

INVESTIGATIONS ON THERMAL BEHAVIOR FOR DIFFERENT COOLING MEDIA IN A THROUGH HOLE BALL SCREW SHAFT USING COMPUTATIONAL FLUID DYNAMICS TOOL

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Abstract— The interest for higher efficiency and tight part resistances obliges machine instruments to have quicker and more exact feed drive frameworks. As attempted and tried innovation, ball screw drive frameworks are utilized a dominant part of machine apparatuses because of their minimal effort and high level of solidness. A fast ball screw drive framework creates more heat and results in more prominent thermal error. This thermal error leads to dimensional error of machined work-piece. The thermal error in system influences the positioning error of ball screw drive system. In this study, we examine the situation of a fluid cooling framework utilizing air and Ideal CO₂ gas, as coolants in a Ball screw shaft to minimize the positioning error and warm dispersion of the ball frame work here we are varying inlet speed of the coolant. And the variation of temperature across nut and bearing were analyzed by varying inlet velocity of coolants. The accompanying study likewise shows level of situating positioning error improvement when a dissemination of different coolants passed, and by changing the speed of coolant.

Index Terms— BSA, Positioning accuracy, CFD,

1. INTRODUCTION

The Ball screw drive frameworks are broadly utilized as a part of a few machine devices because of their less cost and high level of firmness. In the 1900s specialists found that around 40-70% of blunder was perceived in accuracy parts emerged due to heat generation [6]. In a machine device there are numerous heat sources, for example, pressure driven oil, drives, pumps, engine, guide ways, cutting activity and in orientation. A large portion of the exploration was done machine instrument warm conduct and warm slip pay on axles, orientation, machining process, and ball screw blunder remuneration. However couple of research has been focused on control of heat generation on ball screw system. Which unfavorably influence situating precision of machine instruments In past writing Xu et al. completed a novel heat

source control system called as "focus gap air cooling" on the Ball screw frameworks.

In this study coolants like air, Ideal CO₂ gas, are passed into centre-hole Ball screw system to achieve a cooling effect. To decrease the thermal poisoning error the coolants passed at the Inlet with increasing velocity in order to predict the thermal behavior screw shaft screw system

Ball Screw Systems (BSA's) are essential parts in present day CNC machine devices that change over rotary movement into direct movement. They include a Ball Screw, with an outside helical furrow or raceway, a Ball Nut, with an inner helical depression or raceway, and a framework for re-coursing balls, which are moving components fitted between the Ball Screw and the Ball Nut. Below figure shows the vertical machining center.

1.1 Literature Review

Z.Z Xu, X.J.Liu: In ball screw warm bearing heat impact will results position slip; a rapid ball screw framework at high velocity for the most part makes more heat and results in more prominent heat development..It will come about the exactness of situating error. Here he used air as cooling media in a ball screw shaft to overcome thermal blunder of the ball screw framework and viability of air cooling framework, heat conduct models utilizing FEM and changed lumped capacitance strategy, were produced independently. Here they were recreated the temperature dispersion, and heat conduction of ball screw framework & air cooling execution were examined additionally to predict temperature appropriation with time.

Zhe-Zhu Xu, Xiao-Jing Liu and Sun-Ki Lyu: Here thermal error controls instead of thermal error minimization was studied Also screw and nut model was used for the study The screw was provided with central hole for passing air and axial thermal deformation was studied with no cooling, nut cooling, screw cooling, screw& nut cooling. Positioning error

was estimated with different condition of cooling i.e. nut cooling, screw cooling, screw& nut cooling. Analysis of positioning error was estimated at small stroke and big stroke condition from the study It is found that the thermal positioning error was maximum at no cooling condition Thermal images in no cooling, nut cooling, screw cooling, screw& nut cooling was shown. Also Noise was studied at different cooling conditions.

Arun k sukumarn,Raji R.V: The effect of variation of rotating Reynolds no and axial Reynolds number on heat transfer & fluid flow in rotating annulus for a radius ratio, He has validated experimental work with the fluent results. He given Boundary condition as the wall of the inner rotating cylinder is kept at operating temperature. Results for various axial Reynolds number and radial Reynolds number were studied. Here he was presented how the axial Reynolds number and radial Reynolds number will change with respect to the change in heat transfer. From the analysis it was concluded that when rotational Reynolds number increases the magnitude of axial velocity decreases, rotation has significant only at low axial Reynolds number at high axial Reynolds the effect of rotation will very small.

C.H. Chien and J.Y. Jang : They have numerically analyzed the 3D fluid motion & temperature distribution in a motorized high speed spindle with a helical water cooling channel. They used the k-epsilon turbulence model to develop the fluid model. The effect of different heat sources and cooling water flow rate were examined in detail. It was shown that the average maximum temperature along the spindle axis is decreased from 24.5°C to 22.2°C when the water flow rate was increased from 0.4 to 1.2L/min

1.2 Problem Description

If the temperature of screw shaft increases during operation, the screw shaft deforms due to heat thereby to lower the poisoning accuracy. If the temperature of screw shaft increases by 1°C, the screw shaft is elongated by 12µm/m.[7] so faster the speed of ball screw travel, more will be the heat generation and higher the temperature. And which will lowers the positioning accuracy of ball screw system. So if high accuracy is required it is necessary to take a temperature increase in screw shaft. So main objective of our study is to

- 1) To decrease the thermal deformation of screw shaft which will lowers the positioning error
- 2) Instead of conducting the experiment on real time basis it was opted to do simulation on the basis of experimental results available in literature. Further the possibilities of temperature and hence thermal error minimization were worked through the simulation software.
- 3) To decrease the temperature of screw shaft.
- 4) Modeling the hallow screw shaft and analyzing the temperature and thermal deformation by passing

the different fluids like Air, Ideal CO₂ gas by varying inlet velocity

2. Numerical analysis

In the present work, numerical analysis of lead screw shaft is done by passing different fluids like air and ideal CO₂ gas with increasing inlet velocity. The variation of temperature and thermal deformation is analyzed across nut area and Bearing area. The simulation is done in ANSYS CFX and the results are validated using Experimental study mentioned in Zhe-Zhu Xu,Xiao-Jing Liu,Chong-Hun Chol [2,3] was taken and the dimensions and boundary conditions are same as that in experimental setup.

2.1 Modeling

First step in CFD analysis is creation of geometry of flow region for calculations. For our study we are modeling the lead screw shaft with exact dimensions as shown below. For exact representation of fluid flow the naming is done in modeling itself .To represent the flow direction and flow path inlet and outlet regions are named specifically

One important thing here is to creation of geometry for CFD calculations is to allow flow sufficiently developed across the entire length of domain. We need to encapsulate the development of complex wake-making .In this study diameter of flow of fluid is clearly defined and the type of fluid also defined

2.2 Meshing

One of the most important step in analysis is to creation of mesh, CFD requires the subdivision of domain in to a number of domain geometry that is been created. for this particular study, hexahedron or Brick element with structural mesh is taken. The required fluid flows that are described in each of these cells are usually solved numerically so that the discrete values of parameter such as velocity, pressure and temperature are determined. This gives the CFD solution which is governed by number of cells within the domain. Generally the large numbers of cells are preferred to get exact results table.1 shows the mesh report.

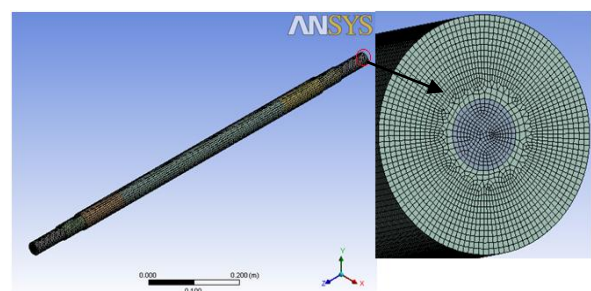


Fig.1 Mesh model of screw shaft with Brick element.

2.3 Boundary conditions

The assumptions made for analysis is incompressible, two dimensional axi-symmetric steady state flows.

Main heat generating units in this study is Ball screw shaft and Bearings. The heat generation for 500rpm of screw shaft is calculated for both nut area and Bearing area. The major heat generation is friction between balls of the nut and surface of screw shaft. The calculated heat flux on the surface of nut area and Bearing area is directly applied in order to predict the thermal error.

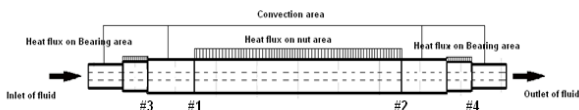


Fig.2 Screw shaft with boundary conditions

Table.2 Screw shaft with boundary conditions

Domain	Zone	Property	Boundary condition
Fluid	Inlet	Flow regime	Subsonic
		Heat transfer	Static temperature
		Turbulence	Medium& intensity and eddy viscosity
		Mass& momentum	Normal speed
Fluid	Outlet	Flow regime	Subsonic
		Mass and momentum	Average static pressure
		Blend in Pressure profile	0.005
		Average pressure	Avg over whole outlet
		Relative pressure	1.00 atm
Solid	Nut area	Heat flux	400w/m ²
	Bearing area	Heat flux	350w/m ²
	Convection area	Convection	15.37w/m ² C

3.0 Thermal analysis on screw shaft

3.1 For no cooling condition

In no cooling condition under the atmospheric temperature of 20°C there is a maximum of 48.37 °C is observed at mid section of the screw shaft. This temperature is analyzed at 500 stroke length of screw shaft at 500rpm of screw shaft. Under no cooling there is more positioning error causes on screw shaft due to the thermal deformation. The variation of temperature and corresponding deformation is shown in below

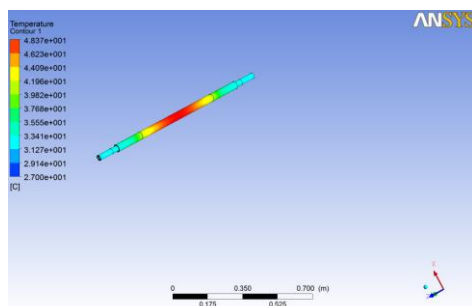


Fig.3 Temperature variation in screw shaft in no cooling

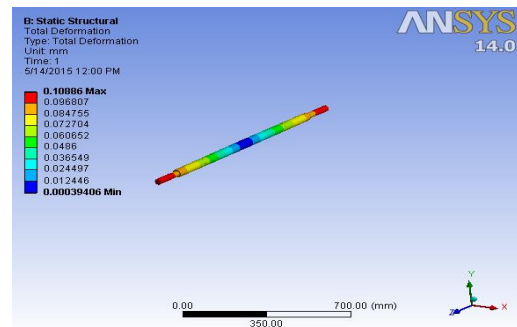


Fig.4 deformation of screw shaft for no cooling

At 500rpm the variation of temperature along the axis of Screw shaft is found that it is a bell shape because from the origin the temperature varies in equal amount along both directions. However the maximum temperature is observed at mid section only because of heat generated in screw shaft.

3.2 For air cooling

By increasing the velocity of the inlet air starting from 10m/s it is observed that temperature at mid section is decrease by 2% when compared with no cooling condition. Further increasing inlet velocity of air to 20m/s there is 27% of sudden decrement in the maximum temperature at mid section of screw shaft. Like that if we increase the inlet velocity we will reach maximum of 27°C for 60m/s inlet velocity for which the deformation was expected to be 20µm which will not harm to positioning error.

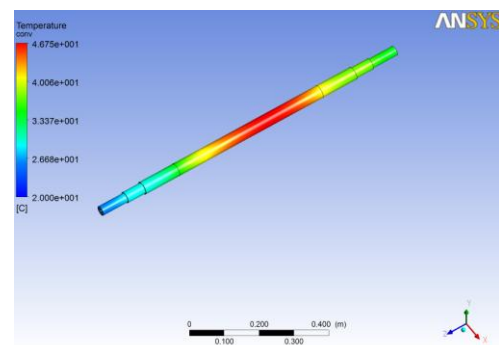


Fig.5 Temperature on screw shaft for 10m/s inlet velocity of air

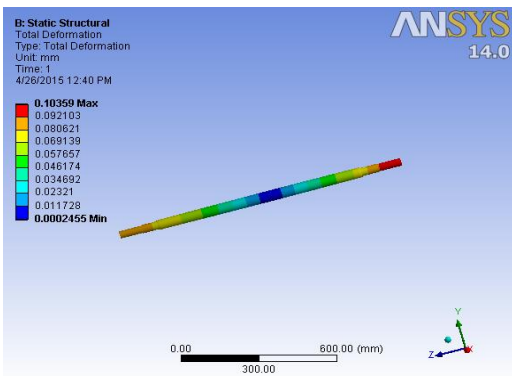


Fig.6 Deformation of screw shaft for 20m/s inlet velocity of air

3.3 Ideal CO₂ gas as a coolant

Under special conditions its cooling capacity lies between air and water. So nearly 75% of less velocity is required as compared to air to overcome from positioning error. Also it has good corrosive resistance. Fig 18 shows the temperature variation for Ideal CO₂ gas cooling.

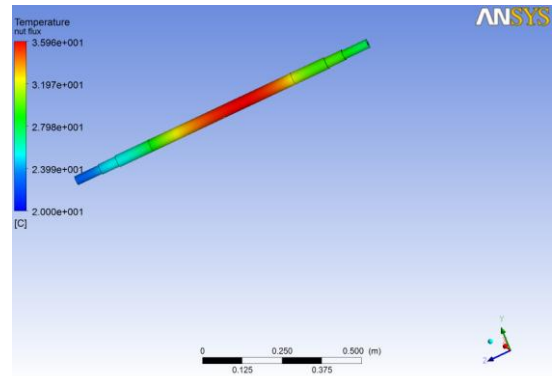


Fig.10 Temperature on screw shaft for 10m/s inlet velocity of Ideal CO₂ gas

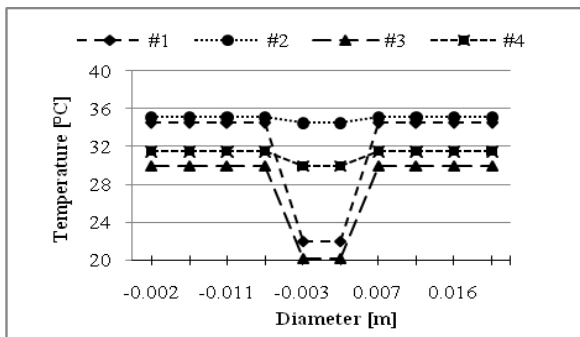


Fig.7 Variation of Temperature across the diameter of screw shaft at different sections for 10m/s inlet velocity of air

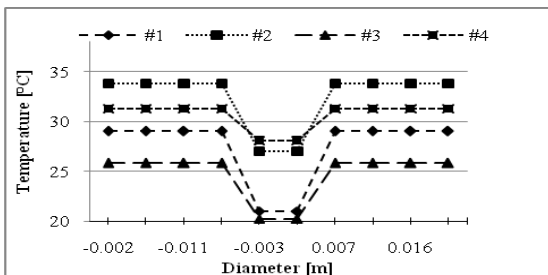


Fig.8 Variation of Temperature across the diameter of screw shaft at different sections for 20m/s inlet velocity of air

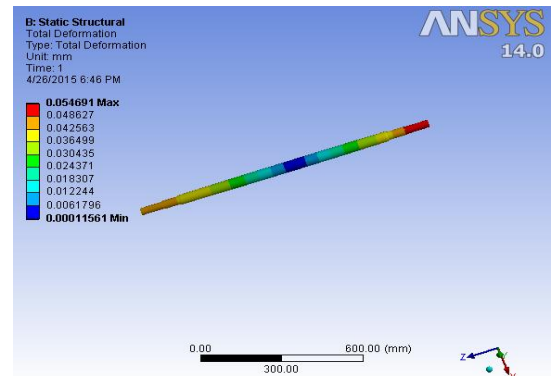


Fig.11 Deformation on screw shaft for 10m/s inlet velocity of Ideal CO₂

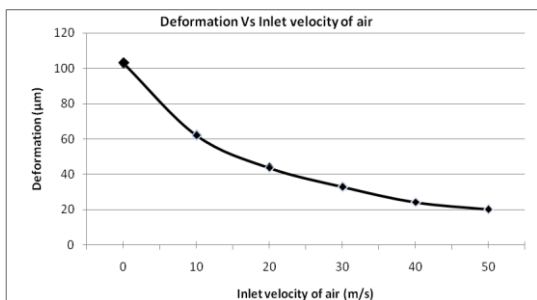


Fig.9 Variation of deformation of screw shaft Vs inlet velocity of air

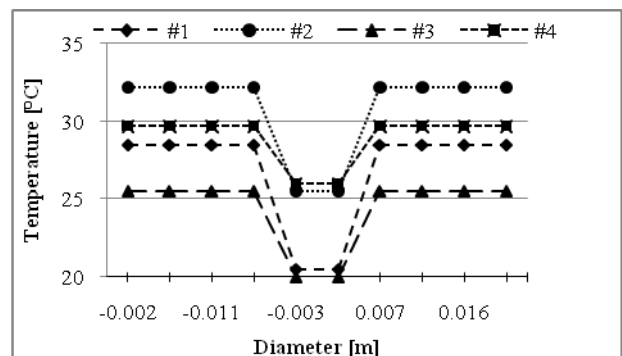


Fig.12 Variation of Temperature across the diameter of screw shaft at different sections for 10m/s Ideal CO₂ gas cooling

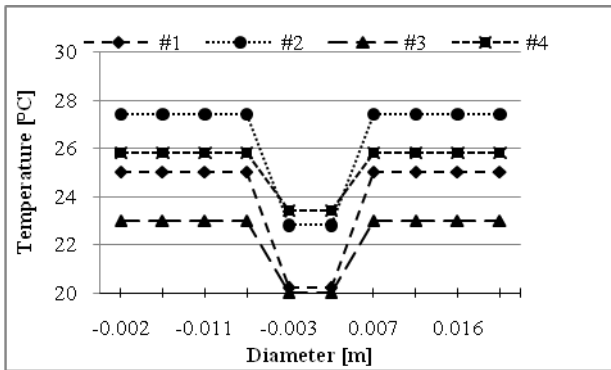


Fig.13 Variation of Temperature across the diameter of screw shaft at different sections for 20m/s Ideal CO₂ gas cooling

The decrease in deformation on screw shaft increase in velocity of inlet Ideal CO₂ gas is shown below

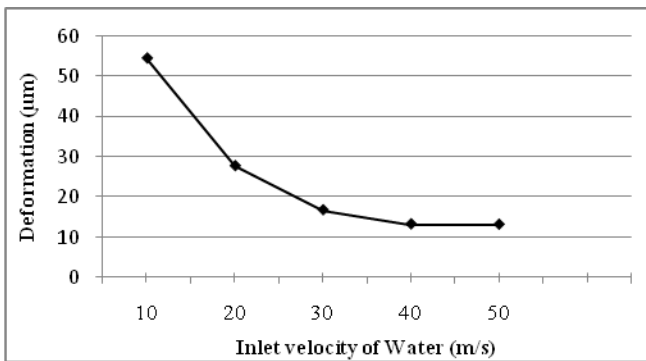


Fig.14 Variation of deformation of screw shaft Vs inlet velocity of Ideal CO₂ gas

4.0 CONCLUSIONS

In this study simulation of screw shaft is carried to predict the thermal deformation, air, and Ideal CO₂ gas are used to reduce the deformation. For air, thermal deformation is reduced up to 20µm for 60m/s inlet velocity. So to overcome this we have used Ideal CO₂ gas which will act as coolant and also it is non corrosive. Almost 40% less velocity is required to achieve the thermal deformation within 20 µm. Deformation decreases 80% when Inlet velocity of air is increased from 0m/s to 60m/s. Deformation decreases 87% when Inlet velocity of Ideal CO₂ gas is increased from 0m/s to 40m/s.

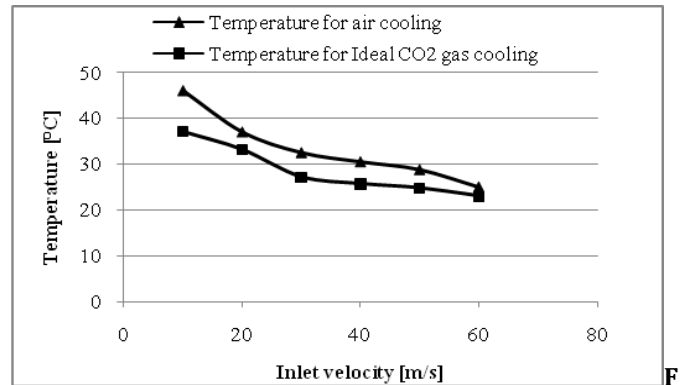


Fig.15 comparison of temperature for air and Ideal CO₂ gas cooling

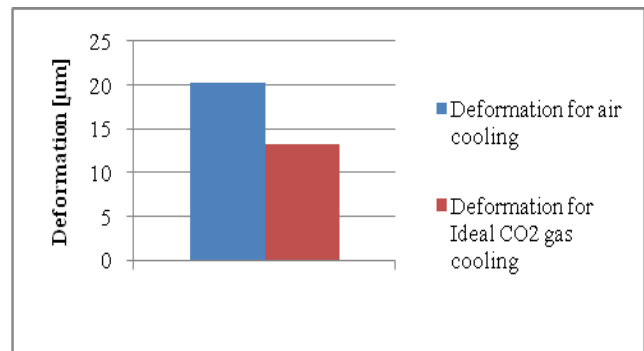


Fig. 16 Comparison of deformation air and Ideal CO₂ gas cooling

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