© 2015 IJSRSET | Volume 1 | Issue 5 | Print ISSN: 2395-1990 | Online ISSN: 2394-4099
Themed Section: Engineering and Technology

Design and Fabrication of Hydraulic Dough Divider

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ABSTRACT

A hydraulic drive system uses pressurized hydraulic fluid to power hydraulic machinery. Pascal's law is the basis of hydraulic drive system. Present paper deals with the design and manufacturing of a hydraulic controlled system which divides the dough into desirable number of parts. Two stage telescopic cylinder controls the entire operation, in which the first stage compresses and distributes the dough and the second stage raises the blade to cut the dough. Entire system is designed and simulated using fluid SIM-H software and is modelled using CREO.

Keywords: 2 Stages Telescopic Cylinder, Hydraulic Circuit, Power Pack

I. INTRODUCTION

In the present day, with the revolution in the materials and mechanical elements, applied technologies perceive folded growth. Food industries focus on production of hygienic food (quality) with highly optimal machineries which have better maintenance and cost effectiveness [1]. The role of machines in the production is utmost important. Hydraulic dough divider which is mainly used in food industries for dividing dough into equal pieces and weight for the production of food products like pizzas, croissants, buns, rolls etc. The shape of the tray guarantee even distribution of the mass and regular weight of the dough pieces and the lever which is fitted helps in firming and dividing [2]. In present day bread dough dividers, a system called the volumetric system is used to form loaves of dough of approximate standard weight. In the volumetric system, the dough is forced into so-called scaling pockets at an approximate pressure off from twenty to forty pounds per square inch, at the same time shearing the dough on five sides of the cube of a dough piece, the object being to forcibly eject the gaseous bubbles from the dough so that the varying expansion factors will be eliminated and a standard material weight of loaf can be obtained [4]. There are finely and accurately machined separating plates to divide the dough into equal pieces, In between these plates there consists of cutting blades which cuts the dough on compression.

II. RELATED STUDY

The assessment of product quality through texture analysis is an essential tool for both bread products development and production. L. S. Young [1] described the terms used in texture analysis of the intermediate product (dough) and the final baked product and included the practical relevance of testing methods to these products. The principles connected with the measurement of the rheology of the dough for the processing steps, e.g. mixing, moulding, etc., and examples of the instrumentation used were illustrated. For the final baked product the texture of the crust and crumb structure along with freshness, volume and appearance are all important criteria by which the product was judged. The tests and instruments used for these tasks were described. The application of texture analysis to dough and bread was also explained. Finally future trends in potential instrumentation and measurement techniques were discussed. Igor Burstyn et.al [2] conducted a study to measure full-shift exposure to inhalable dust in bakeries and defined the determinants of full-shift exposure. A regression model explained 79% of the variability in exposure. The model indicated that tasks such as weighing, pouring and operating dough-brakers and reversible sheeters increased the exposure, while packing, catching and decorating decreased the exposure. Bread and bun production lines were associated with increased full-shift inhalable dust exposure, while cake production and substitution of dusting with the use of divider oil were associated with decreased exposure. Production tasks and characteristics are strong predictors of personal full-shift exposures to flour dust among bakers; these can be altered to reduce exposure levels. Sheeting is a common method for processing developed doughs, the elasticity of which governs dough's sheetability as dough springs back exiting rollers. To characterize dough sheetability, a study was conducted by M.J.Patel et. [3] al, testing 18 different doughs made from six different flours. Each dough was sheeted using an instrumented sheeter and data for exit sheet thickness and roll forces were captured under a range of sheeting conditions. The true rheological properties of doughs were measured and used to calibrate the ABBM constitutive model for dough. Numerical simulations of sheeting operations were conducted; the R2 coefficients between measured and predicted sheet thicknesses and roll forces (vertical and horizontal) were nearly all >0.9. Relaxation times were derived from dough model parameters and revealed that flour quality for dough elasticity should be assessed by examining moisture effects on dough relaxation time. Panagiotis H. Tsarouhas [4] described the classification methodology over a 2-year period of the primary failure modes in categories based on failure data of bread production line. He estimated the probabilities of these categories applying the chi-square goodness of fit test, and calculated their joint probabilities of mass function at workstation and line level. Then, he presented numerical examples in order to predict the causes and frequencies of breakdowns for workstations and for the entire bread production line that will occur in the future. The methodology was meant to guide bread and bakery product manufacturers, improving the operation of the production lines. Since bioactivity of β-glucan has been linked with its physicochemical properties, Tamer H. Gamel [6] investigated the effects of straight-, sponge- and sour-dough bread making processes on physicochemical characteristics of β-glucan in whole wheat/oat bread. The presence of β-glucan-degrading enzymes in the whole wheat flour used in this study were found to depolymerize β-glucan at a rate of 0.054 min−1, causing a significant reduction in β-glucan molecular weight (Mw) during dough process. Sour- and sponge-doughs had lower rates of β-glucandepolymerization, resulting in breads with medium to high β-glucan Mw range (600–1087 kg/mol) compared to straight-dough method. Dough pH, titratable acidity and fermentation plus proofing time showed significant impacts on β-glucan Mw and viscosity, but not on solubility. Acetic and propionic acids were present in all doughs, whereas lactic acid was only found in sour-dough. The effect of fiber addition on the distribution and mobility of protons in biscuits was studied by M.R.Serial et. al [7] using low resolution time domain nuclear magnetic resonance (TD-NMR). The proportion of flour was reduced in order to incorporate inulin and oat fiber. NMR temperature dependent experiments are carried out in order to gain insight on the processes occurring in biscuit baking. Proton populations were identified measuring spin–spin relaxation times (T2). The major change in the relaxation profiles upon incorporation of fibers corresponds to mobile water molecules, which appear to be related to dough spreading behaviour and biscuit quality. Biscuit samples baked in a commercial oven were studied by two dimensional spin–lattice/spin–spin (T1–T2) relaxation maps. The T1/T2 ratio was used as an indicator of the population mobility, where changes in the mobility of water in contact with flour components as starch, proteins and pentosans were observed.

III. METHODOLOGY

Figure 1 show the methodology involved in design and fabrication of hydraulic dough divider. It begins with the definition of the problem where the objective is decided. Literature survey includes the collection of related data that supports the current modification of the design. Building the model depends on the design calculation and the selection of the material [5]. Each component is constructed and assembled. Next phase is the testing phase where the numbers of trials are taken and the results are validated with the already existing system. Required modifications are made in the system in order to rectify the errors and optimize the results.

For the selection of cylinder, it is necessary to know the total weight that the cylinder has to lift and the pressure needed. So the necessary parts of the machine which has to be lifted by the cylinder have to be made [6]. Once the dead weight and the load are built, the selection of cylinder (diameter) could be carried out. Equation (1) shows the relationship between pressure, load and the diameter.

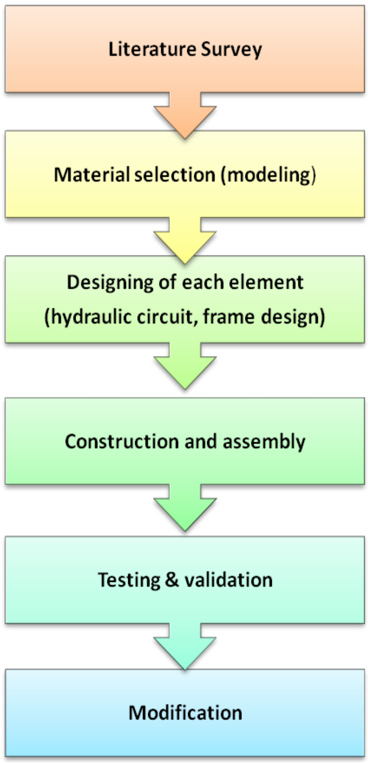

Figure 1: Methodology in design and fabrication of hydraulic dough divider

$P=mg/ (\pi d^2/4)$............... (1)

The two stage telescopic cylinder is more easy and reliable method for doing two staged operation which is used in this machine. The main reason for the selection of this type of cylinder is that, 1st stage is connected to the die that compresses the dough and the 2nd stage is connected to the cutting blades which cuts the dough on compression. Therefore both the operation is done using single cylinder at a single stroke of action.

IV. CONSTRUCTION AND WORKING

The design of whole machine consists of parts like frame, cylinder base, dividing plate, cutting plate, direction control valve etc. Initially construction is carried based on initial design and trial and error method is adopted at few points until an optimum result is reached. Some are the parts of Hydraulic dough divider are explained as below. Figure 2 shows the frame made of MS material (I beam) and is covered with GS sheets of 1mm thickness. Some of the machines used to fabricate frame are Arc Welding Machine, Power Grinder, and Sawing Machine etc. Figure 3 shows the top cover of the dough divider and it is made of MS material and it is 10 mm in thickness. Dividing plate or die shown in figure 4 made of MS sheet of 4 mm thickness. Figure 5 shows the cutting plates which divides the dough into equal number of parts. It is made up of stainless steel material and of 2mm thickness. Figure 6 shows the hydraulic cylinder / 2 stage double acting telescope cylinders. 1^{st} stage actuating pressure plates followed by 2^{nd} stage actuating cutting blades. It is controlled by 4/2 direction control valve. Directional control valves shown in figure 7 are one of the most fundamental parts in hydraulic machinery as well and pneumatic machinery. They allow fluid flow into different paths from one or more sources. They usually consist of a spool inside a cylinder which is mechanically or electrically controlled. The movement of the spool restricts or permits the flow, thus it controls the fluid flow. Figure 9 shows the hydraulic power pack which is a standalone unit with no assembly required other than filling the hydraulic reservoir with fluid. The unit should be located as close as possible to the valve(s) it will operate. All the parts are assembled together which is shown in the figure 10. The hydraulic circuit shown in figure 11 is designed for the machine using the software named fluid SIM-H. From the circuit, the fluid is taken from the tank (T) with the help of a hydraulic pump which is driven by an AC motor (M). Then it is sent to the cylinder via 4/2 control valves. When the lever is not actuated the fluid circulates within the tank and the pump. When the lever is actuated the fluid enters through B to cylinder, moving it upwards. Again when the lever actuates the fluid returns from A back to the tank moving the cylinder downwards.

Figure 2: Frame

Figure 3: Top Cover

Figure 4 (a): Dividing Plate top view

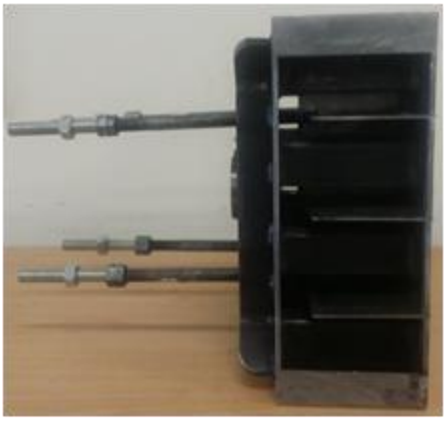

Figure 4 (b): Dividing Plate side view

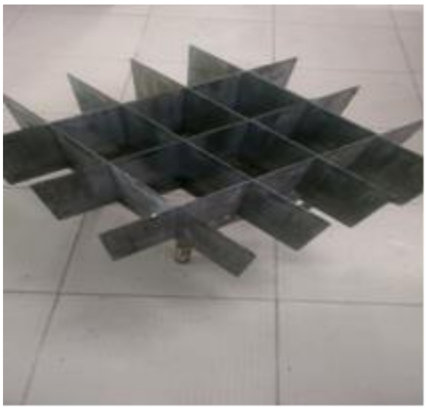

Figure 5: Cutting Plate

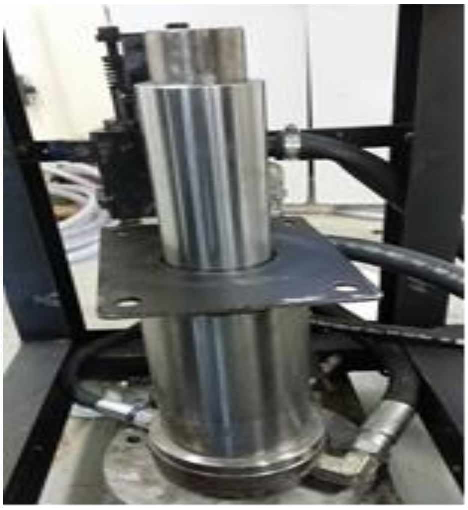

Figure 6: Hydraulic Cylinder

Figure 7: Directional control valve

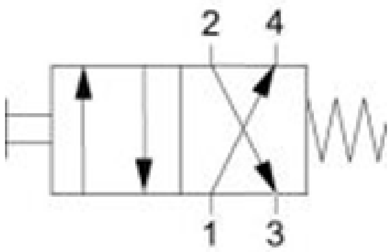

Figure 8: 4/2 Valve

Figure 9: Hydraulic power pack

Figure 10: Complete Assembly

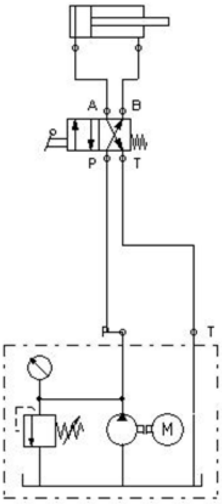

Figure 11: Hydraulic circuit using fluid SIM-H

Figure 2 shows the frame made of MS material (I beam) and is covered with GS sheets of 1mm thickness. Some of the machines used to fabricate frame are Arc Welding Machine, Power Grinder, and Sawing Machine etc. Figure 3 shows the top cover of the dough divider and it is made of MS material and it is 10 mm in thickness. Dividing plate or die shown in figure 4 made of MS sheet of 4 mm thickness. Figure 5 shows the cutting plates which divides the dough into equal number of parts. It is made up of stainless steel material and of 2mm thickness. Figure 6 shows the hydraulic cylinder / 2nd stage double acting telescope cylinders, 1st stage actuating pressure plates followed by 2nd stage actuating cutting blades. It is controlled by 4/2 direction control valve. Directional control valves shown in figure 7 are one of the most fundamental parts in hydraulic machinery as well and pneumatic machinery. They allow fluid flow into different paths from one or more sources. They usually consist of a spool inside a cylinder which is mechanically or electrically controlled. The movement of the spool restricts or permits the flow, thus it controls the fluid flow. Figure 9 shows the hydraulic power pack which is a standalone unit with no assembly required other than filling the hydraulic reservoir with fluid. The unit should be located as close as possible to the valve(s) it will operate. All the parts are assembled together which is shown in the figure 10. The hydraulic circuit shown in figure 11 is designed for the machine using the software named fluid SIM-H. From the circuit, the fluid is taken from the tank (T) with the help of a hydraulic pump which is driven by an AC motor (M). Then it is sent to the cylinder via 4/2 control valves. When the lever is not actuated the fluid circulates within the tank and the pump. When the lever is actuated the fluid enters through B to cylinder, moving it upwards. Again when the lever actuates the fluid returns from A back to the tank moving the cylinder downwards.

V. RESULTS AND VALIDATION

By using equation 1 and substituting the pressure and weight of the dough, a standard telescopic cylinder is selected with the dimensions mentioned in the table 1. There are stages used to actuate both dividing and cutting plate.

TABLE I
SPECIFICATION OF SELECTED CYLINDER

Sl. No	Name	Outer diameter (mm)	Inner diameter (mm)
1	Jack	150	110
2	1st Stage Cylinder	110	70
3	2nd Stage Cylinder	70	30

Frame of the entire system is made of I section beam (40 mm X 80 mm X 3mm) and the entire dimension of the frame is (720 mm X 410 mm X 480 mm). It is covered by the top cover which is 10 mm in thickness and has a dimension of (400 mm X 450 mm). The dividing plate or the die has the overall dimension of (115 mm X 77.5 mm) it is supported by the square tubes. The cutting blades have a dimension of (350 mm X 310 mm X 140 mm).

Selection of an induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type.

TABLE 2
SPECIFICATION OF MOTOR

Details	Units	Values
Power Supply Frequency	Hz	50
Frame Size	mm	200
Ingress Protection	IP	55
Number of Poles		2,4 and 6
Power	kW	18.5

All the dimensions and specification mentioned satisfies a smooth operation of hydraulic system which is designed. The weight of the dough which is applied is balanced and been lifted to obtain desired number of dough divisions. Therefore the entire design is safe, cost effective and compact [5].

VI. CONCLUSION

In this work a prototype model of the hydraulic dough divider was designed fabricated with the measurements with respect to the real-time system. A two stage telescopic hydraulic cylinder will first actuate the die and compress the dough. Once it compress to the maximum level, the 2nd stage of cylinder gets actuated and the blades cuts the dough. The final product achieved will be 12 pieces of dough having equal weight. It is the replacement of the traditional method which is less time consuming compared to the manual methods. Appropriate design and validation using CAD software's will boost the system to obtain optimum results.

Significant changes can be made to this work, as it has used a hydraulic cylinder in the machine there is chance of oil leakage and it could be unhygienic. As long as making of food product is concerned, proper food grade materials are strictly to be used. Here the die has been made with MS sheet, which is not an appropriate food grade material. So it could be changed to aluminium or Teflon plastics. Pneumatic cylinder can be preferred than the hydraulic cylinder, since compressed air is used which will result in faster action and also more hygienic. Stainless Steel can be used instead of the Mild Steel which is suitable for food grade Products, even though it is bit expensive. Size of the system can be increased in order to increase the production of dough. Also by using thermal mechanism the divided dough can be converted into a finished product.

VII. NOMENCLATURE

P= Pressure generated, N/m^2
m= mass of the dough, kg
g= acceleration due to gravity, m/s^2
d= bore diameter, m

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