Design of Lead Screw Mechanism For Vertical Door Wrapping Machine.

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Abstract---Now days to stay in competitive environment every industry should be cost effective and should provide quality product with in time. To achieve higher productivity and quality products at low cost, industry should go towards semi-automation or automation. Operations that are repeating in nature should be automated. In steel doors manufacturing industries packaging of doors is on of the operation that is mostly done manually. Manual operation requires more manpower, more time, higher cost, and low quality at a time more fatigue at apart of worker, hence lower productivity. So packaging operation of doors should perform using semi-automatic or automatic wrapping machine. In vertical wrapping machine consist of rotating base which holds the door and vertical lead screw mechanism which holds the stretch film roll and moves up and down for wrapping. In this research design and modelling using Creo parametric-2 of vertical lead screw mechanism is done and analysis of stresses and deformation is also done using ANSYS 13.0 software.

I. INTRODUCTION

This design is concerned with the wrapping of maximum 10foot height of door. Lead screw mechanism consist of

- Lead screw, lead screw nut assembly. Lead screw supporting structure, lead screw driving motor, limit switches.
- Lead screw nut assembly consist of attachment for holding stretch film roll.
- Lead screw supporting structure holds lead screw and guide way for nut travelling.
- Two limit switches are provided to control nut assembly travel. One is fixed at lower end to restrict travelling bellow which nut will not travel; second one is movable on vertical structure to control motion of nut assembly up to door height.
- Lead screw driving mechanism consists of motor which rotate lead screw.

II. DESIGN OF LEAD SCREW MECHANISM.

This mechanism consists of following parts.

- Lead screw.
- Bearing.
- Lead screw nut and assembly.
- Lead screw driving mechanism.
- Motor
- Limit switch.
- Supporting structure.
- Lead screw selection.

A. Lead Screw Selection:

In lead screw selection process we find out length of lead screw, material selection for screw and nut, outer or major diameter, minor diameter, pitch diameter, pitch, lead, type of thread.

Material for screw is steel (C 45 or C 55) [1] Material for nut is bronze or cast iron. We select bronze nut because of its high friction resistance and wear resistance. [2]

Lead screw length required is 10foot, because of maximum height of door that can be wrap on the machine is 10 foot. Diameter required for such type of screw is selected from lead screw catalogue. [3] It is given in table.1.1

Table. 1.1: Selection of lead screw

Length limitation	
Screw diameter	Maximum length
10mm	1200mm
10-16mm	1800mm
>16mm	3600mm

Our lead screw length requirement is 10foot so it is 3100mm so we chose diameter of screw >16mm.

For selection of thread on screw, there are three different types of thread forms available.

- Square threads. [4]
- Acme threads. [4]
- Buttress threads. [4]

We use acme or trapezoidal thread because of Acme threads are trapezoidal in shape. In fact, Acme threads are modification of square thread. The efficiency obtain by using acme thread is slightly less than that obtain by square thread because of its slight slope. Acme threads are extensively used in lead screw and split nut of the lathe. Because of split nut can be easily engaged with the lead screw or disengaged from it. These threads are easy to manufacture compare to square threads.

Selection of lead screw dimensions: [5] we select nominal diameter 24mm for our application. Standard dimensions are given bellow Table. 1.2. All dimensions are in mm. In Fig.1.1 shows Terminology of trapezoidal screw thread

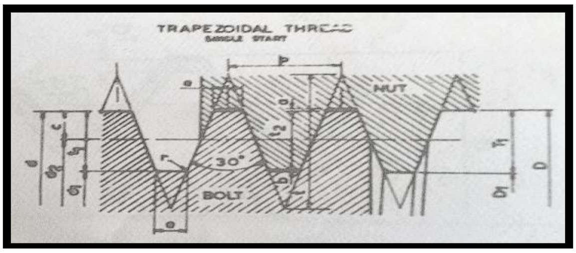

Fig. 1.1: Terminology of trapezoidal screw thread.

Table. 1.2: Standard dimensions of trapezoidal thread

Nominal dia.	**Pitch**	**d_1**	**D**	**D_1**	**d_2**
24	5	19	25	20	22

e	**t_1**	**T_1**	**a**	**b**
1.7	2.8	2.3	0.3	0.8

Other dimensions are given bellow.

t = 1.866(p) = 9.33mm.
t_2 = 0.5(p) + a − b = 0.5(5) + 0.25 −0.75 = 2mm.
C = 0.25(p) = 1.25mm

B. Bearing Selection.

1) *Selection Of Thrust Bearing :*We have to select thrust bearing to accommodate our lead screw diameter. Our lead screw end diameter is 20mm. We select bearing from SKF catalogue. Thrust bearing is used for caring thrust load due to up and down motion of lead screw. Designation of bearing is 51204. Selected thrust bearing have outer diameter 40mm and inner diameter is 22mm.

2) *Selection Of Cylindrical Roller Bearing:* It is used for holding another end of lead screw which is free and does not carry thrust load. We select bearing from SKF catalogue for 20mm end diameter. Designation of bearing is NU 204 ECML. Outer diameter of this bearing is 47mm and inner diameter is 22mm.

C. Lead Screw Nut Assembly:

In lead screw nut assembly consist of attachment to carry plastic stretch film roll it has one plate that is directly welded on the nut and second one plate is bolted on this plate, to provide modification in design if required.
Dimensions of nut are 65mm × 65mm × 65mm.dimensions of plate welded with nut is 150mm × 200mm and thickness of plate is 10mm. Dimension of the plate bolted with the nut is 150mm × 600mm.

Than on surface of second plate we weld 100mm×50mm rectangular hollow pipe having thickness 5mm, and 300mm long. On this plate we weld hollow circular pipe of outer diameter 65mm and inner diameter 60mm and length 500mm. plastic stretch film roll is inserted on this hollow pipe. Creo model of this attachment is given in fig. 3.1.

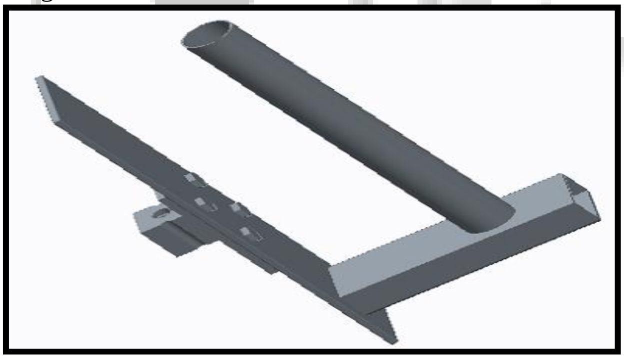

Fig. 3.1 Cero model of nut assembly attachment.

On nut assembly attachment we put stretch film roll in hollow pipe. Length of stretch film roll is 500mm; Inner diameter of stretch film roll is 70mm.In Fig. 3.2 actual Stretch film roll is given.

Fig. 3.2 Stretch film roll.

D. Lead Screw Driving Mechanism:

We drive lead screw with the help of motor. For this we find out torque and power required to lift our assembly of nut.

Total mass of assembly = Mass of lead screw nut + Mass of plate bolted with nut. + Welded plate + Mass of rectangular hollow pipe + Mass of Circular hollow pipe + Mass of stretch film roll.

Total mass of assembly = 2.3 + 2.35 + 7.074 + 4.40 + 7.71 + 4.85 = 28.68kg.

By considering factor of safety 1.74 we take mass of this attachment 50kg.

So we find out torque and power required to lift 50kg of mass. For this we have to find out liner velocity of nut assembly.

1) Linear And Rotational Velocity Of Lead Screw: Our screw is single start so Lead = pitch = 5mm, it advance 5mm in one revolution.

Consider the wrapping of 2400mm×2100mm and profile 105mm size door.

– It requires average 4min: 15sec (255sec) to wrap manually. We find out how much revolution required to at reaching 2400mm height.
– 5mm axial advancement = One revolution so for, 2400mm axial advancement = number of revolutions are = 2400/5 = 480revolution.
– We design our machine to wrap such type of door with in one minute so our rotational velocity of lead screw becomes 480revolution/min.
– Linear velocity.
  In 60 sec = 2400mm linear advancement, so
  In 1 sec linear advancement = 2400/60 = 40mm/sec. or 2400mm/min.

2) *Torque And Power Calculation For Lead Screw.* [5] :

Total torque (T) = Torque required to overcome friction between the lead screw and It's Nut (T_1) + Torque required to overcome friction at collar. (T_2) (D, 1)

Torque required overcoming friction between the lead screw and its nut is given by

$T_1 = W\tan(\alpha_1+\lambda)\times\frac{D_m}{2}$ (D, 2)

Hear, W = load to which lead screw is subjected i.e. load Due to the mass of 50kg.so load is 490N.

Hear,
D_m = mean diameter of lead screw.
α_1 = helix angle.
λ = angle of friction

$D_m = \frac{d+d_1}{2}$, Hear (D, 3)

d = outer diameter of selected screw and
d_1 = core or minor diameter of selected screw.

So, From (D, 3) $D_m = \frac{d+d_1}{2} = \frac{24+18.5}{2}$ = 21.25mm.

We can also directly select from table. A (2) it is 21.5mm. So we select standard value 21.5mm.

$\tan(\alpha_1) = \frac{p}{\pi D_m} = \frac{5}{\pi(21.5)} = 0.074026.$ (D, 4)

So, $\alpha_1 = \tan^{-1}(0.074026) = 4.2336^0$

Again, $\tan(\lambda) = \mu$ Hear,
μ = Co-efficient of friction between screw and nut. We take μ = 0.15 for steel screw and bronze nut.

So, $\lambda = \tan^{-1}(0.15) = 8.53^0$. (D, 5)

We put all values of (D, 3), (D, 4) & (D, 5) in (D, 2) we get.

$T_1 = W\tan(\alpha_1+\lambda)\times\frac{D_m}{2}$ =

490tan (4.2336+8.53)× $\frac{21.5}{2}$ = 1193.22Nmm.

Now torque required to overcome friction at collar is given by

$T_2 = \mu_c \times W \times \frac{r_1 + r_2}{2}$ hear, (D, 6)

W = load to which lead screw is subjected.

μ_c = coefficient of friction of thrust bearing and screw. = take 0.10

r_1 = outside radius of thrust bearing. = 40/2 = 20mm.

r_2 = inside radius of thrust bearing. = 22/2 = 11mm.

Value of r_1 and r_2 are selected from selected bearing basic dimensions topic B subtopic i.

$T_2 = 0.10 \times 490 \times \frac{20+11}{2}$ = 759.5Nmm.

Put the values of (D, 2) & (D, 6) in (D, 1) we get.

$T = T_1 + T_2$ = 1193.22 + 759.5 = 1952.72Nmm.

Power required = $\frac{2\pi NT}{60\,(1000)}$ Kw. (D, 7)

Hear, T = total torque. From (D, 1)

N = rpm of lead screw = 480rpm

Power required = P = $\frac{2\pi NT}{60\,(1000)}$

Put the values of (D, 1) & rpm in (D, 7)

$\frac{2\pi(480)(1.95272)}{60\,(1000)}$ = 0.0981544Kw = 98.15W.

E. Selection Of Motor To Drive Lead Screw. [6]: :

From design data book we select motor according to our power, torque requirement and rpm value. Power, rpm and other values of selected motor are given bellow. Basic dimensions of motor are given in fig. 5.1.

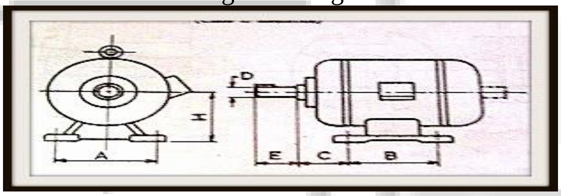

Fig. 5.1: Basic dimensions of lead screw driving motor.

Power rating: 0.37kW, Motor rpm: 1000rpm, Frame no: 80, H (Tol-0.5): 80mm. A = 125mm, B = 100mm, C = 50mm, D = 19j6, E = 40mm, Bolt size = M8.

In market motor of 1hp, 0.75Kw, 500rpm and torque 14.2Nm available which satisfy our power, rpm and torque requirement, so we can directly utilise this motor for driving lead screw. We have to reduce 500rpm to 480rpm. Diameter of pulley connected with motor is 75mm. So for reducing 500rpm to 480rpm with the help of pulley diameter and rpm relation.

$N_1 D_1 = N_2 D_2$, [7] (E, 1)

Hear,

N_1 = rpm of motor pulley. = 500rpm

D_1 = diameter of motor pulley. = 75mm

N_2 = rpm of lead screw pulley. = 480mm

D_2 = diameter of of lead screw driving pulley.

So, $D_2 = \frac{N_1 \times D_1}{N_2} = \frac{500 \times 75}{480}$ = 78.125mm. ≈ 80mm.

F. Limit Switch:

Two Limit switch is provided to control linear motion of lead screw.

First one is adjustable; as heights of the doors are varying from minimum to maximum it stops the motion according to height of door. If height of door to be wrap is 6foot than limit switch is set to 6foot height so lead screw travel is restricted up to 6foot. Second one is to control the nut assembly motion bellow which lead screw nut assembly travel is restricted. So it is fixed at lower end.

G. Supporting Structure:

Supporting structure is provided for rigidity of our system. Plate of 800mm×300mm and 12mm thick used for base of our supporting structure.

On base plate we weld 100mm×50mm rectangular hollow pipe having thickness 5mm and 3800mm long. Length of this pipe is decided by considering height of lead screw and height of rotating plate mechanism from base.

Two 16mm solid thick plate having length 300mm and width 100mm, such that distances between these two plates are same as lead screw length that is 3100mm. These plates are provided for holding lead screw and guide way of stainless steel rods. On the top plate to accommodate cylindrical roller bearing hole of 47mm diameter is provided and to accommodate thrust bearing at lower plate 40mm diameter is provided. These plates also have two circular holes of diameter 15mm to accommodate stainless steel rods for guide way of nut.

Supporting structure with nut assembly is given in fig. 7.1 and in fig.7.2 is another view of supporting structure.

Fig. 7.1: Supporting structure for lead screw.

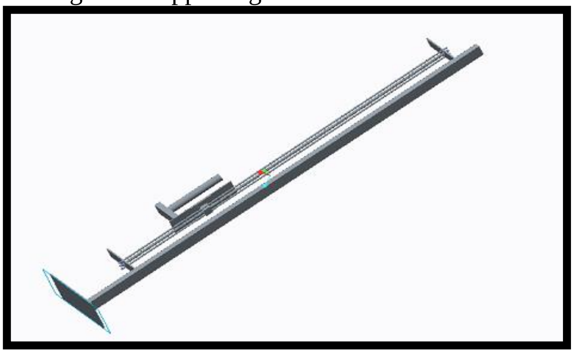

Fig. 7.2: Another view of supporting structure of lead screw.

H. Analysis Of Stresses And Deformation In Lead Screw Mechanism:

In this analysis area in which maximum value of deformation and stress are induced is found out using Ansys software. In lead screw stretch film roll up and down mechanism load of 49N is act on vertical hollow circular pipe and surface of horizontal rectangular pipe. Load of 290N is act due to lead screw assembly on the end of lead screw.

To check our structure stability we analyse structure at 100N load at circular hollow pipe, and 1000N at lead screw end.

To carry this load thrust bearing is attached with the end of lead screw. In Fig. 8.1 and fig. 8.2 shows the maximum value of von misses stress and area on which this stress is developed due to loading.
In fig. 8.3 and fig.8.4 shows the maximum value
Of deformation and area on which this deformation is take place due to loading.

From fig. 8.2 (b) Maximum equivalent von-misses stress developed due to loading is 9.999×10^6 (10 Mpa), It is act on the thrust bearing which carries load. Our bearing material Stainless steel X105CrMo17 yield stress value [7] is 680 Mpa, so our bearing is not fail under this loading condition and design is safe.

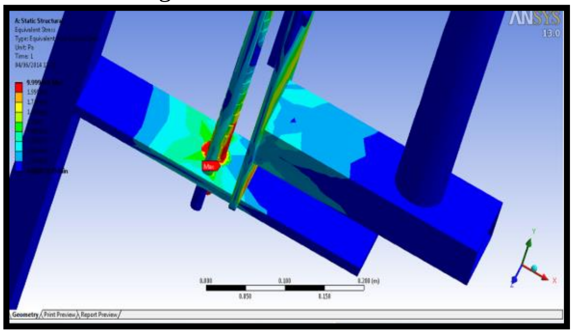

Fig. 8.1: Equivalent von-misses stress due to loading on lead screw mechanism.

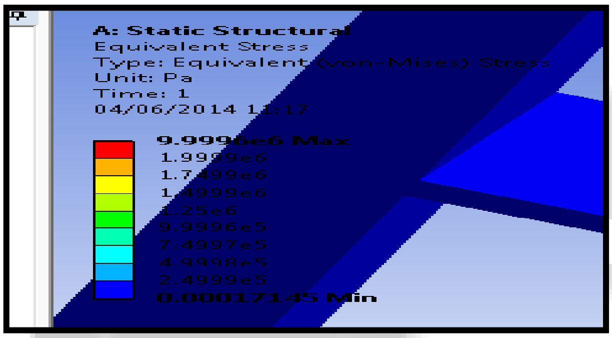

Fig. 8.2: Equivalent von-misses stress due to loading on lead screw mechanism.

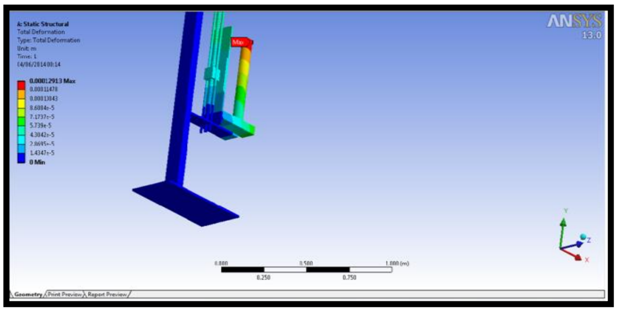

Fig. 8.3: Deformation due to loading on lead screws mechanism.

Fig. 8.4 Deformation due to loading on lead screws mechanism.

From Fig.8.4 maximum deformation of 0.12913mm is occurred at the top surface of the hollow circular pipe. This deformation is also negligible so our design is quite safe for deformation.

III. RESULTS

Design of lead screw mechanism for vertical wrapping machine is done and from stress and deformation analysis our design is quite safe.

IV. CONCLUSION

Design of lead screw mechanism for vertical door wrapping is done numerically. Using Creo parametric -2 modelling software models of different components of lead screw mechanism of vertical door wrapping machine is done. Analysis of stresses and deformation in mechanism is done with the help of ANSYS 13.0 software.

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