



Design and Fabrication of a Multi-Purpose Homogenizer

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Abstract

The homogenizer is vital equipment in numerous production sectors such as in food processing, animal feed processing, chemical and pharmaceutical industries, waste recycling and mineral and allied industries. In this work, a multi-purpose homogenizer suitable for the mixing of different materials (animal and fish feeds, coal fuel, foundry sand etc) was designed; fabricated and the performance of the machine evaluated. The cost is about #205,000.00.



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1. Introduction

The use of homogenizer is indispensable in the solid-solid mixing of particles for agro processing, food processing, pharmaceutical, and metallurgical industries [1-5]. The design and fabrication of mixers are based on standard scientific theories and principles available in literature [1-65]. Most animal and fish feed mills depend on mixers of various kinds and capacities [6,62]. Coal is mixed with other fuel materials such as wood dust, rice husk, saw dust and starch (binder) for smelting process. Foundry sand is made from aggregates of different particle sizes and compositions obtained from different sources [7]. To carry out proper mixing and evenly blending of material, a homogenizer (mixer or agitator) is required. Homogenizers have different applications to many fields of operation but are similar in their operational principle. It is widely used in mixing different particulate materials before agglomeration [8, 63].

There are several choices of mixing equipment like horizontal and vertical agitated chambers, tumbling vessels, and air agitated operations [9-13]. Some of the key issues in solids mixing are material handling, proper mix time, mixer volume, scheduling and surge, segregation, and feeding, especially in the case of continuous mixing [4,5].

The construction of homogenizer could be vertical or horizontal depending on the level of mixing required. It is important that the material should be properly agitated to optimize the effective blending. In view of this, due consideration should be given to the material properties (particle size, flow properties, repose and discharge) the machine is intended to be used for. The mixing of various materials of different particle sizes to produce a uniform blended aggregate in feed mills for agriculture, mineral processing and extraction plants require special agitator. The high cost of importation of such machine as essential equipment needed in most of the agriculture and engineering laboratories or workshops usually prompts the construction of the workable homogenizer. However, most available mixers are customized for specific application.

1.1. Mixing mechanisms and sampling

Accurate and adequate mixing is highly vital in animal food production, whether or not there is additive or supplements to enhance the quality of the feed product. During mixing, considerations should be given to appropriate sequence of ingredient addition, right mixer feed level, dry mix [14], wet mix, and product discharge times [1,15,16] at mills as reported by Fahrenholz, [17] in his report. The purpose of study by Reese *et al.*, [18] was to establish the impact of factors such as; sample location, mixing time, number, and blending technique on analyzed nutrients and ingredients mixed in a single screw vertical mixer. The result showed that homogenized, pelleted diet yielded the optimum performance and maximizes production [14,19]. The mixing process can be observed as an overlap of dispersion and convection. Movement of the particulate materials is a requirement of both mechanisms. Dispersion is completely the random change of place of the individual particles while convection causes a movement of large groups of particles relative to each other. The whole volume of material is continuously divided up and then mixed again after the portions have changed places [20]. Alhwaige *et al.*, [21] studied the mixing process of free flowing polymers binary mixtures at different densities and colours in three mixers. The study analyzed the variation of the proportions of the marked particles with time and position in the bed or in the mixer. The results showed that complete mixing was attained at a bed depth of 17 cm and gas velocity of 1.38 Umf in the fluidised bed; 40% filled up level and 40 rpm in the V-mixer and 50% filled up level and 5 rpm in the Nauta-mixer. Tamir and Luzzatto [22] developed and successfully tested an innovative machine for solid-solid and gas-gas continuous mixing, based on the impingement of two streams. The test showed that the new device is convenient, easy to operate and more energy-efficient in comparison to other available solid-solid pneumatic mixers: fluidized bed, spouted bed, air mixer, and mixing silo. Static mixers are in-line devices consisting of motionless mixing components, inserted in the given length of the pipe. Homogenization is attained by using the flow energy of the material to be mixed while the mixing effect is dependent on the continuous separation, distribution, and reunion of particles in the stream of material [23].

1.2. Applications to agriculture industries

Feed mixers are used in feed mills for the mixing of feed ingredients and premixes. They play vital role in the feed production process, with efficient mixing being the key to good feed production. If feed is not mixed properly, ingredients and nutrients will not be properly distributed when it comes time to extrude and pelletize. Owing to the increased use of low-inclusion ingredients in feeds, it becomes more significant methods to evaluate efficiency [2]. The study compared different internal and external indicators of feed mixing efficiency using an experimental horizontal paddle mixer to evaluate dry mix cycle and the wet mix cycle.

1.3. Addition of small volumes of liquids

According to Kirchner *et al.*, [24] the separation of the food compounds from the supplements is common in animal feed production. To evade this, small amount of liquids [25-27] like water, molasses or vegetable oils are often mixed with the feed production line to cause small lumpiness

of fine particles. The addition of small quantity of liquids influences the distribution of particles during mixing [25], the product material and technical characteristics.

Conversely, the mixing homogeneity of feeds achievable due to inadequate quantity of liquids added is not sufficiently characterized for now. Moritz *et al.*, [28] showed that moisture increased pellet durability and decrease pellet mill energy consumption for corn-soya bean-based diets; and high moisturized pellet diets are good for bird performance within 3-to-6weeks grower period. Lundblad *et al.*, [29] experimented two diets (barley, oats and soybean meal) and (maize and soybean meal) for finishing pigs to evaluate the influence of adding water at the mixer on feed processing and pellet feature; both with and without use of an expander. Adding up to 120gwater per 1kg feed into the mixer before steam conditioning and pelleting of the barley-based diet, enhanced pelleting efficiency and pellet durability index (PDI).

There are wide varieties of feed mixers such as ribbon mixers, double shafted paddle mixers, horizontal mixers [30], and other feed mixers among which are continuous and vertical mixers, roller mills and hammers and batch mixers. The continuous mixers are pre-eminently suitable for equal dividing liquids into powdered material (for instance, molasses into mash). The quantity of liquid is exactly registered by the flow-meter which is suitable for automatic control. Ottevanger's vertical mixers are used to mix different raw materials or powdered finished products which are difficult to transport [31]. The Food and Agriculture Organization of the United Nations (FAO) stated that unless the fisheries biologist understands and specifies the activities of the feed mill and its laboratory, profitable fish farming will be a matter of chance. FAO reported results showing that vertical mixers are not efficient for uniform mixing of solids and liquids or for materials of quite different particle size or density [32]. SKIOLD company delivers diagonal mixers, horizontal mixers, paddle mixers and small batch mixers for all purposes and capabilities [33]. The Alvan Blanch mixer is ideal for blending a wide range of dry products of varying densities, meal, rolled grain, cake, pellets, dried beet pulp, vitamin/mineral premix and proportions of moist products such as brewers grains. Liquid molasses may also be introduced in ratios of up to 10% if evenly applied [34].

1.4. Applications to metal casting industries and fuels in combustion engines

Foundry sand mixers: Hand methods of mixing sand may be hard and difficult when there is large quantity of stock to work with. EIRICH specializes in foundry sand mixer machines for preparing bentonite-bonded molding sand, and for many years, the company has maintained a close working relationship with foundries, mold makers and research organizations [35]. Most small foundry shops mix their sand manually which is not efficient since homogenous mix cannot be guaranteed and even when foundry mixers are available, most of them are imported, thereby costing the nation huge foreign exchange. A foundry sand mixer capable of mixing foundry sand was designed and fabricated by Osarenmwinda and Iguodala [36]. **Continuous whirl mixers** manufactured by AalenerGießereimaschinen GmbH (AAGM) manifest in particular, in the mixing quality of the sand with the minimal consumption of binders and curing agents, the short throughput and mixing times, and simple operation and control. The capacities ranges from 1t/h to 100 t/h and can be customized to individual requirements [37]. **Core Sand Mixers** for sand plant and sand preparation equipment are produced by Vijay Engineers and fabricators in India [38]. **Mixers and SMC** were designed for use with high-capacity DISA mixers. The DISA SMC regulates and monitors the process in the sand mixer and ensures that the characteristics of the prepared moulding sand remain within a constant range. The regulation is automatic and continuous by in-mixer analysis of the sand during mixing [39].

Jiang *et al.*, [3] analyzed the significance of the gravel filling degree, the drum rotational speed, number of lifters and drum diameter selected as the influencing mixing factors in the rotating drum (rotary kiln and ball mill) being widely used in food processing, smelting, cement, pharmaceuticals

and other related industries [3,4,40,41]. Wu and Saxena, [42] studied the mixing of light paper pellets in a sand fluidized bed at varying paper pellets proportions (0-20 mass%) over a range of air velocities (0-1.5 m/s) at surface and ambient conditions.

Mixers are incorporated in the fuel reticulation for combustion engines. Some works [5,43-45] have intended to enhance fuel economy and decrease emissions during conversion from a diesel engine to a dual fuel engine not taking into account the enhancement of homogeneity of the mixture inside the engine and precise control of the air-fuel ratio. Recently, an innovative air-fuel mixer was developed, fabricated and assessed to be suitable for mixing air, hydrogen and CNG [46].

The work of Li *et al.*, [47] on the properties and mechanism enlightened on novel method to make magnetic bio-derived chars by physical co-mixing. Kushnir *et al.*, [9] designed and manufactured an experimental feed mixer aimed at understanding the essence of the theoretical calculations of the lobed mixer and technique of the experiments. Previous researches on mixer based feed preparation include a number of leading scientists [10,11] and the factors of assessing the quality of the mixture acts [12]. Of recent, Dhankani and Pearce, [13] developed an open-source 3-D printable laboratory sample rotator mixer in two alternatives that allow users to opt for functionality, cost saving and related complication needed in the laboratories. The sample rotator is designed and confirmed suitable for tumbling and gentle mixing of specimens in an array of tube sizes placed horizontally, vertically or any position in between.

The objective of the present work is to construct a homogenizer suitable for the mixing of different materials (animal and fish feeds, coal fuel, foundry sand etc.). The present report covers the design, material selection, fabrication and assembling while testing and performance evaluation of the homogenizer is intended for future research reports. The project will enhance better understanding of the fabrication process and application of homogenizer in mixing difference materials and the techniques involved.

2.1. Methodology

2.1.1. Design process, criteria and tools

The design process offers insights into the several roles played by the materials selection expert and reviews the process and methods that may be applied to enhance and improve the effectiveness of the design process [48]. Criteria and concepts in design go into detail on many of the "soft" issues related to design, process, safety, manufacturability, and quality. They are of critical importance, because parts and assemblies must be made with well understood variance, consistent processing, and the expectation that the part will perform safely and reliably in the ultimate customer's application. The design tools detail is associated with a state-of-the-art design process, which include: discussions on paper and paperless drawings, computer-aided drafting and design, prototyping, modeling, optimization, documentation and so on.

2.2 Design parameters

2.2.1 Volumetric capacity of the homogenizer

The total volumetric capacity of the homogenizer (V_T)

= (vol. of cylinder + conical fulcrum vol.) – vol. of inner cylindrical barrel. That is,

$$V_T = \pi R_1^2 d_1 + \left(\frac{1}{3}\pi R_2^2 [d_2 + X] - \frac{1}{3}\pi R_3^2\right) - \pi R_4^2 [d_1 + d_2 + X] \quad (1)$$

$\pi = 3.142$, R_1 is radius of cylinder, d_1 is height of cylinder, R_2 is Radius of conical part, d_2 is height of cone outside, $(d_2 + X)$ is height of cone with inner extension, R_3 is Radius of cone base and R_4 is Radius of inner barrel/cylinder

2.2.2 Energy transmission and torque

2.2.3 Power and feed charge calculations

The power of the prime mover

= power to drive total weight (of spiral agitator and weight of feed inside the inner barrel)

Total weight of spiral shaft driven by prime mover in the inner barrel = $W_{t_{shaft}}$

Total weight of feed in the inner barrel = $W_{t_{feed}}$

Total volume of inner cylindrical barrel (V_T) is defined as:

$$V_T = \pi R_4^2 [d_1 + d_2 + X] \quad (2)$$

Total length or height of feed movement in the inner barrel = length of shaft

2.2.4 Material balance and feed charge calculations

Applying the law of mass conservation, over a short time interval,

Mass inflow = Mass outflow

$$\text{Material volume inflow at inlet} \quad M_i = A_1 V_1 \Delta t \quad (3)$$

$$\text{Material volume outflow at discharge} \quad M_o = A_2 V_2 \Delta t \quad (4)$$

Hence,

$$\text{Mass inflow at inlet} \quad M_i = A_1 V_1 \Delta t \quad (5)$$

$$\text{Mass outflow at discharge} \quad M_o = A_2 V_2 \Delta t \quad (6)$$

Therefore,

$$\rho A_1 V_1 = \rho A_2 V_2 \quad (7)$$

For mixture of n-number of materials (different compositions or sizes)

$$A_1 = \rho_1 A_1 V_1 + \rho_2 A_2 V_2 + \rho_3 A_3 V_3 + \dots \dots \dots \rho_n A_n V_n \quad (8)$$

2.2.5 Determination of moisture content

$$\text{Moisture Content,} \quad M_c = \frac{W_w - W_d}{W_d} \times 100\% \quad (9)$$

where W_w is weight of wet sample, W_d is weight of dry sample

2.2.6 Rule of mixture

Most importantly; mixing in the manufacture of a uniform blend of numerous constituents reduce the effects of the disparity in their concentrations [49,64,65]. The tracer's concentration (p) and other constituents/ingredients (q) in the mixture are related by (10.1):

$$p + q = 1. \quad (10.1)$$

Considering samples of definite size and their content with the tracer in the mixture; the tracer concentration (x_i) in the samples will vary at random about the tracer's concentration (p) in the total mixture. Thus, the mixing quality can only be evaluated statistically. The lower the variation in concentration (x_i) about the concentration (p), the better is the mixing quality. This can be quantified by the statistical variance of sample concentration σ^2 , also defined as the degree of mixing.

Theoretical variance is calculated from eq. (10.2)

$$\sigma^2 = \frac{1}{N_g} \sum_{tan1}^{N_g} (x_i - p)^2 \quad (10.2)$$

and relative standard deviation (RSD) as (11)

$$RSD = \sqrt{\sigma^2} / p \quad (11)$$

2.2.7 Shaft with spiral plates, pulley and bearing design

A shaft is a rotating solid or hollow circular cross-sectional part which transmits rotational motion and power. It consists of machine elements (pulleys, clutches, flywheels, gears, and sprockets) mounted on the shaft to transmit power from the prime mover (motor or engine) through a machine. The machine elements are attached by keys, press fit, pins, dowel, and splines to the shaft which rotates on rolling bush bearings or contact bearings [50]. A variety of retaining rings, grooves, thrust

bearings and steps take up axial loads and set the rotating elements in the shaft, while the power is transmitted from drive shaft (prime mover) to the driven shaft (wheels, gearbox) by couplings. The shaft is subjected to bending moment, torsion and axial force [50]. The material used is heat treated hot-rolled plain carbon steel already explained [51,53]. Pulleys are used to transmit motion and torque from one shaft to another.

2.2.8 Design considerations for shaft

The parameters in the machine shaft design are regarded as the engineering basis and are adopted as Equations (12) – (24) [53-56]:

2.2.9 Shaft diameter

Hall *et al.*, [53] had established a mathematical expression for determining the size of shaft diameter under torsion as equation (12) and (13) [54]:

$$\tau = 16T/\pi d^3 \quad (12)$$

Thus,
$$d = \sqrt[3]{\frac{5.1T}{\tau}} \quad (13)$$

where τ is torsion, T is torque and d is shaft diameter

2.2.10 Transmitted torque

Accordingly, for a line shaft carrying pulleys, the torque on the shaft is presented by [55] as equation (14):

$$T_s = (9.55 \times 10^6 P)/N \quad (14)$$

where T_s is torque on the shaft, P is power input, N is rotational speed of the shaft.

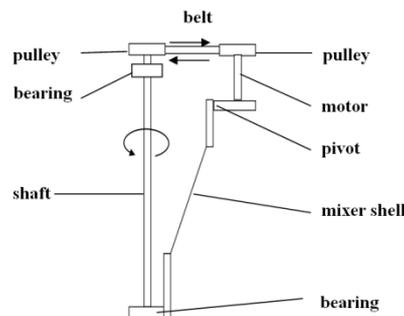


Figure 1: Energy transmission and torque

Angular velocity ω , at certain speed is given by (15) [56]:

$$\omega = \left(\frac{2\pi N}{60}\right) \quad (15)$$

Transmitted power H (in kwh) and angular velocity, ω are related as (16) and (17) [56]:

$$H = M_t \omega = M_t \left(\frac{2\pi N}{60}\right) \quad (16)$$

where $M_t = \frac{H}{\omega} = H \times \left(\frac{60}{2\pi N}\right) = \frac{30H}{\pi N}$ (17)

2.2.11 Design based on strength

The stress at any point depends on the nature of load acting on the shaft presented as basic stress Equations (18)-(24) for shaft design [57] as follows:

2.2.12 Bending stress

The bending stress is defined as;

$$\sigma_b = \frac{32M}{\pi d_0^3(1-k^{-4})} \quad (18)$$

where, M is the bending moment at the point of interest, d_o is the outer diameter of the shaft, k is the ratio of inner to outer diameters of the shaft (in the present case, $k = 0$ for a solid shaft since the inner diameter is zero)

2.2.13 Axial stress

The axial stress is defined in (19) as;

$$\sigma_s = \frac{4\alpha F}{\pi d_o^3(1-k^4)} \quad (19)$$

where, F is axial force (tensile or compressive), α =column-action factor(1.0 for tensile load). α is called column action factor, due to buckling of long slender parts subjected to axial compressive loadings and it is defined as (20) and (21);

$$\alpha = \frac{1}{1-0.0044(L/K)} \text{ For } L/K < 115 \quad (20)$$

$$\alpha = \frac{\sigma_{yc}}{\pi^2 n E} \left(\frac{L}{K}\right)^2 \text{ For } L/K > 115 \quad (21)$$

$n = 1.0$ for hinged end, $n = 2.25$ for fixed end, $n = 1.6$ for ends partly restrained, as in bearing, K is the least radius of gyration, L is the shaft length, σ_{yc} is the yield stress in compression

2.2.14 Stress due to torsion

The torsional stress is given by (22)

$$\tau_{xy} = \frac{16T}{\pi d_o^3(1-k^4)} \quad (22)$$

T is the torque on the shaft, and τ_{xy} is the shear stress due to torsion

2.2.15 Combined bending and axial stress

The bending and axial stresses are normal stresses represented by equation (23);

$$\sigma_b = \left[\frac{32M}{\pi d_o^3(1-k^4)} \pm \frac{4\alpha F}{\pi d_o^2(1-k^2)} \right] \quad (23)$$

Shear stress due to torsion is only considered in a shaft and shear stress due to neglected load on the shaft.

2.2.16 Maximum shear stress theory

The maximum shear stress theory as related to the shaft design is given as (24):

$$\tau_{max} = \tau_{allowable} = \sqrt{\left[\frac{\sigma_x}{2}\right]^2 + \tau_{xy}^2} \quad (24)$$



Figure 2: (a) Spiral agitator plate and (b) Assembly of shaft and Spiral agitator plate

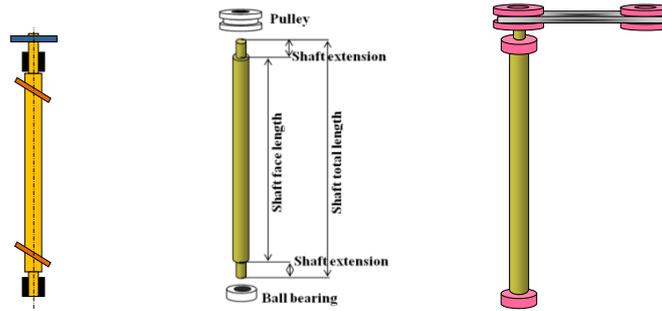


Figure 3: (a) Assembling shaft, pulley, bearing and belt

2.2.18 Pulley–belt design



Figure 4: Assembly of belt and pulleys

2.2.19 Agitation speed

For the rotating shaft-pulley connection; the following design parameters are calculated considering the equation (25) [57];

$$D_s/D_D = N_D/N_s \quad (25)$$

where D_s is diameter of pulley connected to the spiral shaft, D_D is diameter of pulley on power drive, N_D is the speed of power drive and N_s is the speed of spiral agitator.

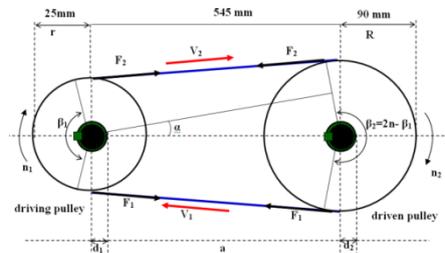


Figure 5: belt and pulleys transmit motion and torque from one shaft to another

2.2.20. Hopper design

The angle of repose of the solid products (sand, maize, palm kernel cake etc) on mild steel is 35° [58]. Inclination angle of the front and side faces of the feed loading bucket are greater than the product repose angle which allows total product migration into the feed throat [56]:

The hopper is made of near rectangular shape loading bucket and the feed throat (a cut right rectangular pyramid, while the feed throat is of cut rectangular prism. The volume (V_{tp}) of the cut pyramid is given as (26) by Adetunji and Quadri [59]:

$$V_{tp} = \left[\frac{h_2 B_2 - h_1 B_1}{3} \right] \quad (26)$$

2.3 Design evaluation

The following parameters (Equations 27-29) are adopted [48] and used in assessing the reliability and useful life of the machine.

i. Mean time to failure (MTTF) is used in assessing the reliability in design; it explains particularly the mean time to first failure and it is expressed as (27):

$$MTTF = \int_0^{\infty} R(t)dt = \int_0^{\infty} \left\{ \exp \left[- \int_0^t \lambda(\tau)dt \right] \right\} dt \quad (27)$$

ii. Mean time between failure (MTBF) is also expressed mathematically as in(27). MTTF of the individual components and MTBF (mean time between successive component failures) are related by (28);

$$\frac{1}{MTBF} = \sum_{j=1}^m \frac{1}{(MTTF)_j} \quad (28)$$

where the whole equipment has m number of components of different ages replaceable at different times of failure. Since MTBF is time dependent; MTTF and MTBF are identical at first time of operating the equipment.

iii. The useful life period of a machine in which there is constant failure rate is expressed as;

$$R(t) = \exp \left[- \int_0^t \lambda dt \right] = e^{-\lambda t} \quad (29)$$

R is reliability of a device, t is operating periods of the same length, λ is the failure rate (constant) (ASM vol, 20) [48]

iv. Efficiency of the mixer ϵ , was determined using Equations (30) and (31) by Hall *et al.*, [60,61] according to Osarenmwinda and Iguodala, [36];

$$\epsilon = \frac{\text{Output power}}{\text{Input power}} \times 100\% \quad (30)$$

For the homogenizer, the efficiency is determined by

$$\epsilon = \frac{\text{Power required}}{\text{Power supplied}} \times 100\% \quad (31)$$

2.4 Design drawings

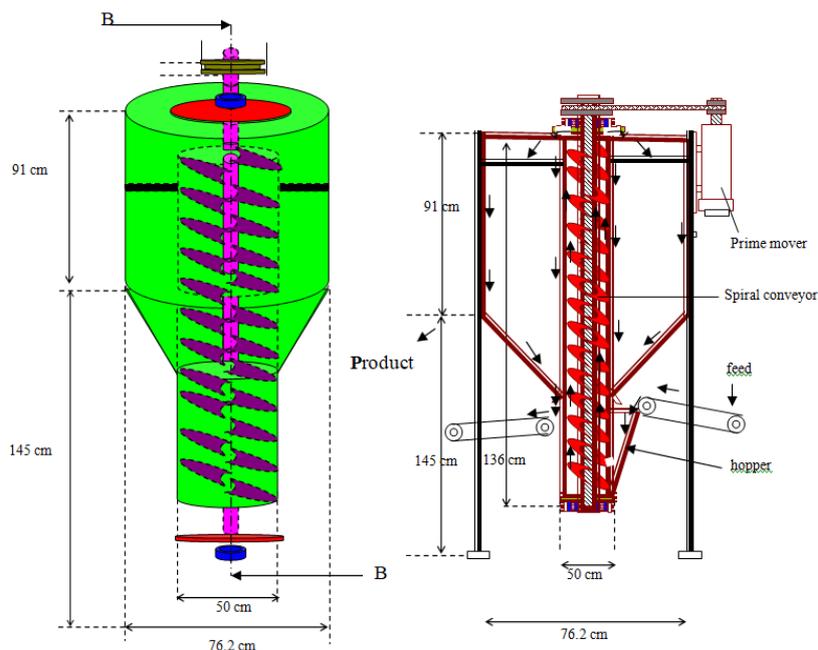


Figure6: Sectional 3D view of multi –purpose homogenizer

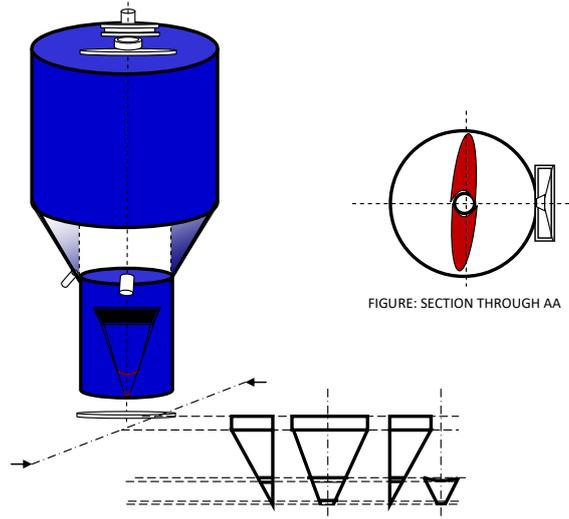
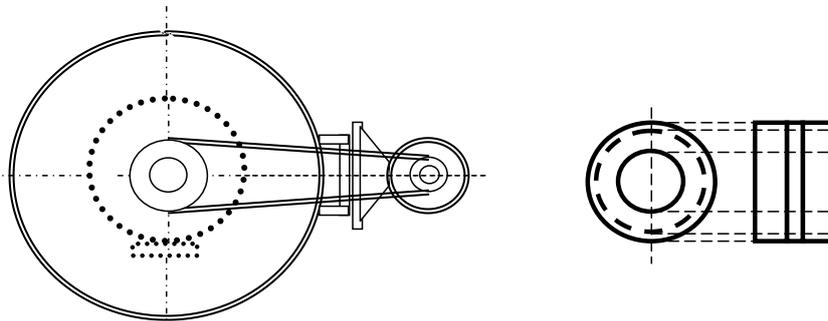


Figure7: 3D drawing of multi –purpose homogenizer



Pulley

Figure 8: Plan view of multi-purpose homogenizer

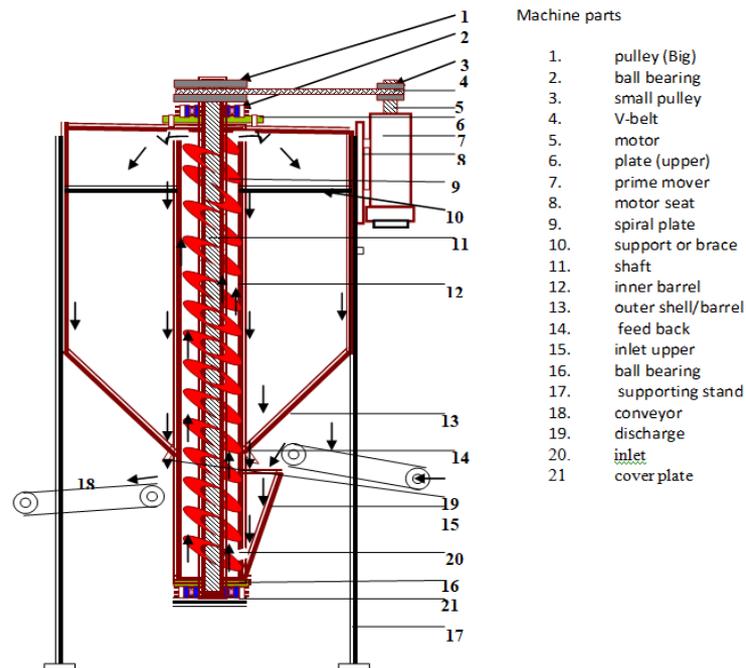


Figure 9: Sectional view through the multi-purpose homogenizer

2.5. Material selection and costing

The materials selected for the homogenizer construction and criteria for selection are stated in Table 1, while the bill of quantity is in Table 2.

Table 1: Material selection

Components	Materials	Characteristics
Ball bearing	Ball bearing	Strong, cheap and allows free rotation
Bolt, nuts and washers	Mild steel bold and nuts	Easy joining and fastening. Disassembling is easy and fast.
Outer cylindrical shell	Mild steel sheet	Corrosion resistant, weld able and can withstand vibration.
Supporting stand	Mild steel angle bar	Withstand eccentric motion, weld able and corrosion resistant.
Spiral plates	High carbon steel	Suitable for vertical transfer of solid materials
V-belt	Impregnated rubber	Cheap and strong
Power drive	Electric motor	Higher efficiency

Table 2: Materials and Cost Valuation

Materials	Specifications	Quantity	Cost (₦)
Electric motor drive	3.0 Horse power,	1	40000
V-pulley	50 mm, diameter	1	4000
V-pulley	180 mm, diameter	1	8000
V-belt		1	3000
Shaft steel rod	24 mm dia, 160 cm long	1	15000
Ball bearing	25.4 mm, internal diameter	2	6000
2.5 mm Copper wire	2.5 mm, 3 core flex	4m	2000
Socket	220V/15A	2	3000
Switch, fuse box	220V/15A	2	2000
Plug	220V/15A	1	1500
Welding electrode	Gauge 12	1 pkt	8000
Flat Steel sheet	240 cm x120 cm x 2mm, thick	2	30000
Steel angle bar	3.81 mm, thick	2	10000
Cutting stone	22.86 cm, diameter	4	4000
Grinding stone	22.86 cm, diameter	5	5000
Gloss paint	Autos-base	4 ltrs	10000
Primer paint	Gloss	1 ltr	1500
Thinner	Solvent	4 ltrs	6000
Plastic filler		4 ltrs	6000
Sand papers	Hard, rough	1pack	1000
	Hard, smooth	½ pack	500
Bolt and nuts		12 pcs	1000
Workmanship (rolling, welding)			5500
Workmanship (Painting)			5000
Transport			15000
Miscellaneous/logistics			12000
Total			205,000

2.6 Construction details

The major components of the homogenizer which include the drums, support frames, conveyor (spiral plate), inner barrel/drum and electric motor were assembled into a unique solid structure by different joining methods (Figures 2-10).

- Housing unit (outer drum): This was made of 91 cm height by 76.2 cm diameter, steel sheet. The steel sheet was cut, rolled to form cylinder and the edge welded.
- Support frame: Four (4) number of steel angle bars were of 145 cm height were welded to the outer drum to act as support for the housing case.

- c. Inner barrel/drum: This was made of iron sheet, roll to form cylinder of 136cm height by 50 cm diameter which was placed inside the bigger cylinder and also housing the conveyor.
- d. Feed inlet: This was made of iron sheet cut and attached with outer section of inner steel shell by welding.
- e. Feed outlet: This was attached with conical part by welding.
- f. Conical fulcrum steel part: This was made of 2 mm long steel sheet having 76.2cm, upper and 50cm, lower diameters respectively, attached to the main drum by welding.
- g. Power drive: The electric motor single-phase 3.0 horse power, 1425 revolution per minute supplies energy for rotating the conveyor which carry the feed up. The electric motor was mounted on the upper side of the homogenizer housing by bolt and nuts; and connected to the rotating spiral conveyor using V-belt. The rotation of the electric motor provides easy up-take of the feed by the spiral conveyor system.

3. Results and discussion

The components were assembled into a unique solid machine of vertical homogenizer type machine designed for dry and semi-wet operation as shown in Figure 10.

3.1. Functionality

The machine is designed to handle all manner of solid particles (agricultural produce such as cereals, beans, husks, clay, minerals, coal, sand, wood dust, etc) of diverse densities depending on variation in their mix ratios. In the test run exercise, the performance showed that the machine can effectively be used in mixing of solid fuel materials for briquetting purpose. The machine can operate within 10-15% moisture per 1.0 kg feed charge content in correlation with Lundblad *et al.*, [29] and in accordance with the various scientific principles recommended in various previous works [62-65].

3.2. Wear and corrosion control

Since the mixer is designed to handle both dry and moistened solid particles, there is the need to protect it against wear and corrosion in order to save the work life span of the mixer. The steel materials from which the inner components such as the long shaft and spiral blades were heat-treated [51,53] prior to fabrication while the entire exterior was coated using plastic resin and oil base paint.



Figure10: Photographic view of multi-purpose homogenizer

4.0 Conclusion

The relevant basic engineering principles were used in the design and construction of the homogenizer. The machine was test run and found to be suitable for solid-solid particle mixing especially for light mineral and agricultural products, and it could be used for small-scale experimentation. The results of fabrication, test run and assessment of mixing efficiency are under consideration for publication in other report elsewhere. Further research could improve and reduce the common errors to the minimum allowable limit.

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