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DESIGN AND ANALYSIS OF ROLLER SCREW MECHANISM FOR ANELECTRIC CYLINDER

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ABSTRACT:

Electric cylinder is a device which consists of an electric motor, roller screw mechanism, belt and pulley assembly, sub rollers. Electric cylinder is having a good control over nonlinear properties like motion and position control. Roller screw mechanism consists of assembly of main roller and sub roller which is driven by an electric motor for having control over the nonlinear properties. The paper mainly consists of design of a roller screw mechanism of an electric cylinder for a hand lever operated plastic injection moulding machine. The analysis of roller screw mechanism is done by using the ANSYS 16.2 software.

KEYWORDS: Roller screw, sub-roller

INTRODUCTION:

A roller screw is a mechanism for converting rotary motion into linear motion, in a similar manner to acme screws or ball screws. But, unlike those devices, roller screws can carry heavy loads for thousands of hours in the most arduous conditions. This makes roller screws the ideal choice for demanding, continuous-duty applications.With roller screws, the application load is transmitted from the motor to the screw shaft through the barrel-shaped surfaces of all rollers. The total surface area of the contacts between the shaft, the rollers and the nut is substantially increased compared to the ball screw design, resulting in larger load carrying capacity and increased service life.roller screws are widely used in high load, high speed, and high precision applications: in the aerospace industry, the roller screw is used for the design of landing gear, in the shipbuilding industry, it is used for driving the propeller; in optical equipment, it is used for precise micro displacement, it is also applied in therobotics as a kind lighter, rapid responding component and it is already applied in machine tools especially the high precision grinder.

Roller screw mechanism consists of square threaded main roller and three sub rollers for having better control over the motion control and position control. In case of small injection moulding machine as it is a hand lever operated system due to which in a every cycle of operation injection velocity and torque goes on varying. Due to these variations, lots of defects are arises into the final product. It is very important to maintain constant injection velocity and torque.

LITERATURE REVIEW:

1) **Shangjun Ma:** his paper describe the new method to find out the relationship between number of rollers and number of starts of thread on sub roller.
2) **A.V. Zhdanov:** This paper provides theoretical aspect of load distribution on roller screw mechanism. The theoretical approach of paper is to use RSM model with elastic contact between main roller and sub-roller.
3) **Hui Wang**: This paper focused on contact stresses developed between main roller and sub roller assembly.This paper study the impact of surface hardness of the roller on the performance of the roller screw, sums up the effect of hardness on the bearing capacity of the roller, and provides the theoretical support and references for the designing and application of roller screw.

OBJECTIVES:

1. Design of roller screw mechanism to maintain constant injection velocity.
2. To maintain constant torque.

DESIGN OF ROLLER SCREW MECHANISM:

For the design of roller screw mechanism, consider maximum value of load on plunger with factor of safety.

DESIGN OF MAIN ROLLER:

As the maximum load acting on a plungeris 690kg .
Total load acting on a plunger is given by,

$$W = 690*5 = 3450 \text{ kg}$$

$$W = 3450*9.81 = 33845 \text{ N}$$

Now find out the core diameter of roller (d_c),

$$W = (\pi/4)*(d_c^2)*\sigma_c$$

Elastic strength of steel is 200 N/mm^2 and fos 2

$$\sigma_c = 200/2 = 100 \text{ N/mm}^2$$

$$d_c^2 = (33845*4) / (100*\pi)$$

$$d_c = 21 \text{ mm}$$

Now calculating the outside diameter of roller

$$D_o = d_c / 0.84$$

Do = 26 mm

Pitch of roller screw (p) = Do - d_c

p = 5 mm

Mean Diameter (d) = (Do+ d_c) / 2

= 23.5 mm

Now calculating helix angle,

$$\tan \propto = pitch/(\pi * d)$$

$$\alpha = 5 / (\pi * 23.5) = 3.87^{o}$$

Torque transmitted by the roller screw is given by, T =

$$W \tan (\text{Ø}+\alpha)^* (d/2)$$

$$= 33845^* \tan (0.14+3.87)^* (23.5/2)$$

$$T= 27878.16 \text{ N/mm}$$

Shear strength of screw is given by,

$$T = (\pi /16)^* \Gamma^* d_c^3$$

$$\Gamma = 27878.16/ 21^3 * (/16)$$

$$\Gamma = 15.33 \text{ N/mm}^2$$

Compressive strength of screw is given by,

$$\sigma_c= W / ((\pi/4) * d_c^2$$

$$= 33845 / ((\pi/4)^* 21^2$$

$$\sigma_c= 97.71 \text{ N/mm}^2$$

As the calculated value of stress is within the elastic limit hence design is safe.

TORSIONAL BUCKING OF SCREW:

Buckling of scre is very much similar to the bending which is used for the long length of shaft. By using Euler's Formula,

$$W_{max} = n^* \pi * (2^* E^* I / L^2)$$

As per end condition, for cantilever n = 0.25 and for steel material,

$$E= 2^*10^5 \text{ N/mm}^2$$

Length of roller screw 300 mm and diameter of screw is 26 mm.

Moment of Inertia (I) = $(\pi /64)^* d^4$

$$I = 22431.76 \text{ mm}^4$$

$W_{max} = (0.25^*\pi^*2^*2^*10^5{}^*22431.76) / 300^2$

W_{max} = 78301.62 N

Euler's buckling of the screw takes place at load of 78302 N but our load is 33845 N is within limit.

Factor of safety = ($W_{buckling}$ / W_{actual})

F.O.S. = (78301.62 / 33845) = 3

As our factor of safety is 2 is within the limit. Hence our calculations are safe.

Buckling strength is given by,

$$\sigma_{buckling}=W_{buckling} / \text{Area of screw}$$

$$= 78301.62 / ((\pi / 4) * 26^2)$$

$\sigma_{buckling}$ = 250 N/mm^2

Above calculation shows that or assumption ofσ = 100 N/mm^2 is perfect as buckling of screw will takes place at 250 N/mm^2.

DESIGN OF SUB-ROLLER:

For the design of main roller e have consider the max load acting on a plunger 640 kg. In this paper we are using 3 number of sub-rollers.

For the design of sub-roller,

Load acting on each roller is calculated by

$$W_{roller} = (640^*9.81) / \text{no. of rollers}$$

$$= (640^*9.81) / 3$$

$$W_{roller} = 2093 \text{ N}$$

Shear strength of screw is given by,

$$\Gamma_{screw} = W_{roller} / \text{Shear area of roller}$$

$$15.33 = 2093 / (\pi^* (26-21)^*n^*)$$

Where, n= no of turns = 10

Length of Sub-Roller = n* pitch

Lsub-roller = 10*5 = 50 mm

Shear strength of sub-roller is given by

$$\Gamma_{sub\text{-}roller} = W_{roller}/ \text{shear area of roller}$$

$$= 2093 / (\pi^*(26-21)^*10^*2.5)$$

$$\Gamma_{sub\text{-}roller} = 6.33 \text{ N/mm}^2$$

The shear surface area = $\pi^*(26-21)^*3$

= 47.28 mm^2

Force applied on the main roller = 33845N

No. of turns of threads on single roller = 10 turns

Hence, the force applied on the single thread or turn = force applied / no of turns

= 33845/10

= 3384.5N

Stress developed on the roller root = force on single thread / shear surface area [4]

= 3385 / 47.28

= 71.59MPa

RESULT AND DISCUSSION:

A) BY USING SOFTWARE:

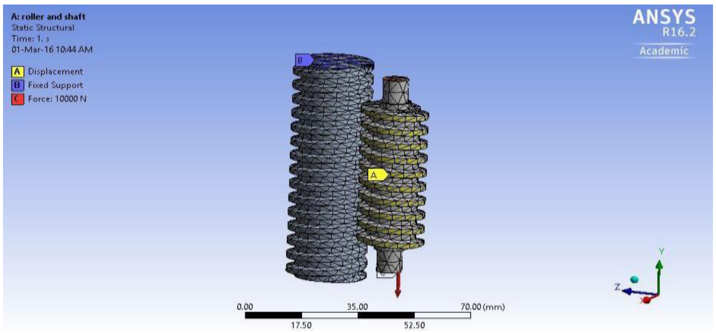

Fig. Force Constrain on mechanism

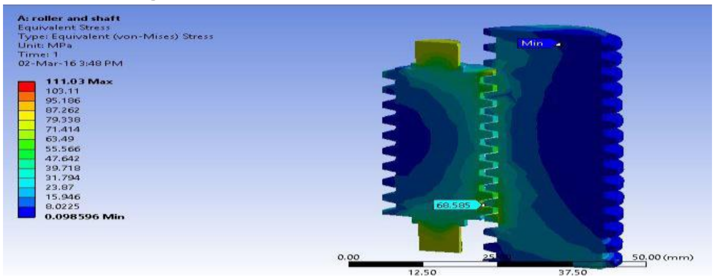

Fig. Maximum stress developed at meshing

Comparison of theoretical and analytical method.

Sr. No.	Component name	Shear Stress (by analytical) (MPa)	Shear Stress (by theoretical) (MPa)
1	Roller screw	68.585	71.59

CONCLUSION:

From the study the roller screw is a critical part of roller screw mechanism. So we designed and did the analysis for shear stress using SOLID WORKS and ANSYS 16.2. The shear stress at roller screw root is 68.58 MPa by analysis and 71.59MPa by theoretically. The values by analysis and theoretical have no much difference and also they are within permissible limit. Hence, design of main roller and sub-roller is safe.

MAIN ROLLER:

SUB-ROLLER:

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