The Design and Development of Versatile Mixing Machine

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Abstract

A machine that can be used to mix various types of substances such as food, soap ingredients etc, is developed. The uniqueness of the machine rests on the fact that the mixer member can be changed at will to suit the nature of materials being mixed. The machine is powered with a 0.75kw electric motor, which transmits the drive through a v-belt to the driven component. This component is supported in two bearings. Through a coupling cylinder a solid shaft connects a hollow shaft, which at its end is installed a mixing impeller. This terminal end of the machine is detachable and could be coupled to another mixing device that would suit the ingredients to be mixed. The cost of the machine is N30,000 and is constructed with readily available materials. It can be cheaply maintained and is 60% efficient.

Introduction

Several types of size reduction, mixing devices/equipment are in vogue as reported by DeGermo (1969), Obert and Young (1982), Davies (1957). Most recently these machines have been improved and perfected, yet there remain noticeable gaps in all the new products. Most of these new machines are massive, expensive and sophisticated in operations. The needs for cheap and simple attritions machines or mixing machines for simple local processing operations such as bread manufacturing, pap preparation for local farmers do exist in Nigeria. This work presents a typical versatile mixing machine that can be universally applied in the rural community.

The Feature of the Machine

Fig 1 shows the pictorial view of the machine. The various components of it are identified. The orthographic projections of some of the machine parts such as the mixing chamber and drive mechanism are not shown and the other parts orthographic projections are omitted for brevity.

Operation of the Versatile Mixing Machine

According to design, the particular machines is capable of mixing ingredients for bread making, pap making etc; simply accomplished by dismantling the mixer mechanism, cleaning the machine as appropriate, and then installing and appropriate mixer for the function required to be accomplished.

Thus, once, the machine is set for a specific function, such as ingredients for bread making, the constituents of the ingredients are introduced into mixing chamber as shown in Fig 1. this done, the machine is activated using the 0.75kw motor installed as shown in the figure. In some operations it may take up to 15 to 30 minutes to obtain an adequate blend for the materials in the mixing chamber. When this condition of uniformity of mixture of the material constituents, the mixture is discharged through the exit hopper and conveyed to where it is required to be utilized for other processing or utilization.

The Design of the Mixing Machine (Versatile)

Materials Selection

The materials selected for fabricating the machine are those readily available and cheap to make for low maintenance expenses. These are aluminum sheet, carbon steel, mild steel pipes, galvanized metal sheets, electric motor (purchased off the shelf) v-belts (purchased) but to design specifications, standard items (belts, nuts washers etc bought-out item) to march design specifications. So also are the bearings chosen to suit the designs. Others are the mild steel, angled irons, pulley (selected) based on design specifications. The details of the material are given in table 1, bill of materials for the machine.

Design Calculations for the Machine

The synopsis of the design calculations of the machine is given in Appendix 1. It involved the computations of the major components of the machine, such as the power selection for the machine and sizing of the various parts of the machine.

Manufacture/Fabrication of the Machine Components

The mild steel sheet was used to construct the mixing cylinder by applying the normal mechanical engineering method of fabricating a cylinder from a aluminum sheet by using such processes as cutting, filing, dressing etc, for a metal sheet fabricated, applying the necessary welding and/or brazing techniques that are appropriate. The shafts and pipes were machine to production drawing specifications and by using the general purpose machine tools, the lathe, milling machine, shaping machine, the grinder and drilling machine etc. as appropriate. The construction of the mixer of the machine involved a lot of construction activity, and is accomplished by using the aluminum sheet metal, utilizing the shearing machine. The details of the production of the other parts are omitted. It suffices to mention that standard items such as the V-belt, pulling sheave, bolts, nuts, screws etc bearing were purchased, but based on the design calculation supporting such selections. Since the machine can be used to mix edible materials, the decision to use aluminum materials for the mixer and the cylinder is convincing.

Table 1

S/N	Item Description	Qty	Amount
1.	Anglar Bars	4	3,000
2.	Pulley	2	3,000
3.	Ball Bearing	2	1,500
4.	Galvanized Pipe	1	3,000
5.	V-belt	1	1,500
6.	25mm (dia) Rod	1	1,500
7.	Aluminum sheet	2	2,500
8.	Electric Motor Hired		2,000
9.	Bolts/Screws/Wasters		500
10.	Paint		500
11.	Miscellaneous		5,000
	Total		**21,300**

Test

The designed machine was put on test, powered by the 0.75kw motors. It performed; the mixing of the ingredients for making bread was satisfactory. It was however observed that for a 25kg of materials introduced, only 15kg of the material were fully mixed, implying that the efficiency of the machine is 60%.

Discussion

The machine which operated in the same manner as Reiz Mgf.Co product in the introduction of the feed into the machine, is not efficient. It however, performed the function of mixing the function of mixing the constituents. Furthermore, the machine which was fabricated with some materials as used in Okocha et al (2001), remarkably, was more versatile in application, as the machine can mix any ingredients not only soap ingredients as in Okocha et al. the designed machine is cheaper and prone to ease of maintenance as the major components of the machine can be disassembled and assembled easily, and furthermore sourced locally.

Recommendation

Fabrication of the parts of the machine should be improved. It is a good idea to standardize all the models of the mixers so that they can be purchased off the market to use with any of the designed machines.

Conclusion

The designed versatile mixing machine, is capable of reducing the labour involved in mixing materials among the Nigerian populace. Once the machine is acquired, it is possible for each farmer to purchase the appropriate mixer mechanism to suit with machine any time. It means that any government or any non-governmental organizations which intend to help the rural farmer can acquire of the designed machine and the farmers can easily utilize that machine by employing their own personal appropriate mixing mechanism. This will help to reduce rural poverty and enhance the agricultural products processing in the community.

Appendix 1

Versatile Mixing Machine Design Analysis

This analysis is to be confined to the belt drive, power, shaft diameter determination etc and mixer design and other relevant parameters. An exhaustive design calculations of all the machine parts will not reported, to shorten the report.

The V-Velt Drive

The decision is to power the machine using a 1kw electric motor, running at a constant speed of 1800rpm. The data for the design of the drive is summarized thus: Electric motor rating (0.75KW – IKW) (1hp) range of motor utilized for computation. Diameter of driving puller (d), 60mm motor seed (n), 1800rpm

Speed ratio of the drive, (2:1) centre distance of power transmission, 400mn = C. Let the selected service factor for the motor be 1.2. Since the normal running power is 1KW (chosen) then the Design Factor = 0.75 x 1.2 = 0.9 KW.

This design however is based on 0.75km motor not the 0.9kw (allowing for factor). Using the equations of V-belt drive mechanism as presented by Paul and Adam (1982), the relevant parameters are determined and presented thus: using the speed ratio 2:1, the diameter of driven pulley = 120mm.

Using the Belt drive arrangement an open belt arrangement Sin^{-1} (D-d) 12c
Using the normal equation, the belt length is obtained from the equation:
$L = \sqrt{\ } [4c^2 – (D\text{-}d0^2] + ½ (D\theta_1 - d\theta_S)$ …..(1)
Where, θ_S = angle of contact of small pulley θ_1 = angle of contact of large pulley
$\theta_S = \pi - 25in^{-1} (D\text{-}d) / 2c$…………….. (2) Also $\theta_1 = \pi + 2\ Sin^{-1} (D\text{-}d) /2c$……….. (3)
Substituting D = 120mm, d = 60mm, C = 400mm into equation (2) and (3) θ_S = 3.00rgd
θ_1 = 3.29, rad and substantiating, C = 400mm, D = 120mm, d = 60mm, θ_S = 3.00, θ_S = 3.29 into equation (1), L = 1085mm.

From Redford (1973), equation, loud carrying capacity Exp $1\mu\theta_2/S_{in}\beta$) or Exp ($\mu\theta_1/S_{in}\beta$) are determined …….. (4) computing for big and small pulleys, the value for smaller pulley, is observed to be smaller, using θ_S = 3.00, μ = 0.3 (frictional factor), $\beta = 20^0$, $\theta_{1,}$ = 3.29 in equation (4). Smaller pulley therefore governs the design. Then using the equation by Redford (1973), $T_1 – T_c/T_2\text{-} T_c = \mu\theta_S/S_{in}\beta$ ……..(5) where T_1 = Tension in the tight side of belt, T_2 = Tension in slack side of belt, F_c = Centrifugal force in the transmission = MV^2 (N), M = mass, V = velocity of belt. Substituting given data, $\mu = 0.3$, $\theta_S = 3.00$ radians, $\beta = 20^0$ into equation (5), $(T_1 - F_c) / (T_2 - F_c) = 13.89$.

Power Transmission

Let the computation be based on a 0.75kw or IHP electric motor and not on design power of 1.2kw. This is deduced by using the equation Power = $(T_1 - T_2)$…………… (6) Shigley and Mische (1992). Where T_1 and T_2, as earlier defined and V = velocity of belt, obtained from the equation Belt speed

$$\left(\frac{2\pi n}{60}\right)\left(\frac{d}{2}\right) \quad \text{………………..} (7)$$

Where n = 1800rpm, d = diameter of small pulley substituting data into equation (7), belt velocity – 5.7m/sec.

Using the equation $F_C = \left(\frac{W}{j}\right) \quad V^2$ …………. (8) centrifugal force. From table, mass of belt is determined or as weight/gravity constant with W/g = mass = weight, where W = 0.817N, V = 9.81 5.7 m/sec, g = 9.81m/sec^2

Substituting data into (8) $F_c = 2.7$N. Utilizing equation (5b) $(T_1 - F_c) / (T_2 - F_c) = 13.89$, and substituting data $F_c = 2.7$N, and evaluating, $T_1 - T_2 = 130$. g.N further substituting as appropriate and evaluating $T_1 = 144$N and $T_2 = 13$N The maximum tension = 144N.

There should be an element of control of the design, introduction of factor of safety becomes necessary. Let the factor of safety (FS) for the belt be 1.2, for $T_1 = 144$N and (FS) = 1.2 the working tensile load = 144/1.2 = 120N. This permissible tensile load, subject to the factor of safety, introduced has to be subjected to service factor within prescribed hours of operation. For operation of about (10-12 hours), the factor selected from table = 1.4, This data will be used to determine the loading on the pulley thereby stipulate the number of belts to support it.

For a working load = 120N. Introducing the service factor 1.4, the required load be supported = 1.4 x 120N = 168 N. The number of belts required = 168/120 = 1.4 2 belts.

Design Decision

The discussed computations can be repeated with Electric Motor Power of 1.2KW (the design motor) based on using the design service factor of 1.2. This will present new values, yet, the number of belts required for the drive remains 2 belts.

The Coconut

According to the design the mixer can be changed at will, in some cases, higher motor power may be required for the drive remains 2 belts.

According to the design the mixer can be changed at will, in some cases, higher motor power may be required. The method of design analysis applied for the 0.75kw or more can be applied as discussed.

The Design of shaft for Transmitting Power to the Mixer

The shaft consists of combination of solid and hollow shaft joined at the end by a cylinder and a pin.

To determine the diameter of the shaft, it is necessary to determine the reactions at locations B and C and T_1 = tension tight side and T_2 at slack side known as T_1 = 138.3N and 7.4 respectively, and $T_1 - T_2$ = 145.8N, reactions referring to Fig 2

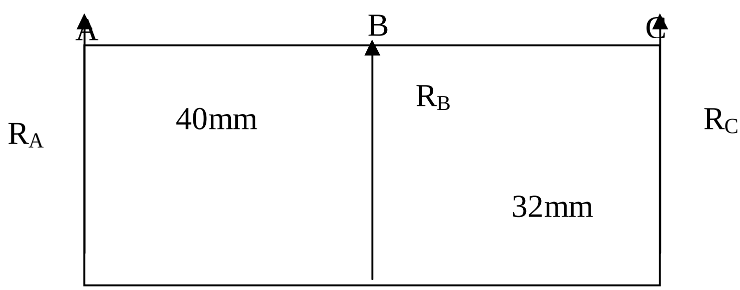

FIG 2: Loading Reactions

$R_B + R_C$ = 145.75N, using $\Sigma M_c = 0$, R_B = 327.9N, Rc = 182.2N
Power = $(T_1 - T_2)$ V, Force $T_1 = T_1 - T_2$ and T_1- T_2 130.87 determined earlier, with R = 120mm/2, Torque = t $(T_1 - T_2)$ = 7.85 N-M after substituting known data.

With the data, R_b and R_c known, $R_A = R_b + T_c$ = 145.75SN, it is possible to draw the shear force and bending moment diagram of the loading. This aspect of the work is omitted for brevity.

Determination of the shaft Diameter

Use is made of the ASME code equation given as = D^3 $16/S_{sy}\,(K_b\, M_b)^2$ + (K + $T)^2$ Holewenli and Laughlin (1983) … (8)
Where d = diameter of solid shaft, M_b – maximum bending moment, T = torque, S_{sy} = allowable shear stress K_b = combined shock and fatigue factor applied to tosional moment, for allowance for keys, shearing stress = 42 mpa, K_b = 1.5 and K_1 = 1.0, substituting into equation (8), data as appropriate,

$D^3 = 2.061 \times 10^{-6}$ 0r d = 13nm

The minimum shaft diameter = 12mm as deduced. The decision to sue a 20mm diameter shaft if appropriate.

The Design of Hollow Shaft

Design is based on torsional rigidity and the appropriate equation is written as:

$\theta = 584T_1/F\,(d_0^4 - d_1^4)$ ……….. (9) Holewenlio and Laughlin (1963) or

$d_0^4 - d_1^4 = 584\ T_1G\theta$

Where d_0 = internal diameter of the shaft.

D_1	=	external diameter of the shaft
L	=	length of the hollow shaft
G	=	Modulus of rigidity of the shaft material
T	=	Torgue.

From shaft specification, g = 80GN/M^2 shaft material (steel) power IKW (used for the design) L = length of shaft. For rmp = 900, angular velocity w (omega) = (2π x 900) / 60 = 30 rad/sec, T = P/W or 0.75/W = T = 7.9N – M. ratio of internal diameter: external diameter, d_i: d_0.

Using equation (9) as modified = and substituting data as appropriate, and θ = permissible angle of twist (Gradian $d_0^4 - d_1^4 = 584T_1/G\theta = 584 \times 7.91 \times 0.6/80 \times 10^9 \times 0.2$

$d_0^4 = 1.98 \times 10^{-7}$ or d_0 = 0.0211mm = 21mm

For the project, the hollow pipe selected had a 25mm outside diameter, so the computed diameter of 21mm, using design data is satisfactory.

Design of the Key

According to Redford (1973), torque which can be applied to shaft when without keyway is given as = torque applied to shaft with keyway …………. (10) 1.0 – 0.2w – 1.1h

Where w = width of keyway/shaft diameter …………..(11)
h = depth of keyway / shaft diameter ………………..(12)

Since w and h and unknown, the specification B.S 4235, part 1.1967 and B.S 46 Part 1, 1958, recommendation that for motor shaft diameter of shaft = 13mm, so the above relations cannot be applied in the design of the keys required key.

Let, the shearing on the key be expressed as

F = Qbt ………………….(13)

Where Q = permissible shear stress

Let the key fail by compression

i.e $F_t = Q_t\sigma_C/2 = \sigma bt$

$b/t = \sigma C / 2Q$……………… (14)

The Coconut

Equation (14) applies of the key is equally strong in both shearing and compression stresses. For mild steel key, the crushing strength is usually twice that of the shearing, ASME Code, Hence of mild steel b/t = 1. T = t (for square key)

The decision is to use a square key for the designed shaft. Method of designing the key is as follows:

The strength of the key = shearing strength of the shaft key shear strength = F_t = 2b Q_k…………. (15)

Where Q_k = shearing stress of the key material torque T = F_t xd/2 = Qb Q_k d/2 ………(16).

Thus, shearing of the shaft = T = πd 3/16 T_s………………..(17)

From Eqts (16) and (17), d^3 T_s = σ b Q_C x d/2 ……………(18)

From research report, the width of a key equals the ¼ the shaft diameter, i.e b=t= d/4 ..(12)

Substituting equation (19) into (18) Q = πd/2 = 1.5d (for square key) ………………..(20)

Thus for equal strength of key and shaft the length of thekey should be 1.5 x dia of shaft. For this design, the shaft diameter from shaft where the key is to machined has a diameter of d = 30mm. from equation 920) L = 1.5 x 30 45mm.

From equation (19) b = t = d/4 = 30/4 = 7.5mm b = 7.5.

The required square key will have these dimensions width = 7.5mm, thickness, b = 7.5mm and length L = 45mm.

The Design of the Mixer Lonpeller for the Machine

Since the mixer impeller is variable depending on the mixing materials required, such as food, food ingredients, pap, soap materials etc. they will be of forms as axial or centrifugal impellers. For the prototype produced for a pap production – mixture of sugar, milk, flour (cassava) and water, an axial mixer is selected as the mixer for convenience.

The Design of the Mixer Impeller

Using the equations by Broung (1973), Douglas (1977), Cherkassy (1980), equations for pump flows are written as discharge Q

Q = $N_Q N_R D^3_t$………………………….. (1)

Velocity head, H = $N_p N_R^2 D_t^2$/Nag………………..(2)

Power = P = $N_p N_Q^3 D^3_t$/6………………… (3)

Where Q = impeller discharge rate M^3/S H = Velocity head (m)

P = Power (watts) (other constant parameters)

P = Density and g = gravitational Qccnm.sec+2 $^D{}_t$ = Impeller tip diameter

N_Q = Discharge coefficient N_p = Power Number

Drawing the velocity diagram of the fluid flow in the axial flow in the mixer, it is observed that as the fluid outlet relative velocity loaves the blade tangentially, the

relevant equations generated by the mirerare defined analytically, according Douglas (1977), and Chekassay (1980) and for specific head, $H = U/g\ (U\text{-}V_f \tan \beta_2$………….(4)
Where H = theoretical head, U = blade velocity, U_f = flow velocity and β_2 = blade angle at exit.

Computations
For Na = 900rpm, = 15 rev/sec, Hub radius = R_f, /2= Dh = 0.02m, impeller tip radius, $R_t = D_t = 0.08m$, discharge coefficient = $N_Q = 0.4$. Substituting the state data into equation (1). The discharge Q = 0.205m+3+/5 is obtained and from equation.

$V_f = Q/A = Q(R_t^2 - R_n^2)$…………………. (5)
Where $R_t/2 = D_h = 0.02m$, impeller tip radius, $R_t = D_t = 0.08m$, substituting data and evaluating, $V_f = 1.086m/s$.

From the equation, $U_t = WT_t$……………………(6) and r_t = radius of tip and substituting in (6) absolute velocity of the tip U_t, = 7.54m/5 following the analysis, the blade angles are determined, using U_t = 7.54m/5. Following the analysis, the blade angles are determined, using u_t = 7.54m/s.

Where U_h is deduced as = 2 x 900 x 0.02/60 = 0.88m/s, which is the tangential velocity of the hub. Assuming no shock action, the inlet angle at the tipe is deduced, using the equation by Douglas (1977), $\tan^{-1}$ 7.54/1.08.

$\beta_{it} = 81^0C$ At the hub, B, h, = $\tan^{-1}$ uh

$\beta_{it} = 80^0C$.

with data, H = 3m, μ_t = 7.54m/s, V_t = 1.086m/s. Substituting these into equation (4), and evaluating, $\beta_2 = 74.50^0$

Summary Design Data for the Mixer (Material, Aluminum)
Absolute velocity of tip of impeller 7.54m/s
Blade angles inlet $\beta_{it} = 81^0$ V_t = 1.086m/s H = 3m.

Note:
For various sizes and configurations of the impeller say centrifugal or otherwise the relevant parameters involved in the mixing operations can be deduced.

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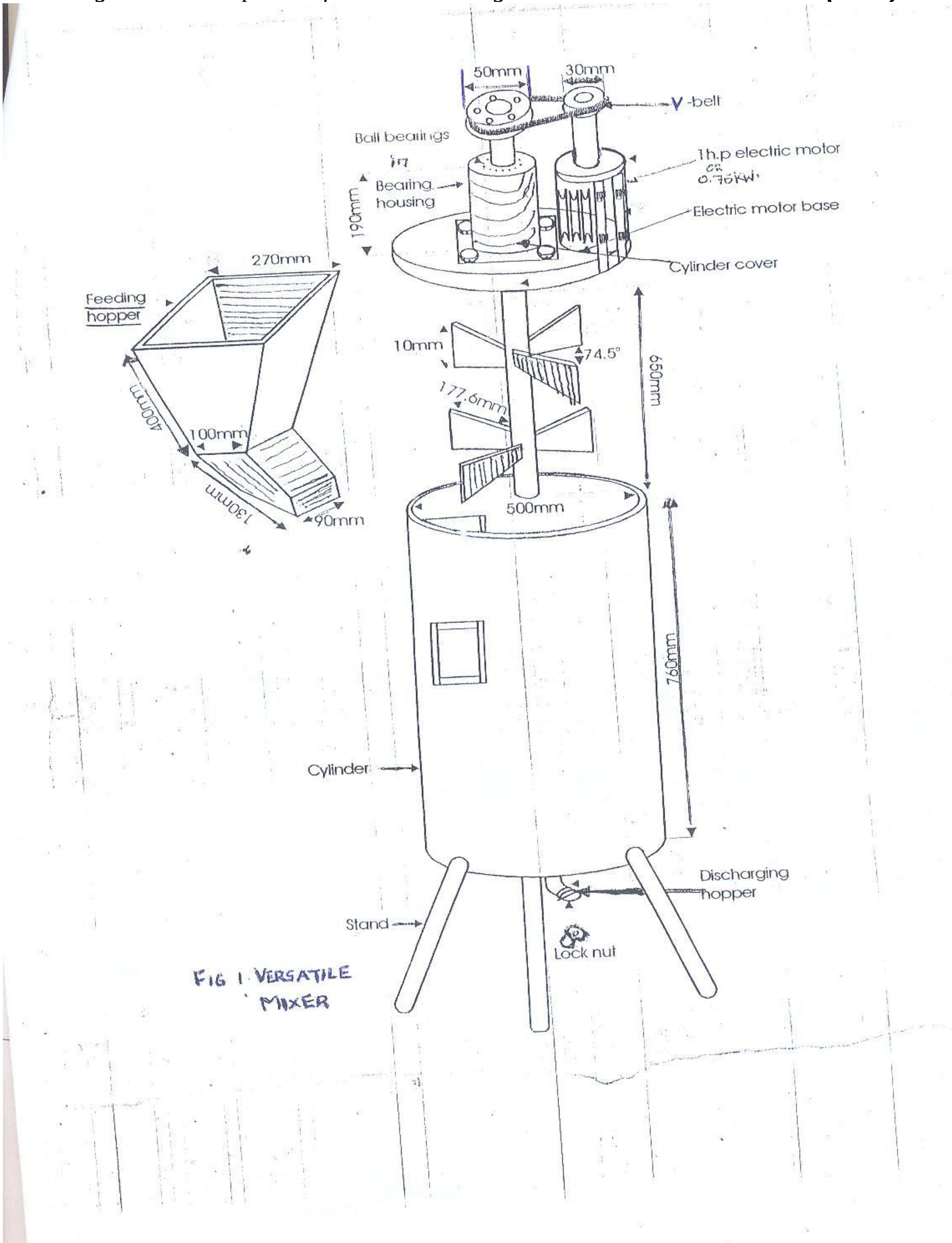
50mm
30mm
V -belt
Ball bearings
1h.p electric motor
Bearing housing
190mm
Electric motor base
270mm
Cylinder cover
Feeding hopper
10mm
74.5°
650mm
177.6mm
400mm
100mm
130mm
90mm
500mm
760mm
Cylinder
Discharging hopper
Stand
Lock nut
FIG 1 VERSATILE MIXER