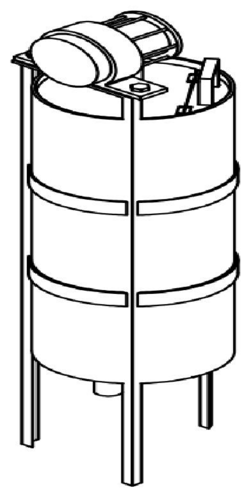


Figure 2: Isometric drawing of detergent mixing machine

Table 1: Design Analysis Result.

Parameters	Symbol	Value	Unit
Volume of Pan	V	0.067	m^3
Height of Pan	Hp	0.623	m
Diameter of Pan	Dp	0.370	m
Mass of Detergent	Ms	88.4	Kg
Radius of Paddle	r_p	0.09475	m
Force of The Shaft	Fs	867.204	N
Rotational Speed of Shaft	N_2	70	Rpm
Angular Velocity of Shaft	ω_s	7.33	rad/sec
Torque on Shaft	Ts	82.16	Nm
Power Required	P	602.23	W
Diameter of Shaft	Ds	0.021	m
Efficiency	ε	80.7	%

4.0. Testing, Results and Discussion of mixer.

4.1. Testing of mixer

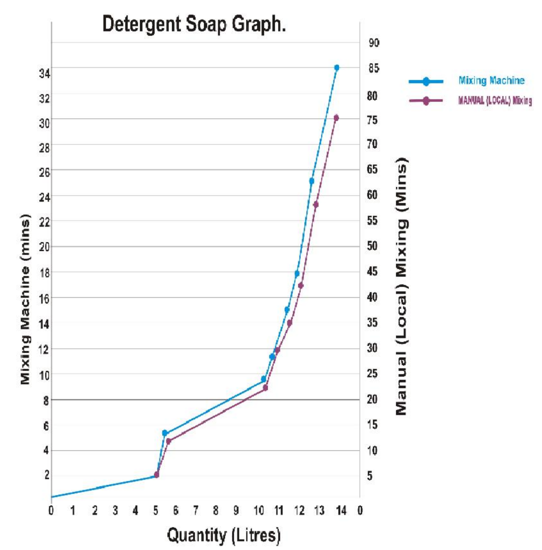
The machine was first turned on to ensure the impeller is rotating freely. The mixing pan was then loaded with a proportion of water and detergent constituent while the motor is rotating to ensure it turn and mix evenly, with little water added. When a homogenous mixture has been obtained, the discharge valve was open while the machine is still being operating to allow the powder detergent to be pushed out and collected. Also, same operation process was carried out on liquid soap for comparison and reliability measure. The fabricated mixer efficiency was determined to be 80.7 %. This was found to compare favorably with the imported existing foundry detergent mixer which has an efficiency of 89%.

4.2. Results and Discussion

The results of the calculated parameters is as given in the table below;

Table 2: Results for Powder Detergent soap

	Detergent Soap Manufacture			
S/N	**Ingredients**	**Mixing Machine (Mins)**	**Manual (Local) Mixer (Mins)**	**Quantity (Litres)**
1	PKO	2:00	5:00	5.00
2	Colouring	5:01	12:42	5.50
3	Caustic Soda Solution	9:21	22:15	10.50
4	Ash Light	11:00	27:50	11.00
5	Sodium Tripolyphosphate (STPP)	15:10	35:00	11.50
6	Sodium Phosphate	18:00	41:41	12.00
7	Sulphonic Acid	25:15	56:20	12.75
8	Hydrogen	34:00	75:30	13.95



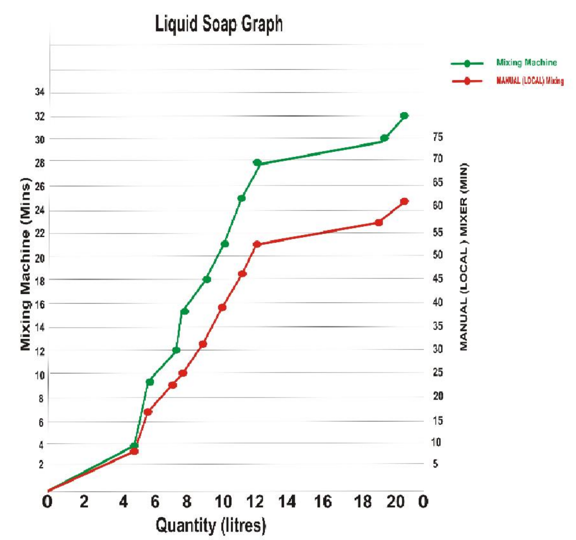


Figure 3: Show the quantity of Powder detergent with time taken to complete mixing.
Figure 4: Show the quantity of Liquid detergent with time taken to complete mixing.

Table 3: Results for Liquid Detergent Soap

Liquid Soap Manufacture				
S/N	Ingredients	Mixing Machine (Mins)	Manual (Local) Mixer (Mins)	Quantity (Litres)
1	Nitrosol + Water	4:26	9:00	5.00
2	Sulphonic Acid	9:50	17:51	5.75
3	Texapol + Water	12:01	23:02	6.75
4	Caustic Soda	15:50	25:00	7.75
5	Soda Ash	18:00	32:15	8.75
6	Sodium Tripolyphosphate (STPP)	21:42	39:10	9.75
7	Sodium Lauryl Sulfate SLS	28:19	46:00	10.75
8	Colour (Blue)	28:17	53:11	11.75
9	Water	30:12	58:11	19.50
10	Perfume	32:12	62:50	20.00

Hence, the mixing machine was compared with manual mixer to see the performance and reliability while in operation. The time for various volumes of detergent and liquid mixture constituent using manual (local) mixer and an electric motor of capacity of 1hp was recorded as shown in table 4 and 5 above. Also, The graphical representation of powder and liquid constituent mixture showed in figure 6 and 7 above proved to be highly superior with the mixing time and the result shows that mixing machine is more effective and efficient (80.7% calculated) than the manual (local) mixer.

5. Conclusions

The design and fabrication of Detergent Mixer using locally available materials have been achieved. The detergent mixer components machine frame, mixing pan, motor support, electric gear reducer, shaft, discharge valve and mixing paddle were design produced and assembled together to fabricate the mixer. Some of the determined mixer parameters are volume of mixer pan, force of shaft, torque on shaft, diameter of shaft, mixer efficiency and maximum mass of detergent the mixer can mix at a time are $0.067m^3$, 867.204, 82.16Nm, 0.021m, 80.7% and 88.4kg respectively. The application of this detergent mixer by laundry workshops will eliminate the use manual effort which is cumbersome, time wasting and inefficient. It also save the cost of purchase and manufacture for production and also encourage its use for laundry at home.

Appendix – Derivation of the efficiency of the mixer

The efficiency, ε of a machine is determined using:

$$\varepsilon = \frac{Output\ Power}{Input\ Power} \times 100\% \quad \text{..................Eq. (19)}$$

For the detergent mixer, the efficiency is determined by:

$$\varepsilon = \frac{Power\ Required}{Power\ Supplied} \times 100\% \quad \text{................Eq. (20)}$$

Power required has been calculated as **602.23W**

Power supplied is the power ration of the gear motor provided i.e. 1hp.

1hp = 746W and the efficiency is evaluated using:

$$\varepsilon = \frac{602.23}{746} \times 100\%$$

$$\boldsymbol{\varepsilon = 80.7\%}.$$

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