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Analysis of equivalent torsional shear stress and bending stress on shaft of three bearings and shaft mechanism in winding machine application

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Abstract

Three bearings and shaft mechanism converts the constant rotary motion of a plain shaft into a traversing action that moves an attached carriage used in positioning and reciprocating linear-motion applications. It is a mechanical alternative of electronically controlled linear-motion drive systems. It runs on a smooth, unthreaded shaft. The rotary input of the motor-driven shaft is converted into linear output by the action of specially machined bearings. The mechanism generating the linear output is friction between the bearings and the shaft.
This mechanism is totally backlash-free and automatically reciprocating in bi-directional linear travel. It works on the principle of friction and linear thrust which generates the imaginary screw profile. It consists of an assembly of a shaft and bearings. The bearings are mounted in such a way that it generates the imaginary screw profile on the shaft.
In this research paper the researchers designed and analyzed the suitable shaft for the working application.

Keywords: *Shaft, lead screw mechanism, three bearings and shaft mechanism, linear drive, winding machine.*

1. Introduction

This linear drive works on the principle of friction and linear thrust which generates the imaginary screw profile. The mechanism of frictional linear drive consists of an assembly of a shaft and three bearings. The bearings are mounted in such a way that it generates the imaginary screw profile on the shaft.
There is clearance between the shaft and bearing on either side of the ridge. This clearance permits the bearing to be pivoted, angled left or right on the shaft and still maintain point contact with the shaft.
A three bearing assembly is fixed within the housing. Each bearing is held at a specific angle relative to the shaft. When the shaft rotates, the bearings generate axial force on the central ridge. This causes the bearing assembly to roll along the length of the shaft. The rotary input provided by the motor-driven shaft is thereby converted to linear output. As the bearing assembly moves carries the tool mounting head with it.
The angle at which the bearing assembly contacts the shaft is adjustable. The travel direction of the tool mounting head is determined by this angle. Changing the angle of the bearing assembly is done mechanically making the reversal process totally independent of the drive motor or other controls.
Reversal occurs when contacting a hardware fixture called an "end stop" triggers the spring-actuated reversal mechanism. When the reversal mechanism is triggered, the entire bearing assembly is flipped on the shaft to it's opposite to mirror position and reversal is instantaneous. The end stops are -positioned adjustable to determine the system's stroke length.
At no time does the bearing lose contact with the drive shaft. This is how three bearings and shaft mechanism prevent backlash, because there is no play between shaft and bearing. Furthermore, the shaft on which a three bearings and shaft mechanism operates is not threaded, which means dirt and debris cannot be trapped and cause clogging or jamming. Three bearings and shaft mechanism drives move loads with a rotating, smooth, unthreaded driveshaft. Replacing the threaded nut is a housing containing three r shaft-mounted, metal bearings. The bearings mount in a pivoting ring carrier enclosed in housing. Each bearing contains a specially machined inner race that maintains contact with the shaft and is free to rotate with it. The outer race is fixed to the pivoting ring carrier. The rings themselves mount at an oblique angle to the driveshaft.
Rotating the driveshaft applies an axial thrust from friction and compression to the rings and housing. Adding one extra ring i.e. Changing a three-ring into a four ring design for example doubles axial thrust. Power-transmission efficiency for the devices is greater than 90%. Bearing-to-shaft angle determines pitch or linear distance travelled per shaft rotation. Pitch adjustment can be made as the shaft

rotates, allowing a fixed-speed driveshaft to generate a wide range of linear travel rates.
Direction of travel and thrust can be reversed with a simple mechanical switch. The switch flips rings to their mirror image angle at the desired reversal points. This action is triggered automatically by the motion of the feeder itself through the application of friction and compression and requires no external devices. And direction reversal is backlash-free and far simpler mechanically than other linear drives.
In this research paper the forces which acts on the shaft are calculated tested and analyzed. The two measure forces which acts on the shaft are bending force and torsional shear force.

2. Torsional shear stress and bending stress

A shaft transmitting torque or power is not only subjected to shear stresses but also to bending moment due to self-weight of the shaft, pulleys and due to the pulls exerted by belts.
Thus, at any point in the shaft, the component of stresses are:

- The shear stress due to torsion,
- The bending stresses (tensile or compressive) and
- Shear stress due to other forces causing bending.

3. Design

3.1 Design of shaft

The shaft is designed by the consideration of combined forces of torsional force and bending force.
Material selection: Stainless steel 304 grade.
Properties of material: Yield Strength: 215 N/mm²
Bending stress (σb) = 215/3 = 71.67 N/ mm²
Shear stress (τ) = 215/4 = 53.75

$$P = \frac{2\pi NT}{60}$$

$$186.43 = \frac{2*\pi*360*T}{60}$$

$$T = \frac{186.43*60}{2*\pi*360}$$

T = 4.94520 N.m
T = 4945.20 N.mm
Maximum bending moment**,**
M = 29.83* 350
M = 10300.5 N.mm

Equivalent Torque

$$Te = \sqrt{T^2 + M^2}$$

$$= \sqrt{(4945.20)^2 + (10300.5)^2}$$

$$= \sqrt{(24455095) + (106100300.25)}$$

$$= \sqrt{130555395.3}$$

= 11426.08 N. mm

$$Te = \frac{\pi}{16} * \tau * d^3$$

$$d^3 = \frac{Te*16}{\pi*\tau}$$

$$= \frac{11426.08*16}{\pi*53.75}$$

= 1082.65
d = 10.27 mm

Equivalent Bending Moment

$$Me = \frac{1}{2}\left(M + \sqrt{T^2 + M^2}\right)$$

$$= \frac{1}{2}\left(10300.5 + \sqrt{(4945.20)^2 + (10300.5)^2}\right)$$

$$= \frac{1}{2}\left(10300.5 + \sqrt{13055303.3}\right)$$

$$= \frac{1}{2}(10300.5 + 11426.08)$$

Me = 10863.29 N.mm

$$Me = \frac{\pi}{32} * \sigma b * d^3$$

$$d^3 = \frac{Me*32}{\pi*\sigma b}$$

$$= \frac{10863.29*32}{\pi*71.67}$$

= 1543.91
d = 11.56 mm

Considering diameter of the shaft 15 mm.

3.2 Analysis of shaft

The shaft is been analyzed for the equivalent bending stress and torsional shear stress and then total deformation is been found out.

3.2.1 Analysis of equivalent stress on shaft

After designing the shaft on the basis of equivalent torsion and bending criteria, the shaft has been tested and analyzed

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on ‘Ansys workbench software’ and the results are as follows.

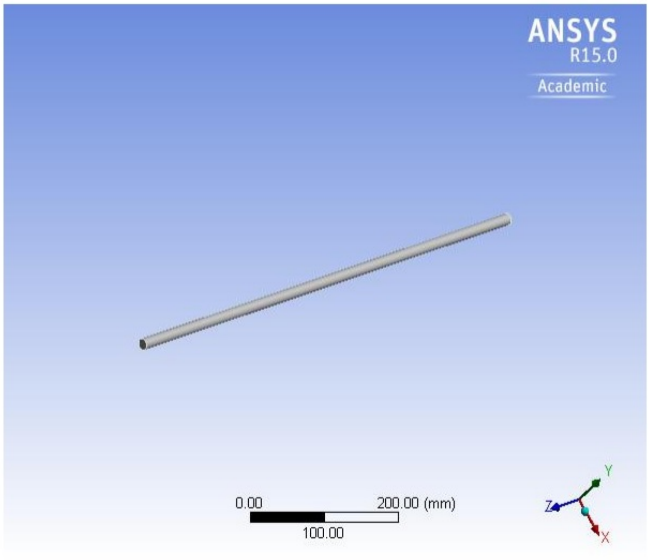

Fig 3.1: Shaft

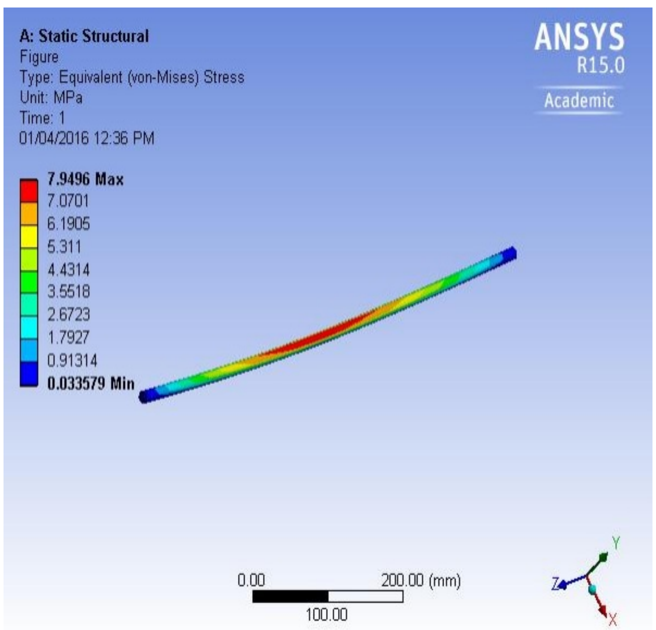

Fig 3.2 Equivalent stress on shaft

3.2.2 Analysis of total deformation on shaft

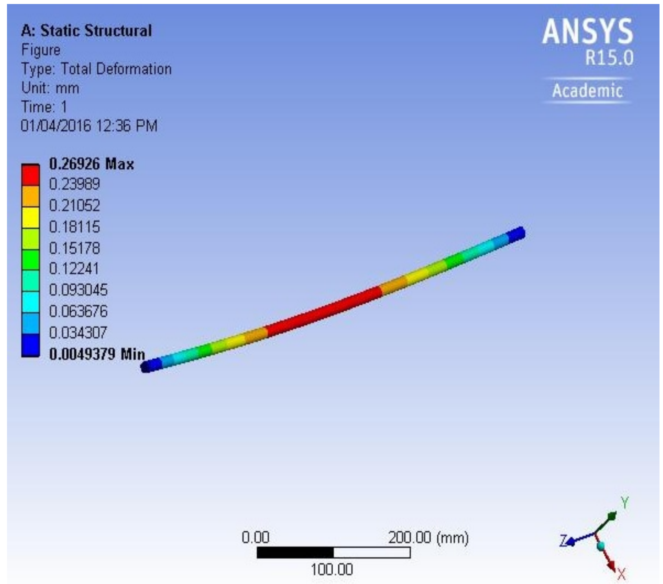

Fig 3.3: total deformation of shaft

4. Conclusions

As the maximum equivalent induced stress is 7.949 MPa which is permissible hence the design is safe.
As the total maximum total deformation is 0.269 mm which is permissible. Hence the design is safe.
Hence the material stainless steel 304 with diameter 15 mm is safer as shaft material in three bearings and shaft mechanism application.

References

[1] Florian Thaden, Paul Beutin, Hauke Reese, Reversal mechanism for a rolling ring drive, WIPO, 2015.
[2] George Wardley, A traversing unit, Espacenet, 1981.
[3] Bhandari, V B, Design of Machine Elements, Tata McGraw-Hill, ISBN 978-0-07-061141-2, 2007.