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INFLUENCE OF LOAD AND STIRRER TYPE ON CURRENT, TEMPERATURE AND REVOLUTION PER MINUTE (RPM) DEVELOPED ON A LOCALLY FABRICATED MIXER

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Abstract

A mixer was designed and constructed on angle iron frame 450×400×950 mm (L×W×H), with a spiral(A) and non spiral stirrer(B) 350×10.5mm(L×ϕ) as impeller and powered by a 2.7kw generating set through 0.374 kw(0.5Hp) a single phase electric motor with variable speed control. The mixer was run on equal mass of flour, sand, garri, water and air as load at 5 different loading speeds at one instant ,then the speed kept constant and evaluated on 1 to 5 kg of sand. The revolution per minute/temperature attained in the motor and current developed per each sample were measured by a tachometer, analogue temperature sensor and 266 clamp ammeters. The data on load were regressed against rpm, while a bill of quantity performed on the mixer Result show that the mixer is capable of mixing the materials at various speeds (rpm) of 1280, 1212, 1140, 1035 and 945 for stirrer A and 1302, 1211, 1152, 1046 and 961 for stirrer B, as the load increased from 1-5kg for water /flour mixture. An estimated speed of 1275 rpm for 5kg flour at temperature of 41.4°C and current of 11.12amp was recorded. Regression analysis showed a deceleration of -0.966 between loads and speed (rpm) and indicated that for every increase by 1 kg of load, speed (rpm) reduces by 84.5 and 85.5 for A and B stirrers, which fits the linear model. Economically, small scale processor can afford to run these mixers which was estimated to cost twenty eight thousand naira (₦28,000) or $150 equivalent.

Keywords: mixer, stirrer type, speed, flour, small scale

1. Introduction

Today, most Nigerians like fast foods which are made from flour (bread, cakes doughnut etc) [1]. This has tremendously increased the demand for flour and thus flour processing machines such as mixers. In view of the fact that food structure is composed of more than one material and referred to as the arrangement of the clement in microscopic view [2], so mixing, the unit operation used to bring materials of different phases or structure to a uniform or near uniform phase becomes necessary. Unlike gases, mixing of particulate is done by impacting, scattering, displacing and blending or combination of two or more materials into a mass or compound [3]. Lacey [4] found that convective buck diffusive and shear movements of particles are involved. The selection of a correct type and size of a mixer depends on the type and amount of food being mixed and the speed of operation needed to achieve the required degree of mixing with minimum energy consumption. Octave [5] had surveyed various mixing equipment available. Whether low or high-viscosity mixers, baffled or unbaffled, Twin-shafted or single shafted, the power requirement varies according to the nature, amount and consistency of foods in the mixed position, types, speed and impeller size. Various foreign mixers fabricated based on this principles are effective but not within the rich of a small scale operators, with prizes ranging from ₦50,000 to ₦150,000.examples are Kenwood and Harbot mixers, however, where the processors could afford them, problem of durability, in adherent to operational manual, lack of spare parts, non regular power supply and lack of maintenance culture sets in. The locally fabricated mixers by road side welders do not meet standard specification, and are fabricated without knowledge of food properties. No wonder Onwuka et al. [7] reported that food processing machines are available but with limitations.

To this end, there is a need for a better approach to fabrication in African content which this paper advocates considering simplicity, low power rating and use of local materials. This will encourage small scale fast food processors to adequately produce quality and cheap snacks at low cost. And to those in rural areas where electricity is a limiting factor can use low cost electric generator to power the mixer. This will eliminate drudgery associated with hand mixing, increase production output and reduce cost of production Therefore the major objective of this paper is to produce and evaluate a flour mixer that will operate at low energy input especially using electric generators and then study the effect of various stress (load) type on the mixer revolution, while current and temperature developed in each operation will be determined.

2. Material and Method

2.1. Design considerations

The machine was designed with the following considerations: ability to use low powered generator for rural processors, elimination of drudgery and risk of manual mixing of flour for cake production. The operation and fabrication cost are within the limit of rural dwellers and small scale processors. Maintenance is easy and parts are easily detachable for repairs. The speed of the mixer is to be varied with a variable resistor.

2.2. Design conception

The mixer was conceived to consist of the following major components: the mixing bowl, stirrer and the frame, while the belt and pulley system forms the driver mechanism. The bowl is designed to be easily detachable since a batch process is considered. The stirrer was also made detachable and two types are considered. The mixer was designed to mix either dry and wet flours or paste. The bowl is made from galvanized metal sheet measuring 300 × 310 × 3mm. The discharge of the material after mixing was manually conceived. The frame was made with angle iron of 3mm thickness, while the floor on which the bowl rest is a wooden material 400 × 450 × 30mm in dimension.

2.3. Design calculations

i. The bowl was design based on the bin volume as

$$V = \pi r^2 h \tag{1}$$

Where $r = d/2$ and d – Diameter of the bowl is 300mm, h is the height of the bowl is 310mm and the bowl has a volume of 22m^3, this is where the mixing takes place and it contains the cake flours. ii. The stirrer comprises the stirrer's rod which was constructed from a stain less steel rod 360×10.33mm (L×) and an impeller (rectangular or spiral), made from 7mm thick stainless steel rod. iii. Shaft: An important consideration in the design of a mixer is the power to drive the impeller. The stirrer is attached to the shaft, the torque on the stirrer shaft was calculated according to Khurmi and Gupta [8] for circular solid shaft

$$\frac{T}{J} = \frac{\tau}{r} \tag{2}$$

$$\frac{32T}{\pi d4} = \frac{2\tau}{d} \tag{3}$$

Where T – twisting moment on the stirrer, d – diameter of the shaft, mm,τ_{max} stress on the shaft, J – Polar moment of inertia of the shaft about the axis of rotation

$$d = d\sqrt{\frac{6T}{\pi\tau_{max}}} \tag{4}$$

and for shallow shaft

$$J = \frac{\pi(d_o^4 - d_1^4)}{32} \tag{5}$$

$r = d/2$ (radii, d-diameter of the shaft respectively), d_o, d_1 = outside and inside diameter of shaft.So

$$T = \pi\tau(d_o^3)(1 - K^4) \tag{6}$$

If $k = d_1/d_o$, the ratio of the diameters, power to drive the shaft is given as

$$P = \frac{2\pi NT}{60} \tag{7}$$

N = number of revolution of shaft per minute

$$T = \frac{60P}{2\pi N} \tag{8}$$

The stirrer speed was calculated from equ.9 Where

$$N_1 = \frac{d_2}{N_2 d_1} \tag{9}$$

N_1 – speed of electric motor, N_2 speed of the stirrer shaft (rpm). iv. Belt and Pulley: Certified iron pulleys are selected due to its low cost and weight per unit mass. Calculation was based on Khurmi and Gupta.[8]

2.4. Assembly and description of the machine operation

The constructed machine is operated with electric motor (0.373 kw) which transmits torque on the shaft (Stirrer) through the V belt. It has a variable resistor which is used to vary and control the speed of the stirrer. The materials to be mixed are feed into the bowl before attached to the machine and then put on. As the stirrer rotates it agitates the materials and incorporate air and when the desired mixture is obtained , the dough is let out by bringing out the bowl from the machine manually, then introduce the material into another bowl for panning fig 1 shows the assembly and isometric drawing of the mixer.

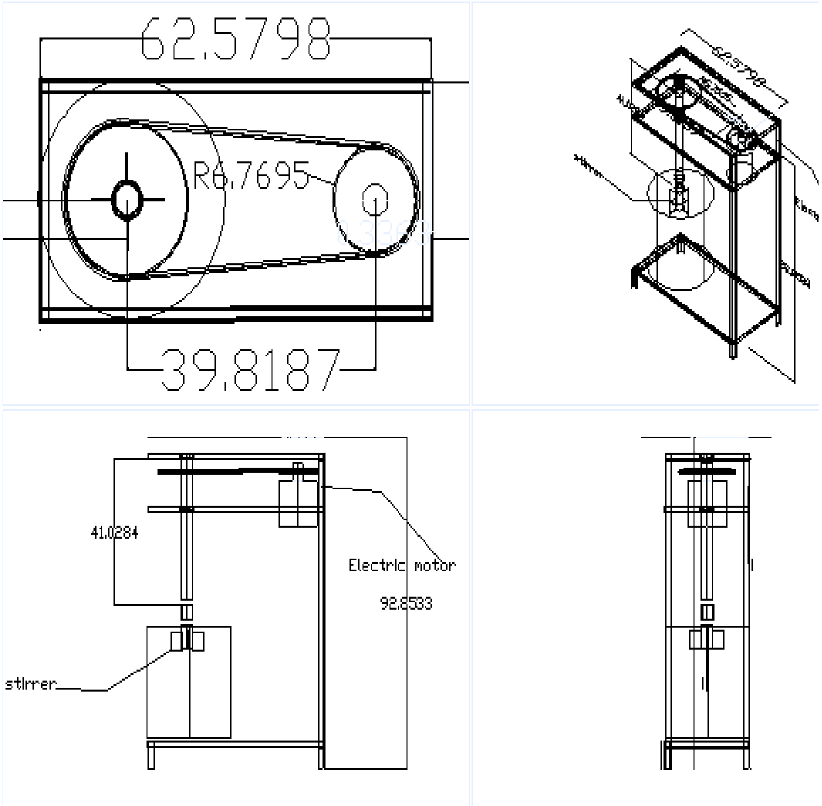

Figure 1: Assembly and isometric drawing of the mixer.

2.5. Performance evaluation

The mixer was used to mix air, 4kg of wheat flour and 7 liters of water at different calibration (1, 2, 3, 4 and 5) and the number of speed (rpm) of the motor measured using a digital tachometer, the temperature developed and the current flow were measured with analogue temperature sensor and 266 clamp ammeter.

On the second instant, the calibration (1,2,3,4,5) varied and the load (garri) was kept constant, then evaluated for speed, temperature and current as above. Then, the shaft calibration was kept constant at 4, while the load (sand) was varied from 1kg – 5kg and the number of revolution, temperature and current measured.

One kilogram – 5kg flour were mixed with 0.5-2.5litres of water and the various speed (rpm), temperature and current were measured at calibration 4 for stirrer A and B.

The various speeds(rpm) of the mixer obtained were regressed against load (L) and a plot of revolution (N) against load (L) in kg plotted, and fitted to the straight line model.

$$N = \alpha_o + \alpha L \tag{10}$$

Where, N – Number of revolutions (rpm), α_o – Intercept on the Y- axis, α – slope of the graph, L – load (kg).

3. Result and Discussion

3.1. Result

The result of the performance evaluation of the mixer is shown in table 1, when the mixer was run on air at a maximum speed it gave a maximum revolution of 1360 rpm but at a load of 4kg of flour at the sample speed, the rpm reduced to 998 and 940 rpm for stirrer A and B respectively (table 2) with water and flour as load. The same table indicates that temperature developed increased with increase in load, but different by load type but insignificantly temperature was between (34.2 – 41.4 ℃). Onwuka[10] have reported that the rate of decay in concentration and temperature fluctuation is one of the criteria used to determine good mixing.

The table further revealed that the higher the load, the higher the current developed in the system with a maximum of 11.12 amp on the 4kg flour. A minimum current was developed in air load showing no resistance to flow.

The regression analysis conducted between numbers of revolution (rpm) versus load (kg) is shown in fig 2 for stirrer A. A negative slope and coefficient of - 84.5 shows a decreasing effect of load on revolution. The relationship with high regression coefficient of 99.3% fit the linear model very well as shown on the equation

Table 1: Effect of (air, water and flour) material at different speed on the revolution, temperature and current developed on the mixer.

S/N	Material	Calibration	Load Kg	speed (rpm)		Temp(℃)		Current (amp)	
				A	B	A	B	A	B
1	Air	1	-	1360	1360	34.2	34.2	2.0	2 0
	Water	1	4	1310	1314	39.0	39.4	10.8	10.84
	Flour	1	4	1280	1288	41.2	41.4	11.0	11.12
2	Air	2	-	1240	1240	35.2	35.2	1.8	1.8
	Water	2	4	1220	1222	38.0	38.3	10.6	10.7
	Flour	2	4	1190	1200	39.0	39.4	10.8	10.10
3	Air	3	-	1140	1140	35.0	35.0	1.4	1.4
	Water	3	4	1100	1114	36.0	36.4	10.5	10.6
	Flour	3	4	1010	1028	37.2	37.6	10.5	10.55
4	Air	4	-	1070	1070	34.8	34.8	1.4	1.4
	Water	4	4	980	1012	35.0	35.4	10.2	10.28
	Flour	4	4	1002	1008	37.4	37.5	10.5	10.61
5	Air	5	-	0	0	0	0	0	0
	Water	5	4	0	0	0	0	0	0
	Flour	5	4	0	0	0	0	0	0

Key: A–stirrer A, B–Stirrer B

Table 2: Effect of speed and stress (garri) on the revolution, temperature and current developed in the mixer (motor).

S/N	Calibration	Load Kg	speed (rpm)		Temp(℃)		Current (amp)	
			A	B	A	B	A	B
1	1	5	1240	1275	41.2	41.4	11.1	11.12
2	2	5	1100	1125	39.2	39.6	10.8	10.10
3	3	5	1005	1032	37.5	37.5	10.3	10.36
4	4	5	998	1006	35.9	37.6	10.0	10.57
5	5	5	0	0	0	0	0	0

Table 3: Effect of speed and stress (sand) on the revolution, temperature and current developed on the mixer.

S/N	Calibration	Load Kg	speed (rpm)		Temp(℃)		Current (amp)	
			A	B	A	B	A	B
1	4	1	1205	1205	41.2	41.4	11.2	11.14
2	4	2	1068	1068	40.0	40.2	10.8	10.22
3	4	3	992	998	39.0	39.4	10.5	10.58
4	4	4	940	940	38.2	38.8	10.2	10.66
5	4	5	900	911	38.0	38.2	10.0	10.18

Table 4: Effect of speed and stress (water) on the revolution, temperature and current developed on the mixer.

S/N	Calibration	Load Kg	speed (rpm)		Temp(℃)		Current (amp)	
			A	B	A	B	A	B
1	1	1	1340	1362	39.8	40.2	10.8	10.93
2	2	2	1320	1338	38.0	39.6	10.6	10.76
3	3	3	1270	1286	36.0	38.2	10.6	10.64
4	4	4	1004	1022	35.0	36.8	10.4	10.28
5	5	5	0	0	0	0	0	0

Table 5: Effect of mixture of flour and water on the revolution, temperature and current developed on the mixer.

S/N	Calibration	Load (Kg)	speed (rpm)		Temp(℃)		Current (amp)		NL		L^2	
		L	A	B	A	B	A	B	A	B	A	B
1	4	1	1280	1302	40.0	40.8	10	10.9	1280	1302	1	1
2	4	2	1212	1219	39.0	39.6	9.8	9.87	2424	2438	4	4
3	4	3	1140	1152	38.0	38.5	9.4	9.48	3420	3456	9	9
4	4	4	1035	1046	36.0	36.3	9.0	9.09	4140	4184	16	16
5	4	5	946	961	35.0	35.2	8.5	8.56	4730	4805	25	25

$N = 1376 - 84.56L$ show significant difference and a correlation coefficient of - 0.996 exist between speed (rpm) and L load (kg) (table vi).

For stirrer B, the same trends follows as shown on table 3 and fig2 (B) with -85.5rpm reduction for every increase in load. And a regression coefficient 99% which also fit the linear model well with the equation $N = 1392 - 85.5l$, N – member of revolution per minute L - load in Kg. This fits the model $N = \alpha_o + \alpha_1 L$ where α_o - 1392 (revolution without load), α_1 - 84.5 (reduction in revolution per minutes).

The effect of load on the revolution shown on table i indicates that the higher the viscosity, the higher lower the rpm and ranged in the order higher-lower: flour-water-flour.

When the effect of gari on rpm was studied (table ii) at a constant weight but with varied calibration-which is the speed control unit attached to the electric motor, the rpm decreased as the calibration was adjusted higher. In fact the calibration was an additional load inform of a variable resistor to the motor which reduce the current flow to the system.

Inwelegbu and Nwodoh [13] worked on FPGA controller design and simulation of a portable dough mixing machine in which they found out that output Torque of a motor is proportional to the armature current.

Table iii shows the effect of various weight of sand at steady adjustment or resistor (Calibration 4) on rpm, temperature and current developed in the system. The outcome followed the same order ie the higher the stress, the lower the rpm, temperature and current flow. This trend was also confirmed in table v as the water and flour were mixed together.

3.2. Discussion

Consequently the linear regression model show that as the load (kg) increases, the rotational speed reduces as a result of shear stress, thereby resulting in more power requirement. This is in agreement with the fact that elastic properties are responsible for significant changes in power consumption [11] and wheat flour is highly elastic when mixed with water to form dough, which is why it consumed the highest quantity of current and higher temperature development as compared to other sampled materials. McCabe et al [12] have reported that other criteria used in determining good mixing includes temperature fluctuation which of course this paper confirms when the current developed varied with the temperature of the system.

The power requirement of a mixer varies according to the nature, amount and consistency of the food in the mixer. There is no necessarily any direct relationship between power consumed and the amount or degree of mixing .When a low viscous liquid is swirled about in an un-baffled vessel as reported [12],the particles may fellow circular path indefinitely and mix little or not at all. Almost none of the energy is used for mixing, but if baffle is added, mixing becomes rapid. Other factor which affects the power requirement includes position, type, speed and size of the impeller [12], which is responsible here for difference between stirrer A and B with a diverse impeller size and shape. The best mixer is one that mixes in the required time with the smallest amount of power, which is what this research has achieved. Furthermore the cost of producing this mixer at ₦28,000 (twenty eight thousand naira is affordable to small scale processors compared to most imported ones such as Kenwood with the same power of 0.5hp sold for ₦50,000 to ₦150,000 .Table 7 reveals the actual cost of fabricating the mixer.

Table 6: Regression, Anova and correlation analysis.

Predictor	Coef	St. Dev	T	P
Constant	1376.10	13.92	98.83	0.000
L Load (kg)	-84.500	4.198	-20.13	0.000
S = 13.28; R – sq = 99.3%; Corr. -0.996; B*				
Predictor	Coef	St. Dev	T	P
Constant	1392.50	10.89	127.86	0.000
L Load (kg)	-85.500	3.284	-26.04	0.000
S = 10.38; R – sq 99.6%; Corr. -0.998. A* = Stirrer A				

4. Conclusion and Recommendation

The development of a low powered mixer has been achieved with a current requirement of 10 amperes . The bill of quantity shows that the fabrication could be accomplish with ₦28,000 twenty eight thousand naira about ($200) two hundred US Dollars (table 7). This development will reduce the drudgery on small scale food processes as encountered in manual mixing method and incessant power interruption since they can now employ small generating sets. The mixer can comfortable mix 15kg of flour at load speed of 10 85 rpm.

I recommend that a thorough rheological study be carried out on the dough mixed with this machine and other samples flours such as cassava or yam should be tried since they form the basic staple foods. These will encourage the use of local raw materials in baking and other related products.

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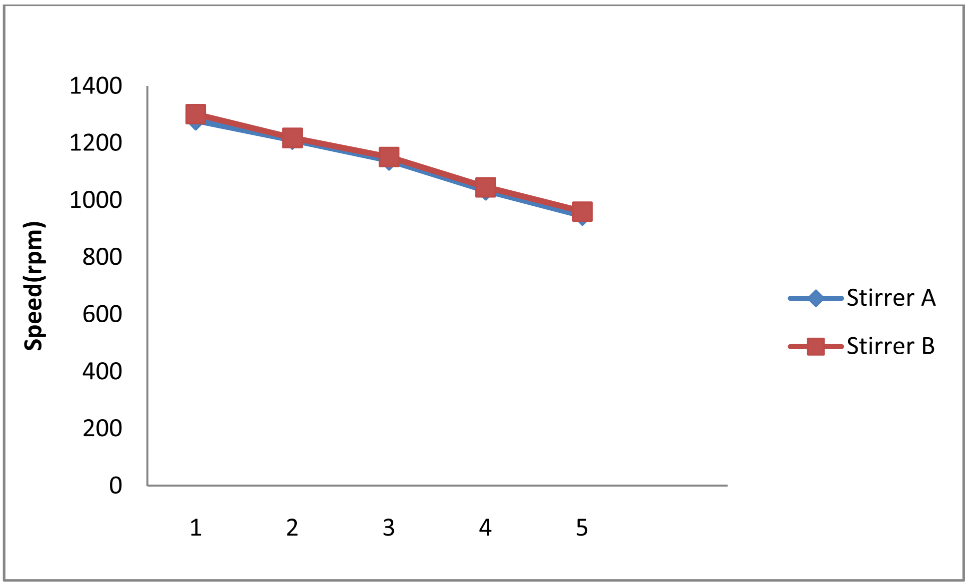

Figure 2: Speed curve (rpm) versus Loading(kg)

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