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Design of Power Driven Dough Mixing Machine

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ABSTRACT

There is still need for improvement on design of dough mixers despite the availability of a number of them in the market. It is required that the constituents be mixed efficiently at a shorter time. The cost of the machine should also be affordable. A dough mixer has been designed for this purpose. Whilst the mixing basin rotates in anti-clockwise direction, the stirrer (suspended on the mixing basin) rotates in clockwise direction. Detailed design of the machine was done. Performance test result shows that proper dough mixing is achieved in a comparatively shorter time and the cost is quite affordable with 86 per cent process efficiency.

Keywords: *Mixing, Rotation, Improvement, dough, affordable.*

1. INTRODUCTION

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. Despite so many dough mixers in the market, many small and medium scale productions in developing economies still use the traditional method of hand mixing of dough for economic reasons. The challenge of producing low cost mixers had led to the development of mega dough-mixing machines which gained popularity in highly intensive bakeries (Vincent, 1966). However, the cost of dough mixing still remained uneconomically affordable for the small and medium scale bakeries (Godwin, 1961). The primary objective of solid mixing requires intimate intermingling of the materials to be mixed. To meet this requirement, the flour is placed in a vessel of some type which allows the material to be moved and stirred in a desired pattern. This is not so simple, as there is no one mixer design that universally satisfies all mixing requirements (Vincent, 1966).

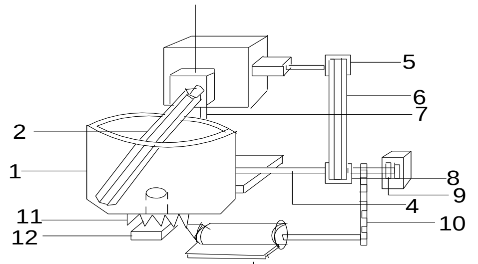


Fig. 1.0 Assembly Drawing of Dough Mixing Machine

2. DESIGN CONCEPT

Figures 1.0 and 2.0 show the assembly drawing and orthographic views of the dough mixing machine respectively. Table 1.0 gives the component parts of the machine

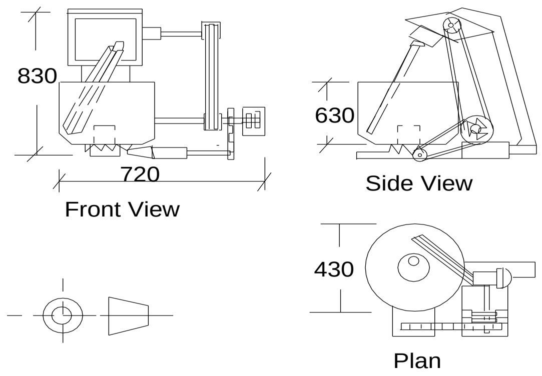


Fig. 2.0 Orthographic View of the Dough Mixer

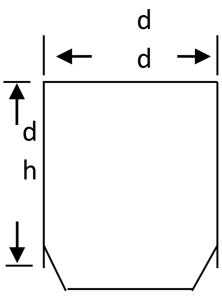
Table 1.0 Parts List of Mixing Machine

S/N	Item	No. Off	S/N	Item	No. Off
1	**Mixing Basin**	1	7	Gear Box Bracket	1
2	**Stirrer**	1	8	Pulley	1
3	**Reduction Gear**	1	9	Bushing	2
4	**Drive Shaft**	1	10	Sprocket	1
5	**Pinion pulley**	1	11	Worm Gear	1
6	**Drive Bolt**	2	12	Base	1

3. DESIGN ANALYSIS

Capacity of the machine 70kg/Hr
Relative density of dough 11.5kg/m^3 (perry, 1998)

3.1 Volume of Mixing Basin



Designing for a mixer capable of mixing 10kg of flour per batch;
Volume of mixing basin, V=10/ 11.5 =0.86m^3
Let, vol. of water + vol. of air space + other ingredients = 12% V
Thus, V = 0.86 + (0.12 x 0.86) = 0.96m^3
But, V= $\pi r^2 h$; let h = 0.85m; r = $(V/\pi h)^{1/2}$ = 0.59;
Thus, d = 0.59x2 =1.18m

3.2 Thickness of Mixing Basin, t

Circumferential or hoop stress on mixing basin (Khurmi, 2003);
$\Delta t = P_i x\ s/2t$; since the mixing basin is open, longitudinal stress is negligible.

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, $\Delta t \leq 5$ Mpa

But P_i = pressure due to (centrifugal force + weight of mixture); $P_i = P_i + P_w$
Centrifugal Force on Mixture, $F_c = mrT^2$; where m= mass of mixture, kg

$\omega = 2\pi N/60$ where r is radius of basin, m; ω is the angular velocity, rad/s; and N=750 rev/min
$\omega = (2\pi \text{ x } 750)/60 = 78.44$ rad/sec.; F_c 11 x 0.59 x $(78.44)^2$ =39931.9 N

$P\omega = \rho gh$; ρ is density of mixture, h is height of mixture, and P = pressure
$P\omega$= 11.5 x 9.818 x 0.75 = 84.6 N/m^2
Since F_c is acting on the circumference of the mixing basin;
Area on which F_c acts; $A_c = 2\pi rh = 2\pi$ x 0.59 x 0.85 = 3.15m
$P_c = F_c / A_c$ = 39931.9/3.15 = 12672.7 N/m^2; P_i = 12672.7 + 84.6 = 12577.3 N/m^2

$t = P_i\ d / 2\Delta t$ = (1275.3 x 1.18) / 2x 5 x 10^6 = 0.0015m; Use 2mm thick plate.

3.3 Drive Shaft

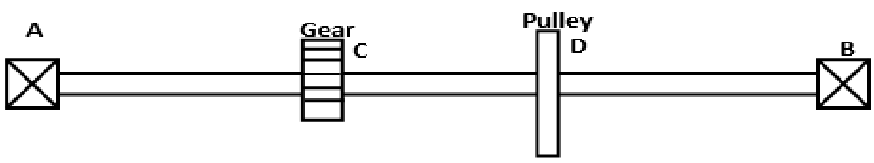


Fig.3.0 Schematic Diagram showing Load acting on Drive Shift

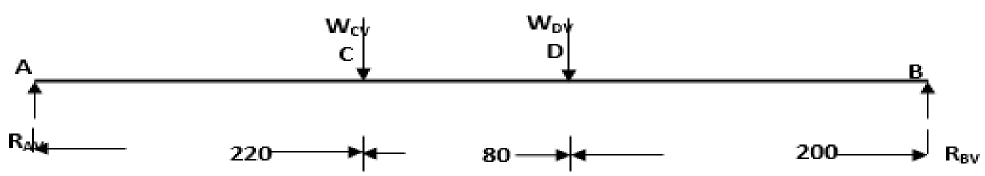


Fig.4.0 Force Diagram (Vertical Lording)

DATA

Coefficient of friction between drive and pulley = 0.3; Angle of wrap = 180^0

Speed = 180 rev/min; Power = Hp (3.3kw)

Torque transmitted is given by (Hall, 1980); T = (9550 x kW)/RPM

T = (9550 x 3.3)/180 = 175N-m; $T=(T_1 - T_2)R$

where R is radius of pulley, 90mm;

T_1 and T_2 are tensions on the tight and slack sides of drive belt respectively.

$T_1 = (175/0.09) /= T_2 = 1944.44 + T_2$ (1)

Also, $T_1 = T_2\ e^{:v} = T_2 e^{\ 0.3B} = 2.57\ T_2$ (2)

From equations 1 and 2; T_1 = 3182.94 N; T_2 = 1238N

Tangential force acting on spur gear, C; $F_{tc} = T/R_c$ = 175/0.08 = 2187.5N

Normal load acting on foot of gear C (Khurmi, 2003); $W_c = F_{tc}/\cos20^0$ = 2187.5/cos20 = 2327.89N

Vertical component of W_c; $W_{cv} = W_c \cos 20$ = 2327.89 cos 20 = 2187.5 N

Horizontal component; $W_{ch} = W_c \sin 20$ = 796.19 N

Horizontal load on shaft at D; $W_{dh} = T_1 - T_2$ = 19.44.94N

Vertical Load acting on shaft at D; W_{dv} = 2000 N = Weight of pulley

For vertical bending moment; $R_{AV} + R_{BV}$ = 2187.5 + 2000 = 4187.5 (3)

Taking moment at A; R_{BV} x 0.5 =2000 (0.3) + 2187.5 (0.22); R_{BV} =2162.5 N

Vertical Bending Moment at C: $M_{CV} = R_{BV}$ X 0.28=605.5 N-m

Vertical Bending Moment at D: $M_{DV} = R_{AV}$ x 0.3 = 2025 x 0.3 = 607.5 N-m

(i.e. from eqn,3; R_{AV} = 4187.5 – 2162.5 = 2025 N)

For Horizontal Loading; $R_{AH} + R_{BH}$ = 796.19 + 1944.94 = 2741.13 N

Taking moment at A; R_{BH} x 0.5 = 1944.94 (0.3) + 796.19(0.22); R_{BH} = 1519.20 N; R_{AH} = 1223.84 N

Horizontal Bending Moment at C; $M_{CH} = R_{BH}$ x 0.28 = 1517.28 x 0.28 = 424.84 N-m

Horizontal Bending Moment at D; $M_{DH} = R_{AH}$ X 0.3 = 1223.84 X 0.3 = 367.15 N-m

Resultant Horizontal Bending Moment;

$R_H = [(M_{DH})^2 + (M_{CH})^2]^{1/2} = [(367.15)^2 + (424.84)^2]^{1/2}$ = **561.51 N-m N-m**

Resultant Vertical Bending Moment;

$R_v = [(M_{DV})^2 + (M_{CV})^2]^{1/2} = [(607.5)^2 + (605.5)^2]^{1/2}$ = **857.72 N-m**

Resultant Bending Moment; $M_R = (R_H^2 + R_V^2)^{1/2}$ = $[(561.51)^2 + (857.72)^2]^{1/2}$ = **1025.17 N-m**

Size of drive shaft; $d^3 = 16/Bs_s\ [(K_b\ M_b)^2 + (K_t\ T)^2]^{1/2}$ (Robert, 1985)

Where d is diameter of shaft, m; S_s is shear stress, 8 MN/m^2; and $K_b = K_t$ = shock factors =1.2

d^3 1= (16/B x 8 x 10^6 $[(1.2 \text{ x } 1025.17)^2 + (1.2 \text{ x } 175)^{2+}]^{1/2}$ = $7.95\text{x}10^{-6}$; d= 0.02m ; **Use26mm shaft.**

4. CONCLUSION

The mixer was fabricated and tested and the Performance was very satisfactory. Also the cost was found quite affordable (Appendix).

Design capacity = 70 kg/hr

Capacity per batch = 10 kg

But thorough mixing of dough was achieved in approximately

10 minutes per batch.

Time for mixing 70 kg of dough = 7 x 10 = 70 mins

Efficiency = (60mins/70mins) x 100 = **86%**

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APPENDIX: MATERIALS, PROCESSES AND COST ANALYSIS OF THE DOUGH MIXER

S/N	Components Qty	Materials	Process	Machines Used	United Cost ₦	Cost ₦
1	Mixing 1	Stainless Steel 1.5 Thick	Sheet Rolling Doming, Welding	Rolling m/c Doming m/c Are welding m/c	4, 000	4,000
2	Stirring Rod 1	Stainless Steel	Turning	Lathe	1,600	1,600
3	Reduction Gear 1	Hard Steel	Turning, Milling	Lathe, Milling m/c	5,000	5,000
4	Pulley 1	Mild Steel	Turning	Lathe	600	600
5	Bushings 4	Bronze	Turning, Boring	Lathe	200	200
6	Drive Shafts 2	Mild Steel	Cutting	Hack Saw	800	800
7	Ball Bearings 4				200	200
8	Bevel Gear 1	Hard Steel	Turning, Milling	Lathe, Milling m/c	3,000	3,000
9	Skid (Base) Lump	Mild Steel	Cutting, Welding	Saw, Welding m/c	1,800	1,800
10	V-Belt and Sprocket Guards Lump	Mild Steel	Cutting, Welding	Hack Saw Arc Welding m/c	1,500	1,500
11	Bolts and Nuts Lump				400	400
12	Spraying Lump				1,000	1,000
13	Labour Lump				6,000	6,000
14	Miscellaneous				2,000	2,000
				TOTAL		**₦ 30,100**

(**Thirty Thousand, One Hundred Naira Only or One Hundred and Twenty US Dollars)**