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Improvement On the Design of An Electric Paddle Grain Dryer

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Abstract:
Drying of grains into various feed-stocks is needed for one or several of the following reasons: need for easy-to-handle free-flowing solids, preservation and storage, reduction in cost of transportation, achieving desired quality of products. Therefore, it is necessary that these grains are properly dried and stored to ensureavailability. The main objectives of this study were to improve on the existing design of electric paddle grain dryer as follows:(1). Replacement of the analog thermometer whose measurement variation could not be established with digital thermometer for better efficiency. (2). Replacement of drying chamber mild steel sheet to stainless steel sheet because of grain contamination.(3). Provision of gear box for stirring as compared to manual system of stirring which is so laborious. (4). Increasing the number of electric heater to supply more heat to further reduce time of drying.The modified electric paddle grain dryer operates on the principle of batch drying. After the grains were selected and loaded, the lid closed and heated air at a certain temperature is blown across the grain from the heater housing through electrical heating element and fan. The heat being supplied by the heater is controlled by digital thermostat with probe which turns off the machine if inlet temperature exceeds the actual temperature required for drying. There is a shaft joined with paddles that passes through the centre of the drying chamber connected to a gearbox through chain and sprocket for stirring the grains when the electric motor is powered ON. After drying, the drying chamber is turned anti-clockwise at angle 180 ^{0}C to discharge grains to the tray placed under the drying chamber.Advantages: (1). Drying time of the grain is reduced due to additional electric heater incorporated. (2). The machine reduces the rate of grain burnt due to automatic rotation of the paddles. (3). Energy for stirring is reduced since the electric motor and gearbox are electrically controlled. The improved design takes care of most of these problems. The heated air is forced and distributed evenly to all grains in the drying chamber with the aid of paddle shaft which rotates through gearbox and electric motor. This makes drying faster and grains are moderately dried.It is an effective tool for drying and its effectiveness exceeds all forms of drying used locally.

Key words: Electric paddle grain dryer, Digital thermostat, Improvement on the existing design, Gearbox, Electric motor, Coupling, Chain and Sprocket.

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I. INTRODUCTION

Drying of grains into various feed-stocks is needed for one or several of the following reasons: need for easy-to-handle free-flowing solids, preservation and storage, reduction in cost of transportation, achieving desired quality of product, etc. (Mujumdar, 2006). Country's food security heavily relies on its ability to safely store its food, feed-grain and seed stocks and to ensure the more food availability for growing population and to

increase the socio-economic condition of the farmers. Shahab and Digvir, (2006) stated that drying is performed by two basic methods: (a) adiabatic process and (b) non-adiabatic processes. The simplest and cheapest method of conserving drying grains is done on the ground in the open air. Some disadvantages of open air drying are: exposure of the grain to rain and dust; uncontrolled drying; exposure to direct sunlight which is undesirable for some grain; infestation by insects; attack by animals; etc, (Madhlopa*et al;* 2002).

Drying has become popular postharvest operation to obtain highly commercial agricultural products and preserve the products for longer shelf-life. The early man relied on the energy from the sun and to dry his grains. As a result of technological improvement, great advancements have taken place in the practice of drying and the manufacturing methods have greatly improved production rate and the production line bottle-neck created by extended drying time inherent in the use old drying methods can no longer be tolerated Adzimah, K.S and Seckley, E (2009). The old methods of drying under natural conditions in hot rooms, hot hearths and storages which involve long drying times, manhandling and little or no control of drying are completely unacceptable today.

The application of dryers in developing countries can reduce post- harvest losses and significantly contribute to the availability of food in these countries. A significant percentage of these losses are related to improper and/or untimely drying of foodstuffs such as cereal grains, pulses, tubers, meat, fish, etc. The traditional methods of drying grains in our localities are so laborious, timeconsuming, does not guarantee the safety of grainsand is ineffective with unfavorable weatherconditions.

Therefore, an improvement has to be done toeradicate the problems associated with the existingcabinet grain dryer.The main objectives of this study are to improve onthe design of an existing electric paddle grain dryer by redesigning the existing electric paddle grain dryer so as to increase the machine efficiency, viable grains and reduce total time of drying.

II. MATERIALS AND METHODS

Description of the existing electric paddle grain dryer.

After the corn was loaded, the lid is closed and heated air is blown inside the drying chamber through electrical heating element and fan. The heat being supplied by the heater is controlled by a thermostat which turns off the machine if inlet temperature exceeds the actual temperature required for drying. There is a shaft joined with paddles that passes through the centre of the drying chamber which is connected to a mild steel handle pipe that was positioned outside the drying chamber for manually stirring of the grains. After drying, the drying chamber is turned anti-clockwise at angle 180 ^{0}C to discharge grains to the receiving tray placed under the drying chamber.

The component parts of the existing electric paddle grain dryer.

Theexisting electric paddle grain dryer consists of (i). Fan (ii). Electric heater housing (iii). Analog Thermostat (iv). Analog probe (v). Grain discharge handle (vi). Ball bearing and housing (vii). Electric cable (viii). Receiving tray (ix). Frame (x). Paddle shaft with handle (xi). Heater and fan housing.

Plate 1. Pictorial view of the existing electric paddle grain Dryer

Problems identified with the existing design of electric paddle grain dryer:

1 Poor heat distribution to grain in the drying chamber.
2. Manually stirring of grain is inconsistence, which causes over-drying of grains and render the dried grains differ in texture.
3. Contamination of grain in the drying chamber because of mild steel sheet which corrode easily.
4. Analog thermometer whose measurement variation could not be established during measurement.

The proposed improved design of the electric paddle grain dryer:

The improvement on the design of the existing electric paddle grain dryer has been carried out based on the problems associated with the existing design by;

1. Automatic mode of stirring which enable proper distribution of heat to grains using gearbox coupled with electric motor system.
2. Replacement of drying chamber mild steel plate to stainless steel plate which is versatile, corrosion-resistance and durable. Stainless is used for structural, hygienic, and decorative purposes across industries.
3. Replacement of analog thermostat with a digital sensor which can display the exact readings.

CHOICE OF MATERIALS.

1**.Mild steel:** This is used for construction of the external body of the dryer.
2 **Stainless sheet:**This is used for construction of the drying chamber, Lid chamber, and discharge trough base, because of corrosion.
3.**Fireclay brick:** Serve as insulator/lagging material between the inner and outer layers of thedrying chamber to ensure that heat loss by radiation and conduction to the outer shell were considerably reduced to the barest minimum.
4. **Heater:** The heater supplies heat for drying the grains and powered by electricity.
5**Fan:** The fan aid in heat distribution by discharging heated air to the drying chamber.
7. Bearing: It allows the stirrer to rotate when turned by the gear box.
8**.Bolts and Nuts:** These are used for fastening the parts to the main frame.
9**.Chain and Sprocket:** These are used a link for transmitting one part to another.
10**.Thermostat:** This turns off the machine if inlet temperature exceeds the actual temperature required for drying.
11.**Gearbox:** This is used to reduce the speed of the paddle/stirrer.
12.**Electric motor:** It supplies drive to the machine.

III. DESIGN CONSIDERATIONS:

Power drive and Transmission

The power transmission is in two stages:Firstly, from the electric motor shaft (driver) connected to the driven gearbox shaft. Secondly, from the driver sprocket on the gearbox to the driven sprocket on the stirring shaft.
An electric motor (1440 rpm)is connected to the input shaft of the gear box of ratio (48:1) through a coupling.
From the above information, the speed of driven pulley on gearbox can be calculated using the relation:

where,
N_1 = speed of the electric motor. (1440 rpm)
N_2 = speed of the input side of gearbox. (1440 rpm)
N_3 = speed of output side of the gearbox.
N_4 = speed of the paddle/stirrer shaft.
Recall that since the electric motor is connected directly with coupling to input shaft of gearbox, therefore, $N_1 = N_2$
$N_3 = \frac{N_1}{48} = \frac{1440}{48}$ = 30 rpm(Khurmi,R.S.K. and Gupta J.K (2012). …….(1)
Where, $N_3 =$ Speed of the output side of gearbox at ratio 1:48 from the gearbox.
$N_4 = \frac{N_3}{3} = \frac{30}{3}$ = 10 rpm …… (2)
Power requirement for rotating the paddle/stirring shaft and gearbox shaft
Power requirement for gearbox shaft, (P_{gb})
P_{gb}= torque x angular velocity of gearbox shaft.) ……. (3)
But Torque, $(\tau_{gb}) = W_{sp}+W_{gb}+W_{wg})$ …….. (4)
W_{sp} = Weight of smaller sprocket on output side of gearbox = 4.7 N
W_{gb} = Weight of gearbox pinion shaft = 15.1 N
W_{wg}= Weight of worm gear = 14.30 N
W_c= Weight of coupling = 5.80 N

$\check{\iota}_{gb}$ = (4.7 + 15.1 + 14.3 + 5.8) = 39.9Nm…….. (5)

Angular Velocity ($\acute{\omega}_{ps}$) = $\frac{v}{r} = \frac{2\pi N}{60}$(Khurmi, R. S Gupta, (2012): ……. (6)

where,

N = Speed of paddle/stirrer shaft

$\acute{\omega}_{ps} = \frac{2\ x\ 3.142\ x\ 10}{60}$ = 1.0476 rad/s.

P_{ps} = torque x angular velocity of paddle/stirring shaft. ……. (7)

P_{ps} = 1.047 x 39.9 = 41.7753W = 0.0477 kW

The power required for rotating the paddle/stirrer and gearbox shaft ($P_{p/g}$)

($P_{p/g}$) = P_{ps} + P_{gb} …… (8)

= (0.0477 + 1.0476) = 1.095 kW.

Therefore, 1.5 h.p (1.095 kW) electric motor is recommended for rotating the paddle/stirrer shaft and gear box.

The design work for the entire output of the stirrer includes: Coupling, Electric motor, Gear box, Chain and Sprocket. The need of the gear box is to reduce the speed of the paddle fins/stirrer so that the grains can receive uniform distributed heated air.

Plate 2. Arrangement of electric motor, gear box and stirrer shaft, sprocket, and chain

Length of chain required

Length of chain $(L) = K\ x\ p$ (Shiegly and Mischke, 2001).

$K = \frac{(T_1 + T_2)}{2} + 2\frac{x}{p} + \frac{(T_1 + T_2)^2}{2} + (\frac{p}{x})$(Khurmi, R. S Gupta, (2014): ……(9)

where,

T_1 = Number of teeth on the smaller sprocket = 14

T_2 = Number of teeth on the larger sprocket = 42

p = Pitch of the chain =8mm

x = Centre distance between the pulleys, = 570mm

$K = \frac{(14 + 42)}{2} + 2\frac{570}{8} + \frac{(42+14\ )^2}{2\pi} + \frac{8}{570}$

K =28 + 142.5 + 997.8 + 0.014 = 1168.3mm

But $L = K\ x\ p$ ……(10)

L=1168.3 x 8 = 1364.3 (Approx. 1364mm)

COMPONENT PARTS OF THE EXISTING ELECTRIC PADDLE GRAIN DRYER.

1. Stirrer/paddle

The shaft consists of a 30mm stainless rod and three dome shape paddle which passes through the central part of the drying chamber with length 700 mm. One end of the shaft was turned to 20 mm diameter and 67 mm length while the other end of the shaft was turned to 20mm diameter and 123 mm length. Toward the end of the 123 mm a hole of diameter 6 mm was drilled to allow the locking position of the driven sprocket. Three numbers of rectangular shaped paddles of 5 mm thick, length 150 mm and 57 mm wide designed to stir the grain in the

drying chamber which is positioned at an angle of 120 ^{0}C to each other along the shaft. The clearance gap between tip of fins and interior chamber surface was limited to 1 to 3 mm in order to avoid from the struck or damage the corn.

2. Drying chamber

The internal port of the drying chamber is made of a 2mm thick stainless-steel sheet measured (500 x 630) and cut with the aid of guillotine shear, rolled to form a semi- circular structure 400mm with radius 165mm.

3.Receiving tray: The receiving tray is a rectangular box of (520 x 470 x 50) mm as length, breadth and height respectively which is positioned below the drying chamber.

4. Fan

The fan aids in heat distribution by sucking ambient air from the surrounding to the heater housing and discharging heated air to the drying chamber. An axial flow fan is used to ensure proper distribution of air to the drying chamber and for effective heat distribution.

5. Thermostat

The thermostat is simply the unit that controls the system and maintains constant temperature in the drying chamber.

6. Electric Heater

The source of heat was from the electric heater coil 1500 watts, two numbers, amperes, 220 volts (single-phase supply). The shape and size of heater was spiral coil type. The electric heater system assembled on top of the drying chamber and the force convection heat from top of the chamber was drawn with the aid of centrifugal fan and transported to drying chamber.

7. Power drive and Transmission

The power transmission is in two stages: Firstly, from the electric motor shaft (driver) connected to the driven gearbox shaft. Secondly, from the driver sprocket on the gearbox to the driven sprocket on the stirring shaft.An electric motor (1440 rpm) is connected to the input shaft of the gear box of ratio (48:1) through a coupling.

8.Lagging of the drying chamber

Different materials are available for insulation but considering the drying temperature, availability and cost of insulating material, fireclay brick 500^{0}C has been chosen for installation, www.Engineeringtool.com (2010):

Principle of operation of the modified cabinet grain dryer:

The modified electric paddle grain dryer operates on the principle of batch drying. After the grains was loaded, the lid closed and heated air required is blown across the grain from the heater housing through electrical heating element and fan which connected to electricity. The heat being supplied by the heater is controlled by digital thermostat which turns off the machine if inlet temperature exceeds the actual temperature required for drying in the drying chamber. There is a shaft joined with paddles that passes through the centre of the drying chamberconnected to a gearbox through chain and sprocket for stirring of the grain. After drying, the drying chamber is turned anti-clockwise at angle 180 ^{0}C to exit grains to the tray position under the drying chamber.

ASSEMBLY PROCEDURES

The assembly procedures are as follows:

1. Insert ball bearing (6208) to left and right side of the drying chamber housing.
2. Insert the stirring shaft to the centre of the drying chamber housing and place it on the frame which guide on a pillow bearing model P6205.
3. Screw the thermocouple sensor to the drying chamber wall.
4. Then position the discharged trough underneath the drying chamber with supporting plate inclined at an angle 5^0 to the frame.
5. Connect the **e**lectric motor and gear box with a coupling flange.
6. Position the coupled electric motor and gear box to the main frame base with M8 bolts and nuts.
7. Connect the chain from smaller sprocket on the gearbox to the bigger sprocket on the stirring shaft.
8. Insert the drying chamber lid which contain fan, heaters, and thermocouple on top of the drying chamber.
9. Thenswitch the machine ON.

Plate 3. Pictorial view of the electric paddle grain dryer

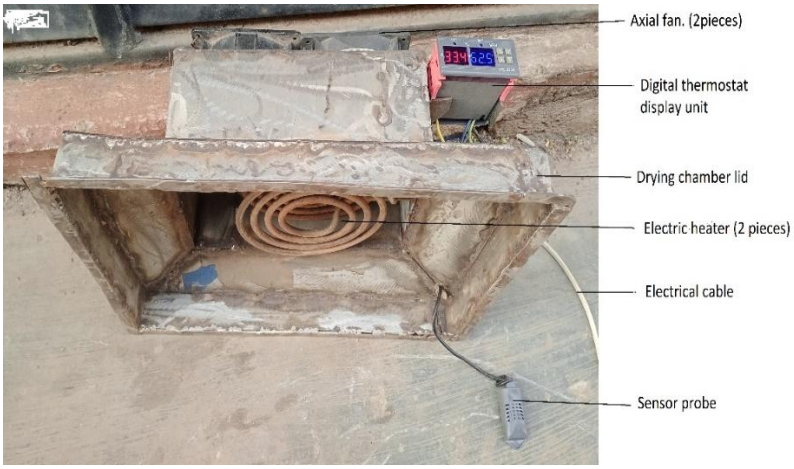

Plate 4. The drying chamberLid, Digital thermostat & probe, electric heater, Fanand electric cable.

IV. RESULTS AND DISCUSSION

Advantages of the modified cabinet grain dryer over the existing dryer

1. Drying time of the grain is reduced due to additional electric heater incorporated.
2. The machine is ergonomic; operation of the machine does not require many labourer.
3. The machine reduces the rate of grain burnt due to automatic rotation of the paddles.
4. Energy for stirring is reduced since the electric motor and gearbox are electrically controlled.

Safety measures on the maintenance of the modified cabinet grain dryer.

The following should be considered in ensuring longer life and smooth operation of the machine, more especially when the machine is not in use.

1. The whole equipment will require being kept in a safe and dry place to avoid rusting of component parts.

2. Sometimes, lubrication of parts such as the bearing, gearbox, and chain. with light oil may be necessary especially when the equipment will not be in use for a very long time. This is also done to prevent rusting of parts.
3. Depending on the environment, some of the system components like the electric motor may be isolated from the circuit for a safer storage strategy.

Conclusion

Generally, grain drying is very important because it increases the storage life of cereal grains. Most dryers have a lot of deficiencies in terms of drying speed, efficiency, productivity, quality, safety and this improved design takes care of most of these problems. The heated air is forced and distributed evenly to all grains in the drying chamber with the aid of paddle shaft which rotates through gearbox and electric motor. This makes drying faster and grains are moderately dried. It is an effective tool for drying and its effectiveness exceeds all forms of drying used locally.

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