Design and Fabrication of a Flour Mixing Machine

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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 9.81m/s²
- The density of stainless steel is 7880 kg/m³
- The density of mild steel is 7850kg/m³
- 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/m³ [7]
### Table 1: Design Analysis

<table>
<thead>
<tr>
<th>MACHINE PARAMETER</th>
<th>INPUT</th>
<th>ANALYSIS</th>
<th>DECISION/REMARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of the mixing basin (V), Diameter of basin (d), Radius of basin (r).</td>
<td>Designed for a mixer capable of mixing 25 kg of flour per batch; Rd of dough = 11.5 kg/m³. Let, vol. of water + vol. of air space + other ingredients = 12% V. Thus, V = 2.17 + (0.12 x 2.17) = 2.43 m³. But, V = ( \pi r^2 h ); ( r = (V/\pi h)^{1/2} ). Thus, ( d = 1.15 \times 2 = 2.31 ) m.</td>
<td>d = 2.31 m</td>
<td></td>
</tr>
</tbody>
</table>

#### Thickness of mixing basin (t)
- Circumferential or hoop stress on mixing basin (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.

\[
P_i = \frac{P_c + P_w}{r} = \frac{5695.97 + 0.065}{1.15} = 5695.97 \text{ kN/m}^2;
\]

\[
P_i \leq 1 \text{ GPa}
\]

\[
P_i = \frac{P_c + P_w}{r} = \frac{5695.97 + 0.065}{1.15} = 5695.97 \text{ kN/m}^2;
\]

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\]

\[
s = \frac{P_i d}{2 \sigma_h};\ t = 0.00157 \text{ m} \approx 2 \text{ mm thick stainless steel plate}
\]

#### Speed of the driven pulley, \( N_2 \)

\[
N_1 = 2840 \text{ RPM} \\
D_1 = 0.050 \text{ m} \\
D_2 = 0.15 \text{ m}
\]

\[
N_2 = \frac{N_1 D_1}{D_2} = \frac{2840 \times 0.05}{0.15} = 946.67 \text{ RPM}
\]

#### Speed ratio, \( r \)

\[
N_1 = 2840 \text{ RPM} \\
N_2 = 946.67 \text{ RPM}
\]

\[
r = \frac{N_1}{N_2} = \frac{2840}{946.67} = 3
\]

\[
N_1 : N_2 = 3 : 1
\]

#### Velocity, \( V \)

\[
\omega = \frac{2\pi N_2}{60} = 99.13 \text{ rad/s} \\
V = \frac{\omega D_2}{2} = 11.5 \times 9.818 \times 0.58 = 0.065 \text{ kN/m}^2 \\
V = 7.43 \text{ m/s}
\]

#### Circumferential force, \( F \) on the basin

\[
V_p = \frac{\pi}{4} \times \frac{(2a)^3 - (2d)^3}{2} \times L_b = \frac{\pi}{4} \times \frac{(0.62)^3 - (0.12)^3}{2} \times L_b = 0.58 \times 2.82 \times 10^3 \times 9.81 = 217.98 \text{ N}
\]

\[
F = \rho \text{ stainless steel} \times V_p \times g
\]
Power output, $P_o$

$F = 217.98 \text{N}$
$V = 7.43 \text{m/s}$

$P_o = F \times V = 217.98 \times 7.43$

$P_o = 1.62 \text{KW}$

Efficiency, $\eta$

$P_o = 1.62 \text{KW}$
$P_i = 1.86 \text{KW}$

Power input, $P_i$

$1 \text{HP} = 0.746 \text{KW}$

$2.5 \text{HP} = 2.5 \times 0.746 = 1.86 \text{KW}$

$p_i = 1.86 \text{KW}$

### Table 2: Constructional Procedure

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

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Driver (prime mover) (rpm)</th>
<th>Driven (basin) (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>2840</td>
<td>71</td>
</tr>
<tr>
<td>120</td>
<td>5680</td>
<td>142</td>
</tr>
<tr>
<td>180</td>
<td>8520</td>
<td>213</td>
</tr>
<tr>
<td>240</td>
<td>11360</td>
<td>284</td>
</tr>
</tbody>
</table>

Design capacity = 100kg/hr
Capacity per batch = 25kg
But thorough mixing of dough was achieved in approximately 15 minutes per batch
Time for mixing 100kg of dough = 4 × 15 = 60mins

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.

References


