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).

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.
Table 1.0 Parts List of Mixing Machine

<table>
<thead>
<tr>
<th>S/N</th>
<th>Item</th>
<th>No. Off</th>
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<th>Item</th>
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<td>Drive Bolt</td>
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<td>12</td>
<td>Base</td>
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</table>

3. DESIGN ANALYSIS
Capacity of the machine: 70kg/Hr
Relative density of dough: 11.5kg/m³ (Perry, 1998)

3.1 Volume of Mixing Basin

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

3.2 Thickness of Mixing Basin, \( t \)
Circumferential or hoop stress on mixing basin (Khurmi, 2003);
\( \Delta t = \frac{P_i x s}{2t}; \) 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, \( \Delta t \leq 5 \text{Mpa} \)

But \( P_i = \) pressure due to (centrifugal force + weight of mixture); \( P_i = P_i + P_w \)
Centrifugal Force on Mixture, \( F_c = mrT^2; \) \( m = \) mass of mixture, kg
\( \omega = \frac{2\pi N}{60} \) where \( r \) is radius of basin, m; \( \omega \) is the angular velocity, rad/s; and \( N = 750 \text{rev/min} \)
\( \omega = \left( \frac{2 \pi \times 750}{60} \right) = 78.44 \text{rad/sec.}; \ F_c = 11 \times 0.59 \times (78.44)^2 = 39931.9 \text{N} \)
\( P_\omega = \rho gh; \) \( \rho \) is density of mixture, h is height of mixture, and \( P = \) pressure
\( P_\omega = 11.5 \times 9.818 \times 0.75 = 84.6 \text{N/m}^2 \)
Since \( F_c \) is acting on the circumference of the mixing basin;
Area on which \( F_c \) acts: \( A_c = 2\pi rh = 2 \pi \times 0.59 \times 0.85 = 3.15 \text{m} \)
\( P_c = F_c / A_c = 39931.9/3.15 = 12672.7 \text{N/m}^2; \ P_i = 12672.7 + 84.6 = 12577.3 \text{N/m}^2 \)

\( t = \frac{P_i d}{2\Delta t} = \left( \frac{1275.3 \times 1.18}{2} \right) / 2 \times 5 \times 10^6 = 0.0015 \text{m}; \) Use 2mm thick plate.

3.3 Drive Shaft

Fig.3.0 Schematic Diagram showing Load acting on Drive Shaft

Fig.4.0 Force Diagram (Vertical Loading)
DATA

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

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

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

\[ T = \frac{9550 \times 3.3}{180} = 175\text{N-m} \]

\[ T = (T_1 - T_2)R \]

where R is radius of pulley, 90mm;

\[ T_1, T_2 \] are tensions on the tight and slack sides of drive belt respectively.

\[ T_1 = \frac{175}{0.09} = T_2 = 1944.44 + T_2 \]

(1)

Also, \[ T_1 = T_2 e^0.3B = 2.57 T_2 \]

(2)

From equations 1 and 2; \[ T_1 = 3182.94 \text{N}; T_2 = 1238 \text{N} \]

Tangential force acting on spur gear, C; \[ F_t = \frac{T}{R} = \frac{175}{0.08} = 2187.5 \text{N} \]

Normal load acting on foot of gear C (Khurmi, 2003); \[ W_c = \frac{F_t \cos 20}{\cos 20} = 2327.89 \text{N} \]

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

Horizontal component; \[ W_{ch} = W_c \sin 20 = 796.19 \text{N} \]

Horizontal load on shaft at D; \[ W_{dh} = T_1 - T_2 = 1944.94 \text{N} \]

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

For vertical bending moment; \[ R_{AV} + R_{BV} = 2187.5 + 2000 = 4187.5 \]

(3)

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

Vertical Bending Moment at C; \[ M_{CV} = R_{BV} \times 0.28 = 605.5 \text{N-m} \]

Vertical Bending Moment at D; \[ M_{DV} = R_{AV} \times 0.3 = 2025 \times 0.3 = 607.5 \text{N-m} \]

(i.e. from eqn.3; \[ R_{AV} = 4187.5 - 2162.5 = 2025 \text{N} \])

For Horizontal Loading; \[ R_{AH} + R_{BH} = 796.19 + 1944.94 = 2741.13 \text{N} \]

Taking moment at A; \[ R_{BH} \times 0.5 = 1944.94 (0.3) + 796.19 (0.22); R_{BH} = 1519.20 \text{N}; R_{AH} = 1223.84 \text{N} \]

Horizontal Bending Moment at C; \[ M_{CH} = R_{BV} \times 0.28 = 605.5 \text{N-m} \]

Horizontal Bending Moment at D; \[ M_{DH} = R_{AV} \times 0.3 = 2025 \times 0.3 = 607.5 \text{N-m} \]

Resultant Horizontal Bending Moment;

\[ R_H = \sqrt{(M_{DH})^2 + (M_{CH})^2} = \sqrt{(367.15)^2 + (424.84)^2} = 561.51 \text{N-m} \]

Resultant Vertical Bending Moment;

\[ R_v = \sqrt{(M_{DV})^2 + (M_{CV})^2} = \sqrt{(607.5)^2 + (605.5)^2} = 857.72 \text{N-m} \]

Resultant Bending Moment;

\[ M_R = \sqrt{(R_H)^2 + (R_V)^2} = \sqrt{(561.51)^2 + (857.72)^2} = 1025.17 \text{N-m} \]

Size of drive shaft; \[ d^3 = \frac{16B S_i (K_b M_b)^2 + (K_t T)^2}{(K_b M_b)^2 + (K_t T)^2} \]

(Robert, 1985)

Where \( d \) is diameter of shaft, \( m \); \( S_i \) is shear stress, 8 MN/m²; and \( K_b = K_t \) = shock factors =1.2

\[ d^3 = \frac{16 \times 8 \times 10^6 \times [(1.2 \times 1025.17)^2 + (1.2 \times 175)^2]}{(1.2 \times 1025.17)^2 + (1.2 \times 175)^2} = 7.95 \times 10^{-6}; d=0.02 \text{m}; \text{Use 26mm shaft.} \]

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 = \( \frac{60\text{mins}}{70\text{mins}} \times 100 = 86\% \)

REFERENCES


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

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TOTAL = ₦ 30,100

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