Design and Analysis of Pulling mechanism in Dumpling making machine

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Abstract: In food industry, Due to high labor costs and employee management issues, specialized in making dumpling food, started to look for a food processing line for making dumplings. In dumpling making machine, there is vertical axes circular table having number of dies. In present work mechanism is developed where motion is converted into reciprocating motion for opening and closing of die to forming dumplings in dumpling making machine. Mechanism can be powered by an electric motor. Using this machine, one can change the dies and also variation in the pressure is needed for different different dumpling reciepes. Therefore in the machine, the task is to develop a mechanism such that it convert rotary to reciprocating motion and also machine have feature for the variation of pressure can be done manually. for this crank slider mechanism selected. In order to variation in forming pressure of dumpling, The change in length of the connecting rod of the slider crank mechanism and compression of helical spring which is assembled in slider, for giving pressure to the dumpling die. The main subject of this report is to design variable length connecting rod and flexible spring slider for the mechanism used in dumpling food making machine.

Introduction

Dumpling is a broad classification for a dish that consist pieces of dough. The dough is made of flour and is filled with cheese, vegetable, fruits or sweets. Traditionally dumpling making process is very messy and complicated. For mass production, the traditional process could not be very much feasible, because it will take time. By use of dumpling making machine this problem can be solved. Due to high labor costs and employee management issues, the specialized in making dumpling food, started to look for a food processing line for making fried and steamed dumplings. With dumpling making equipment operates automatically, able to increase their production amount with better management. Based on the requirements, the dumpling processing line is designed with fundamental facilities including dough belt maker, feeding hopper, dumpling filling placement, forming and wrapping. The fundamental of the design is to build a dumpling production line that is easy to clean, energy-saving and allows making similar foods with great flexibility. Dumpling processing equipment can be operated automatically to reduce labor costs. The thickness of unbaked dough skin is adjustable (4-12mm).The weight of dumpling can be customized. Machine has rotary index table positioned along vertical axes having number of dumpling making dies. When the die turned at deposing point, after filled die needs closing for sealing of dough. This can be done by pulling mechanism below the table. This pulling mechanism should be length and pressure variable manually.

Objective/Methodology

Study of conventional dumpling making machine

Define problem definition and specifications.

Select robust, suitable pulling mechanism for the machine

Design individual component

Analysis of designed pulling mechanism for the machine

Testing and Validation of the newly design mechanism.

Literature Review

1 .Design and force analysis of slider crank mechanism for film transport used in VFFS machine

In this paper, conventional belt transport mechanism is replaced with slider crank mechanism where intermittent motion is converted into continuous motion for packaging. Volume of bag is also increased as compared to conventional mechanism. Flexibility of length adjustment (variation of length) can be achieved by placing restrictor in between the movement of table. This paper is useful for our project for the force analysis of slider crank mechanism and synthesis of slider crank mechanism.

2. Design of a slider-crank leg mechanism for mobile hopping robotic platforms

New leg design for a mobile robot which uses the slider-crank mechanism to convert the continuous motor rotation into piston motion which is used to impact the ground. Slider crank mechanism with a linear spring was used to generate energy-efficient hopping by conserving and releasing potential energy. Dynamic analysis was performed to determine the optimal position for the mechanical switch position of the clutch trigger mechanism. From this paper, dynamic analysis of crank slider mechanism with linear spring can be use in our project.

3. Dynamic modeling of an intermittent slider–crank mechanism

Kinematic and dynamic analysis of the intermittent slider-crank mechanism. The connecting rod is connected with a pneumatic cylinder and a spring model. Some conclusions from this paper can be used in our project that is the pneumatic model solutions are closer to the kinematic solutions and have faster responses than those of the spring model. The spring model can be designed to decrease the production cost and to achieve the same intermittent motion.

4. Kinematical analysis of crank slider mechanism using MSC Adams/View

In this paper, develop model of centric crank slider mechanism in ADAMS/View software, and its following complete kinematical analysis. Simulation of several configurations of the crank slider

Mechanism and the comparison of the outputs showed the impact of the change of the respective parameter. From this paper, computer modeling and analysis of crank slider mechanism can be useful for the project.

5. Dynamic analysis and controller design for a slider–crank mechanism with piezoelectric actuators

Dynamic behavior of a slider–crank mechanism associated with a smart flexible connecting rod is investigated.

Effect of various mechanisms parameters including crank length, flexibility of the connecting rod and the slider's mass on the dynamic behavior is studied. Increasing the crank length leads to higher amplitude of vibration and in an unpredictable motion of the mechanism. Decreasing the slider mass and increasing the flexibility of the connecting rod result in the same conclusions.

6. Dynamic synthesis of machine with slider-crank mechanism

In this paper, method of optimal dynamic synthesis of a machine, which consists of an asynchronous electric motor and a slider-crank mechanism, has been developed. Optimum of the dynamic synthesis of the machine is built on the basis of the equations of the machine motion with rigid links. Dynamic synthesis of a machine, which consists of an asynchronous electric motor and a slider-crank mechanism, has been validated using a numerical simulation of the synthesized machine with a slider-crank mechanism.

7. Failure analysis of threaded connection in large scale steel tie rods

In this paper, work on analysis of the strength of threaded connection and determine the optimal number of turns of thread engagement is critical for structural safety. Full scale tensile rupture experiments were carried out to test the maximum allowable axial loading for different number of turns engagements. This paper suggests the minimum number of turns of thread engagement for preventing failure of thread teeth of steel rod.

Design

Component Design

Double ended threaded stud

A stud is cylindrical rod threaded at both end. Both ends of stud have threaded joint to left hand female threading and right hand female threading rod end bearings.

Material

Both ends having threaded and at the middle of the stud there is need of hex nut for adjustment of length.
Machinability is important consideration for this part. free cutting steel having excellent machinability due to addition of sulphur. EN8(40C10S18) cold drawn bar is suitable material for the stud.

Design criterion:

A connecting rod is which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile forces, therefore, the cross-section of the connecting rod is designed as a strut. Hence the design should be according to buckling phenomenon The dimensions of cross-section are calculated by applying Rankine's formula for buckling of connecting rod. According to this formula:

$$P_{cr} = \frac{\sigma_{cA}}{1+a\left(\frac{l}{k}\right)^2}$$

P_{cr} = Force on connecting rod × factor of safety

For low rpm, factor of safety is 5.

For fluctuating loading,

Reliability factor K_c = 0.897 (90% reliability)

Size factor K_b = 1 (for axial loading K_b= 1)

Surface finish factor $K_a = a(S_{ut})^b$

$= 4.51(600)^{-0.265}$

= 0.8278

$\therefore\ S_e = K_a K_b K_c S'_e$

= (0.8278)(1)(0.897)(0.5×600)

= 222.59

For axial loading, $(S_e)_a$= 0.8× S_e = 0.8× 222.59 = 178.072

Now, $\sigma = \frac{(S_e)_a}{f_s} = \frac{178.072}{1.5} = 118.71$

Appling Rankine formula,

$$\therefore\ P_{cr} = \frac{\sigma A}{1+a\left(\frac{l}{k}\right)^2}$$

$$F\times f_s = \frac{\sigma A}{1+a\left(\frac{l}{k}\right)^2}$$

$$1675.5\times 5 = \frac{118.71\times 3.14\times r^2}{1+\frac{1}{7500}\left(\frac{120}{r}\right)^2}$$

∴ r = 5.1 mm

Rod end bearing with jam nut

Rod ends consist of an eye-shaped head with integral shank that forms a housing for a spherical plain bearing. For the length adjustment, two rod end bearings (right hand and left hand female threaded) can be selected.

Equation from mechanical strength: $P \leq \frac{C_s}{f_s}$

For the dynamic loading capacity: $C_d = \frac{C_s}{\sqrt[3]{n}}$

C_s and C_d are static and dynamic load capacity

f_s is factor of safety, taking 5 to 8 (load in varying direction)

Rod end bearing can be selected on the basis on the loading capacity calculated above.

Loosening of the threads between bolt and nut should not occur under normal condition. However, many of these Fastening become loose when subjected to cyclic and impact loads. Loosening is due to the reduction of friction force in the threads due to consecutive expansion and contraction of the bolt resulting from fluctuating loads.jam nuts are used to prevent the loosening of threads between rod end bearing and stud.

Pin design

The standard proportion for the diameter of the pin is diameter of rod

d=D

Design for fork

$$\sigma_t = \frac{P}{2a(d_0-d)}$$

Standard proportion for the thickness a,

$a = 0.75D$

$a = 0.75(10) = 7.5\ mm$

For fluctuating loading,

$a = 7.5 \times f_s = 7.5 \times 1.5 = 11.25\ mm$

Slider

In this mechanism, hollow bar has to and fro motion for pulling die. It is made of carbon steel with chromium plating. Hollow bar is subjected to axial fluctuating load.

Design

For fluctuating loading,

Reliability factor K_c = 0.897 (90% reliability)

Size factor K_b = 1 (for axial loading K_b= 1)

Surface finish factor K_a= $a(S_{ut})^b$

= $4.51(600)^{-0.265}$

= 0.8278

$\therefore\ S_e = K_a K_b K_c K_d S'_e$

= (0.8272)(1)(0.897)(0.5×600)

= 222.76

$\therefore\ \sigma = \frac{S_e}{f_s} = \frac{222.7}{1.5} = 148.49\ \frac{N}{mm^2}$

For buckling failure criteria,

$\therefore\ P_{cr} = \frac{\sigma A}{1+a\left(\frac{l}{k}\right)^2}$

$\therefore$ F× $f_s = \frac{\sigma A}{1+a\left(\frac{l}{k}\right)^2}$

$\therefore\ 1675.5 \times 5 = \frac{148.49 \times 3.14 \times r^2}{1+\frac{1}{7500}\left(\frac{120}{r}\right)^2}$

$\therefore$ r = 6.4 mm

$\therefore$ d = 12.8 mm

Spring and km nuts

The spring is subjected to fluctuating force. Therefore, the oil-hardened and tempered steel wire of SW grade is selected for this application.

Small pin

Shear failure of pin,

$$\therefore \tau = \frac{P}{2(\frac{\pi}{4}d^2)}$$

$$\therefore d=\sqrt{\frac{2P}{\pi\tau}}$$

For fluctuating loading,

$$\therefore \; S_e = K_a K_b K_c K_d S'_e$$

$$= (0.8272)(1)(0.897)(0.5\times600)$$

$$= 222.76$$

For shear stresses,

$$S_{se} = 0.577 S_e$$

$$= 0.577 \times 222.76$$

$$= 128.53$$

$$\tau = \frac{S_{se}}{f_s}$$

$$= \frac{128.53}{1.5} = 85.68$$

$$\therefore d=\sqrt{\frac{2P}{\pi\tau}}$$

$$= \sqrt{\frac{2\times1675}{3.14\times85.68}}$$

$$= 3.52 \text{ mm}$$

Bill of material

	Parts	Material
1	Stud	40C10S18(EN8) Free cutting steel
2	Rod end bearing	S35C(chromate treatment)
3	Fork/Joint	40C10S18(EN8) Free cutting steel
4	Slider bar	40C10S18(EN8) Free cutting steel
5	Spring	oil-hardened and tempered steel (SW Grade)

Analysis

The static structural analysis is carried out to check the structural deformation and stress produced in the components due to given loading conditions. For the simulation, Ansys workbench platform is used.

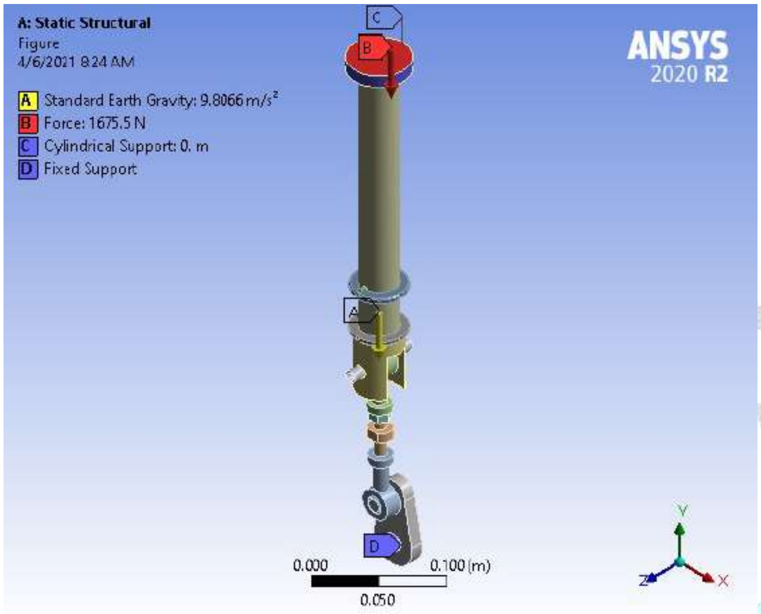
Boundary conditions :

Fixed support : crank pin hole

Cylindrical support : top surface

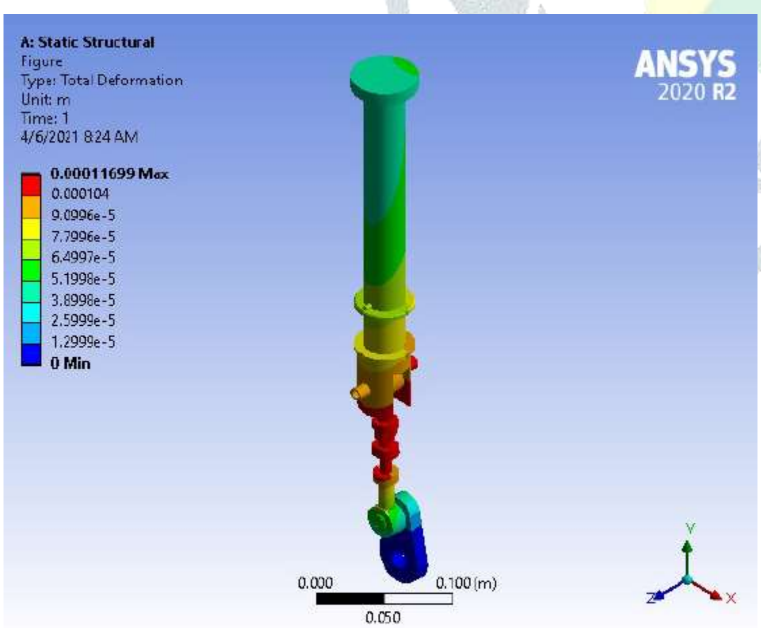
Force : top surface = -1675.5 N

Standard earth gravity = -y direction

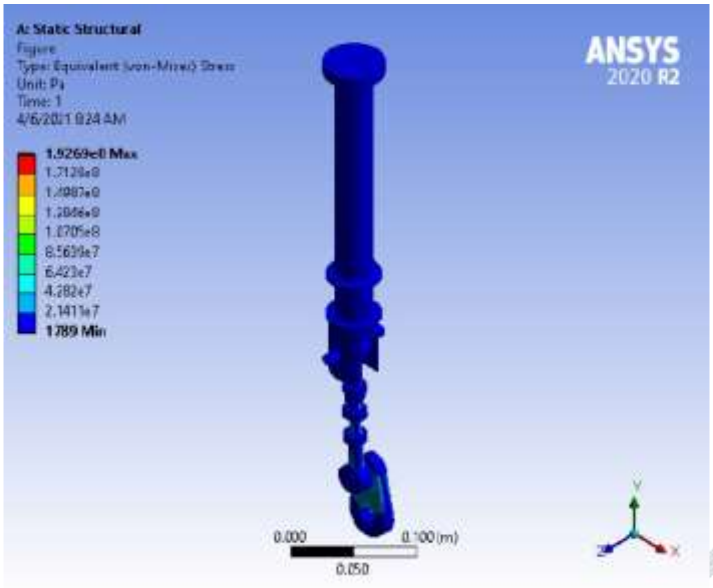


Above figure address the applied loading and supports in the assembly. The fixed support is applied at the pin hole of cam and cylindrical support is applied at the rounded surface of the flange type potion at the top of the assembly. The force acting on the face of flange and in the –y direction.

Simulated model:



This figure shows the total deformation of components of mechanism due to static structural loading. the maximum deformation occurred is 0.1 mm which is negligible.



The above figure shows equivalent (von-mises)stresses generated in the mechanism when it is in static structural loading conditions. The maximum stress generated is 1.92×10^8 which is in the permissible stress range of the material which is 2.5×10^8.

Result and discussion

In this study, design a mechanism that operates dies on rotating index table of machine which also need pressure variation for different variety of dough materials. slider crank mechanism is selected for die opening and closing. stud and rod end bearings used for length variation for different varieties of dough materials. from kinematic analysis of slider crank mechanism, forces acting on the component can be finding out and according to that design of all components can be done. model has done in creo software and it is imported to ansys software for analysis purpose. From the structural analysis, stresses generated and deformation occurred in individual components as shown in table.

Components	Maximum Stresses generated	Deformation occurred
Stud	1.0196×10^8	0.00011671
Rod end bearing	9.7263×10^7	0.00010789
Joint	5.7158×10^7	0.00011677
Pin	8.0426×10^7	0.00011149
Slider bar	1.7195×10^7	0.00009.4487

From analysis all the stress values of individual components are in permissible stresses. And deformation values are also negligible. from the result, prepared design is safe.

Conclusion

From the above work it is conclude that the pulling mechanism for die operation in dumpling making machine which provides rotary to reciprocating motion and also feature of adjustable pressure and length is prepared .for that crank slider mechanism selected for the rotating to reciprocating motion, spring intermediate used for pressure variations and combinations of rod end bearing and stud used for length adjustment of assembly.

From the ansys analysis of assembly and individual parts, we can conclude that the mechanism, component design and their materials are correct and validate for safe application of this mechanism.

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