Design and Fabrication of a Flour Mixing Machine

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Article info	Abstract
 	A mixing machine was fabricated to eliminate the local process of mixing flour for both domestic and commercial uses. The uniqueness of the machine rests on the fact that the mixer basin as well as the stirrer can be changed at will to suit the nature of materials being mixed. The machine was developed to enhance the hygienic processing of flour into dough for bread baking and other related products of flour for human consumption. The mixer eliminates the unhygienic and laborious indigenous process of preparing it. The frame was made of mild steel U and square channel (1270mm x 1000mm) metal sheet welded to cover the whole frame except the underneath. The U-Channel square base housed the gearbox of 1:40 and the transmission system. The machine was designed to mix 25kg of flour and ingredients within 25 minutes into dough. The machine has 87% efficiency. The machine parts consist of 2.5hp electric motor of 2840rpm, driver pulley, V-belt, gearbox, stainless basin, stirrer, shaft, etc.

1. Introduction

Flour is a finely grounded cereal grains or other starchy portions of plants, used in various food products and as a basic ingredient of baked goods. Wheat flour is mostly used for bread production. Wheat is a source of energy (carbohydrate). However, it contains significant amounts of other important nutrients including proteins, fiber, and minor components including lipids, vitamins, minerals, and phytochemicals which may contribute to a healthy diet [1]. Just that in recent time, bread consumption is continuously increasing in many of the developing countries, such as Nigeria. The desire of flour mixing machine increases because in food industries, hotels, bakeries and pizzerias, mixing of flour dough is a major operation in food production [2]. A dough mixer is used for household or industrial purposes. It is used for kneading large quantities of dough. It is electrical, having timers and various controls to suit the user's needs. Some features of dough blenders include high speed, low speed and bowl reverse and a kneading bar in the Centre of the bowl. In African dough mixer is mainly characterized as the matter created for yam pounding, flour mixing with proper amount of water, with addition of recipe ingredients for flour (yeast, fats and oil, sugar [1]. In Food industries, mixing of flour to form dough has been a major operation in their production process. Even in many homes, mixing of flour for baked foods has become necessary; hence the need for an affordable flour mixing machine is on the increase [3]. Mixer is also a kitchen utensil which uses a gear –driven mechanism to rotate a set of beaters in a bowl containing the food to

prepare. It automates the repetitive tasks of stirring, whisking or beating. When the dough hooks are replaced by a beater, a mixer may also be used to knead [4, 5, 6,7,8].

A stand mixer varies in size from small countertop models for home use to large capacity commercial machines. Stand mixers create the mixing action by rotating the mixing device vertically: planetary mixers, or by rotating the mixing container, spiral mixers [9].

All mixing machines available today are designed to incorporate both the mixing and the kneading processes [2]. Bread dough mixing requires a method by which the products are homogeneously mixed and hydrated, resulting in a well-developed gluten network [4, 6, 10,11, 12]. However, the cost of dough mixing still remained uneconomically affordable for the small and medium scale bakeries. The primary objective of solid mixing requires intimate intermingling of the materials to be mixed. This is not so simple, as there is no one mixer design that universally satisfies all mixing requirements. The processes of mixing flour consume time, energy as care must be taken to avoid contamination for proper hygiene. There are already existing flour mixing machine but they have problem like cleaning, high cost and time consuming [13, 14, 15]. In view of this demerit, a machine that can mix up to 25kg of flour which have low cleaning, not laborious, easy to operate will be constructed.

2. Methodology
2.1 Design Considerations and Machine Components
In constructing and fabricating the flour mixing machine, feasibility studies were carried out on the availability, strength, machinability, and the economic considerations on the materials required for the designing of the machine.

2.2 Design Analysis
2.2.1 Design assumptions
- The acceleration due to gravity (g) is $9.81 m/s^2$
- The density of stainless steel is 7880 kg/m^3
- The density of mild steel is 7850kg/m^3
- The volume of flour to be mixed should not be more than 2/3 of the total volume of the mixing chamber;

2.5hp electric motor with high speed (2840rpm) [3]

Capacity of the machine 100kg/hr

Relative density (Rd) of dough 11.5kg/m^3 [7]
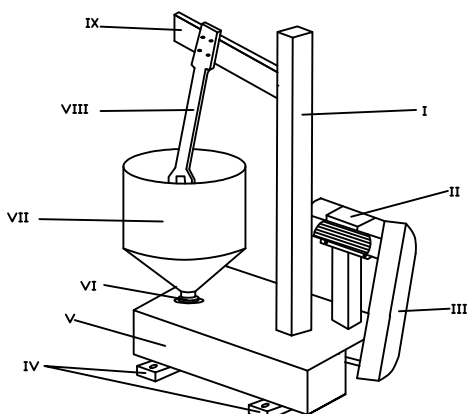
FIG.	LABELLINGS
I	VERTICAL STIRRER SUPPORT
II	ELECTRIC MOTOR
III	ELECTRIC MOTOR SUPPORT
IV	LEG SUPPORT
V	BASE SUPPORT
VI	ROTATION BEARINGS
VII	BARREL
VIII	STIRRER
IX	HORIZONTAL STIRRER SUPPORT

Fig 1: Flour Mixing Machine

Table 1: Design Analysis

MACHINE PARAMETER	INPUT	ANALYSIS	DECISION/REMARK
Volume of the mixing basin(V), Diameter of basin(d), Radius of basin(r).	Designed for a mixer capable of mixing 25kg of flour per batch; Rd of dough = 11.5kg/m³ Let, vol. of water + vol. of air space + other ingredients = 12%V ; let h = 0.58m;	Volume of mixing basin, V=25/11.5 = 2.17m³ Let, vol. of water + vol. of air space + other ingredients = 12%V Thus, V = 2.17 + (0.12 x 2.17) = 2.43m³ But, V=$\pi r^2 h$; r = $(V/\pi h)^{1/2}$ = 1.15m; Thus, d =1.15 x 2 = 2.31m	d = 2.31m
Thickness of mixing basin(t) Circumferential or hoop stress on mixing basin(σ_h)(Khurmi,2003); Where P_i is the intensity of internal pressure; d is the internal diameter of mixing basin, and t is wall thickness of the basin where m= mass of mixture, kg	σ_h = $P_i d/2t$; since the mixing basin is open, longitudinal stress is negligible. $\sigma_h \leq 1$Gpa But P_i = pressure due to (centrifugal force + weight of mixture P_w = $\rho g h$; ρ is density of mixture, h is height of mixture, and P_w = pressure Since F_c is acting on the circumference of the mixing basin; Area on which F_c acts; A_c =$2\pi rh$	P_i = P_c + P_w Centrifugal Force on Mixture, P_w = 11.5 x 9.818 x 0.58 =0.065kN/m² F_c = $mr\omega^2$; where m= mass of mixture(kg) ω=$2\pi N/60$ where r is radius of basin, m; ω is the angular velocity, rad/s; and N=2840/40(1:40) =71rev/min ω = $(2\pi \times 2840)/60$ = 297.4rad/sec.; F_c = 56 x 1.15 x $(297.4)^2$ =5695.97kN A_c = $2\pi rh$ = 2π x 1.15 x 0.58 = 4.19m P_c = F_c/A_c = 5695.97/4.19 = 1359.42kN/m²; P_i = 1359.42 + 0.065 =1359.46kN/m² t = $P_i d/2\sigma_h$ = (1359.46 × 10³ x 2.31) / (2 x 1 x 10⁹) = 0.00157m	t $\approx$ 2mm thick stainless steel plate
Speed of the driven pulley, N_2	N_1 = 2840RPM D_1 = 0.050m D_2 = 0.15m	$N_1 D_1 = N_2 D_2$ $N_2 = \frac{2840 \times 0.05}{0.15}$	N_2 = 946.67RPM
Speed ratio, r	N_1 = 2840RPM N_2 = 946.67RPM	$r_s = \frac{N_1}{N_2} = \frac{D_2}{D_1} = \frac{150}{50} = 3$	$N_1 : N_2$ = 3 : 1 $D_2 : D_1$ = 3 : 1
Velocity, V	$\omega_2 = \frac{2\pi N_2}{60}$ r_2 = 0.075m	ω_2 = 99.13rad/s V = $r_2 \omega_2 = r_1 \omega_1$ V = 0.075 × 99.13 V = 7.43m/s	V = 7.43m/s
Circumferential force, F on the basin	Volume of the empty basin, V_P	$V_P = \pi \times \frac{(D_b)^2 - (d_b)^2}{4} \times L_b$ = $\pi \times \frac{(0.62)^2 \times (0.127)^2}{4} \times$ 0.58 = 2.82 × 10^{-3}m³ F = $\rho_{stainless\ steel} \times V_p \times g$	F = 7880 × 2.82 × 10^{-3}m³ × 9.81 = 217.98N

Power output, P_o	$F = 217.98N$ $V = 7.43m/s$	$P_o = F \times V$ $= 217.98 \times 7.43$	$P_o = 1.62KW$		
Efficiency, η	$P_o = 1.62KW$ $p_i = 1.86KW$	Power input, p_i	$1HP = 0.746KW$	$2.5HP = 2.5 \times$ 0.746 $= 1.86KW$	$p_i = 1.86KW$

Table 2: Constructional Procedure

S/N	COMPONENTS	MATERIALS	DIMENSION	PROCESSES	MACHINE USED
1	U and Square channels for the base, standing arm and extension arm respectively	Mild steel	1524mm x 610mm & 1400mm x 400mm	Cutting, burning, Welding, grinding	Gas and Arc welding m/c, grinding m/c
2	Basin	2mm thick stainless steel	550mm x 640mm	Sheet rolling, doming, welding	Rolling m/c, doming m/c, arc welding machine mc
3	Stirrer	Stainless steel	860mm x 200mm	Cutting, drilling, welding	Hack saw, drilling m/c, arc welding m/c
4	Drive shaft	Hard steel	800mm x 60mm	Turning, milling	Lathe, milling m/c
5	Pulleys	Mild steel	50dia & 150dia	Turning	Lathe
6	A-49 Belt and pulleys guard	Rubber, mild steel	575mm x 5mm	Fixed within the groove, cutting, welding	Hack saw and welding m/c
7	Prime mover (electric motor)	Cast iron	289mm x 90mm	Fastening	Bolts and nuts
8	Shackle bearing	Cast iron	50mm x 12mm	Fastening	Bolts and nuts
9	Flanges	Cast iron	75mm x 10mm	Turning, drilling, welding	Lathe, drilling m/c, welding m/c
10	Couplings	Cast iron	60mm x 19mm	Turning, drilling, welding	Lathe, drilling m/c, welding m/c

3. Tests and Results

The fabricated flour mixing machine was tested and compared to the indigenous method of mixing dough. In order to achieve the desired texture, test for hardness was carried out to know if it is necessary to add water to the mixed flour.

Unlike the other method of mixing flour, this newly designed machine makes the work easier, efficient and much faster than the indigenous way of mixing dough with 87% efficiency. It was however observed that the rate of mixing flour in this machine was faster. This research work has successfully presented a functional and highly efficient low cost flour mixing machine by minimizing traditional technique of mixing and health condition of individual, this machine is design for restaurant and bread making industry usage, in other to improve a healthy and hygienic condition of an individual. It is expected that an average company in Nigeria can afford the machine.

Table 4: Test

Time (s)	Driver (prime mover) (rpm)	Driven(basin) (rpm)
60	2840	71
120	5680	142
180	8520	213
240	11360	284

Design capacity = 100kg/hr
Capacity per batch = 25kg
But thorough mixing of dough was achieved in approximately 15minutes per batch
Time for mixing 100kg of dough = 4×15
$$= 60\text{mins}$$
Determination of Efficiency (£)
Ma= Mass of flour to mix   Mb== Mass of flour after mixing
Hence,

$$£ = \frac{Ma}{Mb} \times 100$$

Ma=25kg   Mb= 28.7

$$£ = \frac{25}{28.7} \times 100$$

$$£ = 0.871$$

4. Conclusion and Recommendations
4.1   Conclusion

A flour mixing machine is developed for the domestic consumers for better efficiency. In addition to the fact that this machine gives more hygienic mixed dough, it also eliminates the indigenous process of preparing dough. The improvement of the flour mixing machine which is able to form dough from flour and ingredients demonstrates that the fact that such food processing equipment helps in producing large quantities and keeps cost under control. The flour mixing machine is fast and reduces wastages. This machine is design for bread making industry and restaurant usage, in other to improve a healthy and hygienic condition of an individual. It is expected that an average bread making industry in Nigeria can afford the machine.

4.2   Recommendations

From this research, we recommend that some chemical analysis of the end product should be carried out to determine the degree of contamination of the mixed flour by the material employed in the machine construction. Also, there is room for improvement in the efficiency and physical outlook of the machine.

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