Development of a Dough Kneading Machine

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ABSTRACT

The design and fabrication of a power operated dough kneading machine was undertaken with the intention of providing a simple and cost effective solution to the problem of dough kneading for low-scale bakers. The developed kneading machine is made up principally of a hopper through which the dough is loaded. The power required to operate the machine was calculated to be 0.828Kw. A 2hp electric motor rotating at a speed of 300rpm using a set of spur gears, which reduced the speed to the required operating speed of 60rpm. The machine is dual powered, human and engine, unlike the conventional kneading machine which is only engine powered. The hopper has a maximum capacity of 20kg. Results of performance evaluation show that at feed rates of 329.3kg/hr and 55kg/hr for motorized and manual operations respectively, the efficiency was 70%.

Keywords: Power-operated kneading machine, throughput, efficiency, low cost.

INTRODUCTION

Grolier (1994), reported the history of bread did not begin until the cultivation of wheat began. Wheat is the only cereal containing proteins that enables the dough to rise and entrap air bubbles during the process of fermentation. Bread is a baked food made from dough of ground or milled cereal grain. Only wheat flour contains gluten, a substance that supplies the structure needed for leavening. For the gluten to develop properly, dough requires about 10-20minutes of kneading. The purpose of kneading is to work the dough into a uniform texture. Wheat flour dough exhibits a wide range of properties when different flour samples are compared. Dough properties influence both the efficiency and throughput in the manufacturing plant as well as the quality of the final baked product (Sufyanu, 2001).

The bakery industry has an important role to play in the economic development of a country, in utilization of its wheat resources and in building up the health of its people (Grolier 1994). One of the most important operations in a bakery is the thorough mixing of ingredients and kneading of dough. Mixing has been defined to be the intermingling of dissimilar portions of a material to attract a desired uniformity, which may be physical or chemical in the final products (Macrae, et al. 1993). Mixing of the ingredients play vital role, because the ingredient must be mixed properly to obtain the desired dough before kneading can take place. In most bakeries, both operations go simultaneously in a mixing machine, but not all mixers can perform both operations (Grolier, 1983). The traditional kneading of dough is time and energy consuming. Certain operations such as mixing of ingredients to obtain uniform dough has not received adequate attention in terms of motorization (Lupton, 1987). This is a very tedious operation and therefore affects production both in quality and quantity. This work is intended to salvage the traditional kneading operation by the development of this machine, which is efficient, cost effective, easy in operation and maintenance and suitable for medium scale bakers.

MATERIALS AND METHOD

Description of the Machine

The kneading machine comprises of pulleys, rollers, a hopper, a handle, dough collection plate, gearbox and cover, shaft, bearings and the supporting frame. The rollers are lying horizontally with 3mm spacing between them, which the dough passes through. A hopper is provided where the dough is been fed to the rollers. Underneath the rollers, is the collection plate, which collects the dough after kneading (Fig. 1).

Design Process

In the design process, the following assumptions were made: Shear stress of dough = 7074 N/m^2, weight of dough fed into hopper

20kg, density of dough = 1,330kg/m^3 (Macrea et al., 1993). Length of roller = 450mm, Length of shaft = 750mm, desired speed of roller – 60rpm (Macrea et al., 1993), diameter of roller = 80mm. The kneading process can be viewed as a rolling process. The rolling force, F (fig. 2) can be found using the equation:

$$F = LW\, Q_p\, \delta_m f \quad (1)$$

$\delta_m f$ = Shear stress of material (N/m^2)

$$F = LW\, Q_l\, \delta_m f \quad (2)$$

Q_p, Q_l = values obtained from tables depending on the value of h_o and L

Depending on if $h_o/L > 1$ or < 1

$$L = \sqrt{R}\ (h_o - h_i) \quad (3)$$

R = radius of rollers (m)

h_o = Initial height of material (m)

hi = final height of material after passing through rollers (m).

Where, F = force of rolling (N)

L = length of contact of material and rollers (m)

W= width of material

Determination of power required

$$F = LW\, Q1\, \delta_m \quad (4)$$

$$L = \sqrt{R}\ (ho - hi) \quad (5)$$

ho = hopper base breath + clearance between the rollers.

ho = 160+3=163mm; = 0.163m.

hi = Distance between the rollers (clearance)

= 3mm = 0.003m

R = radius of roller = 40x10^{-3}m

$$L = \sqrt{0.04}\ (0.163\text{-}0.003) = 0.08\text{m}$$

W = 450mm = 0.45m

δ_m = 7074N/m^2

$$\frac{h_o}{L} = \frac{0.163}{0.08} = 2$$

$$\frac{h_o}{L} = 2$$

Q_i = 1.3

Therefore $F = LWQ_i\, \delta_m f$

= 0.08x0.45x1.3x7074

= 331N

power = Force x Velocity (6)

$$\text{Velocity} = \frac{2\pi NR}{60} \quad (7)$$

Where, N = speed of roller required (rpm)

R = radius of roller (m)

N = 60rpm

R = 40x10^{-3}m

Substituting values into (7)

$$V = \frac{2\text{x}\pi\text{x}60\text{x}40\text{x}10^{-3}}{60}$$

= 0.25m/s

P = 331x0.25 substituting values into (6)

= 82.8W

According to Salvendy (1992), the power an average man can generate is 83W. This means that the machine can be manually operated. Based on the fact that this design required speed of 60rpm and power 82.8W, an electric motor of 2hp, rating 1.5kW and a speed of 300rpm was selected.

Performance Evaluation

Five and half kilogram of dough was used to carry out the test. Initial thickness before and after kneading was taken using vernier caliper and meter rule. Time taken to pass through the rollers to knead the dough sufficiently was taken using a stopwatch for both manual and motorize operations for 6 runs.

Determination of kneading efficiency

The efficiency of the machine was evaluated using the final thickness of the dough after kneading.

$$\text{Efficiency (\%)} = \frac{h_o n}{h_i} \text{x } 100$$

Where, n = number of runs

h_o = Initial thickness of dough before kneading

h_i = Final thickness of dough after kneading

Determination of Feed rate

Three samples of 5.5kg each of dough were used to carry out this test and the average time taken to knead the dough sufficiently was found to be 6 minutes manually and 1minute motorized.

$$\text{Feed rate} = \frac{wd}{T}\,(kg/hr)$$

Where, wd = weight of dough

T = Time taken to knead the dough

RESULTS AND DISCUSSION

The thickness of the dough before kneading was measured to be 60mm, after kneading; the thickness was reduced to 7mm. Time taken for the dough to pass through rollers was one minute for manual and 10seconds for motorized operation. To knead the dough sufficiently, it took 6 minutes for manual operation and 1 minute for motorize operation. From the results, the machine efficiency was obtained to be 70% and a feed rate of 329.3kg/hr and 55kg/hr for motorized and manual operations respectively. It therefore means that, the machine can serve the purpose for which it was designed effectively.

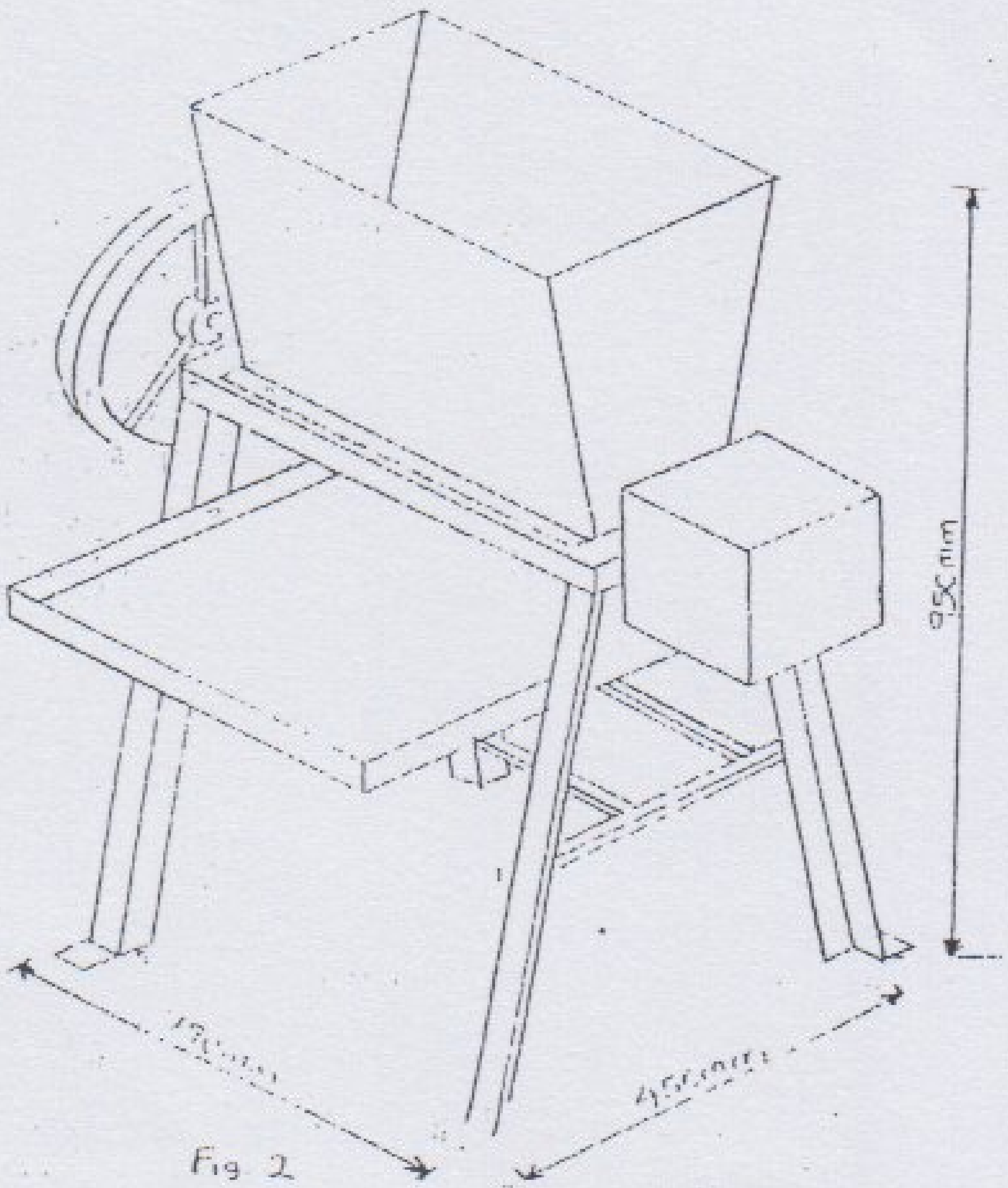

Fig. 2

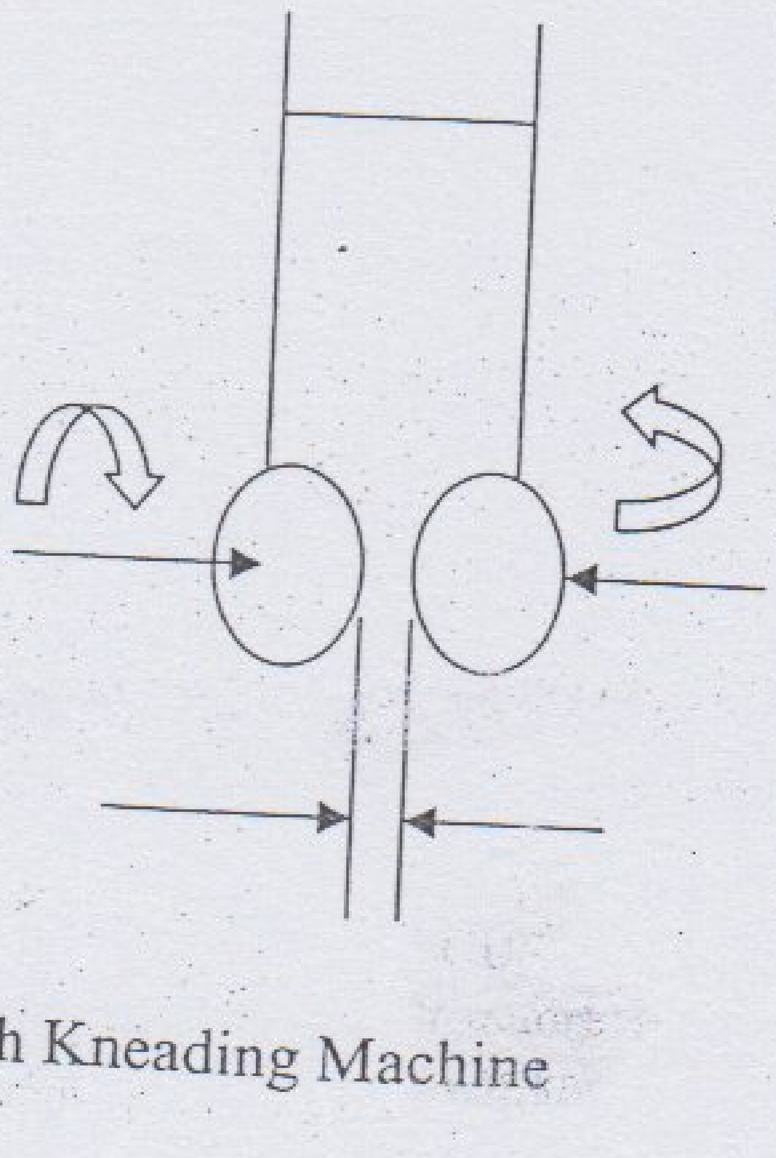

Fig. 1: Dough Kneading Machine

CONCLUSIONS

A machine was designed that will provide efficient kneading of dough. The design was made to tackle the hazard involved in kneading operation of dough and to ensure proper safety of the operator. The mode of operation is simple enough to be understood. The maintenance is easy, since failure can occur possible by bearing, belt and gears due to fatigue and friction.

The following recommendations are suggested for further work:

(i) Provision of proper adjuster for the gap between the two rollers;

(ii) Provision of gear electric motor, which is been designed with to power the machine.

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