Closed Loop Lubrication System with Thermal and Flow Feedback in CNC Turning Machines

Basavachetan S Hipparagi[1] R. J. Naik[2]
[1,2]Department of Mechanical Engineering
[1,2]Gogte Institute of Technology, Belagavi, Karnataka, India

Abstract— This project presents study of closed loop lubrication system for thermal and flow feedback in CNC turning centers and it is important to switch from usual time domain basis to temperature domain basis in order to have higher machining precision, greater reduction in the oil consumption, flexible performance and also cost effectiveness. Lubrication system works by sensing temperature using thermocouples which are embedded in the LM guideways. Lubrication system triggers the oil only if it is more that critical temperature. The program is controlled by NI LabVIEW 2013 and display unit shows us real time temperature Vs Time. Results are obtained by using different MRI time and analyzing.

Key words: Friction, Critical Temperature, LabVIEW, Lubrication, Oil Consumption, Efficiency

I. Introduction

Rubbing so called Friction occurs in every mechanical configuration for example, transmissions, piston rings, valves, machines, and so forth. Shaft misalignment in turning framework is a standout amongst the most familiar reasons for wear and tear. In many engineering framework, when two planes slide against each other, contact is an aggravation. Contact in engineering framework has two undesirable impacts, i.e. it increases wear and tear, includes work which is not valuable (energy loss).Therefore, wear is the dynamically harm including material loss, which happens on the surface of a segment as an outcome of its movement (erosion) in respect to the nearby working parts; and contact between two surfaces changes over kinetic energy into thermal energy, or heat.

As of late there have been quick changes in the method for machine to see lubrication as new innovations have turned out to be open to skills of the human experience who think about the utilization of oil. Carriage motion which permits motion of filing tools for vector machining operations is of incredible significance on the table of CNC machines. It is to be noticed that there will dependably be wear and erosion of parts between two bits of frictions and temperature boost, in this manner manufactures are more influenced by lubrication system, especially to encourage the lubrication system for more exact machining and a lesser amount of oil utilization which takes better approaches to advance.

Much of the time, exactness and accuracy of CNC turning machines are influenced by variety of mistakes. The errors are joined (superposed) bringing about conclusive inconsistencies on surface of work piece. A few errors happen through cutting operation or created by process operation, and some different errors may as of now exist before cutting. The increase in necessities for accuracy of spindle rotation on metal-cutting machine tools, involving the record for thermal distributions, require arrangement of little heat discharge in the bearing when working at very high speeds. In this way, issue of rolling component bearing lubrication on machine device spindle appears and actuality a critical assignment. As indicated by the information of FAG (Germany), with the setting up of high-accuracy bearing in the spindle assembly of machine apparatuses, the high temperature of the spindle bearing must not surpass 50°C - 60°C (temperature rise of 30°C - 40°C), while for the high-accurate machines the temperature must not surpass 30°C - 40°C (temperature rise of 10°C - 20°C).

Many Researches were carried out in the field of CNC machines. M. Sparaham et.al. [1] Investigated the problems with increase in the efficiency of turning centers. Machine lubrication configuration is works wipe out the requirement for regularly imprudent manual oil, giving a more secure, more an imperative part of assembling and generation monitoring support.Programmed lubrication frame incessant, and ideal observed way to deal with machine oil. Nonetheless, conventional mechanized lubrication systems have innate natural and technical–economic issues. With the objective of higher machining accuracy, cost effectiveness, more prominent lessening in oil utilization, and more flexible performance, an automated lubrication control system is presented in this examination work. The new computerized grease control framework in PC numerical control machine device guideways is a novel approach in machining innovation; disappointment identification/remedy in the oil framework might be distinguished by temperature signals from touchy temperature sensors introduced in the machine device guideways, with the signs mirroring the grating, wear, and stacking conditions. Information gathered by means of temperature sensors, information examination, and arrangement of charging signs are investigated by a grease control unit (LCU). The LCU transmits signs to actuators to trigger oil infusion by the oil pump. The show unit shows ongoing measured temperature varieties alongside the pump's operation state

N. J Georgea, et.al [2] has worked on Lubricating and cooling capacities of different engine oils. The greasing up and cooling limits of various SAE 20W-50 multigrade motor oil tests were inspected as far as particular temperature limits and cooling rates. Out of the five specimens of oil coded as A, B, C, D and E, four of them have close related benefits of cooling rates while just B, has a brilliant line qualification with a naturally high cooling rate. Test E of the multigrade oil tests analyzed additionally has the most elevated particular temperature limit which is suggestive of the high inward vitality put away in the greasing up framework. The multigrade oil with higher cooling rate is the best coolant and lubricator and the oil test with most noteworthy particular warmth limit has high inward vitality that is contrarily corresponding to thickness. High vitality and less thick example (E) greases up preferable and begins motors speedier once again different specimens which may have low inward energies and high viscosities when contrasted and test.

Hu Shi et.al [3] Keeping in mind the end goal to research the impact of thermal deformation on the ball screw sustain drive arrangement of an accuracy exhausting machine device, hypothetical displaying of and trial experiments on thermally incited error along with thermal attributes are discussed in this paper. A progression of heat examinations are led on the machine instrument to quantify and gather the thermodynamic information with the feed drive framework working at various velocities.

Kuniaki Dohdal et.al [4] the tribo-attributes of metal shaping at high temperatures have not yet been surely knew because of the complex way of thermal, microstructural, connection, and process parameters. This is an audit paper on the impacts of temperature, covering, and oil to the tribological attributes in hot framing as well as the tribometers for various metal shaping procedures at hoisted temperatures principally in light of the exploratory work.

Chao Jina et.al [5] in high-speed and precision feed systems, thermal locating errors are mainly caused by the non-uniform temperature variations and resulting time-varying thermal deformations under different operating conditions. The research presented here ultimately aims to develop a generic method capable of estimating the thermal characteristics (such as temperature rise of heat sources, thermal positioning error) of the feed system induced by varying functional conditions (feed speed, cutting load and preload of ball screw).

II. DESIGN METHODOLOGY

In the favored exemplification, two thermocouples are arranged at every axis, i.e. the X-axis and Z-axis, for temperature measure of linear guides. In like manner, the thermocouples are implanted inside two parallel linear guideways of every axis. Ideally, the thermocouples TcpA , TcplB, Tcplc and TcplD are symmetrically installed inside the linear guide of the X-axis and Z-axis. In like manner, the thermocouple is introduced on rail guideways for the Z-axis with predefined separate from edge of chuck. In like manner, the thermocouples are introduced on center of rail guideways for the X-axis with predefined distance from spindle axis. It will be valued that sensors are ideally set between two guides adjacent to chuck; every sensor is at predefined length from the thermocouple so that maximum of temperature can be detected. In like manner, sit place of the sensors at predefined length are utilized for recognizing the most of temperature range of the X-axis. Among above thermocouples, the thermocouples TcplA and TcplB measure the temperature of Z-axis linear guideways, while the thermocouple Tcplc and TcplD measure the temperature of X- axis linear guideways.

It is to be noticed that the thermocouples TcplA, TcplB, Tcplc, Tcpld recognize real time continuous temperature in contact interface amongst carriage and rail guides and wherein temperature readings are sent to Lubrication Control Unit (LCU) for handling. As per favored encapsulation of present development, the predetermined interval of the lubrication unit for pumping exact amount of oil or lube oil can be from a few minutes to a few hours. In the favored encapsulation, the lubrication unit is a sort of Versamatic, an independent mechanized apparatus pump which is smaller and proficient. In like manner, the lubrication unit is finished with a built in level switch, pressure switch, built in controller. The lubrication unit additionally incorporates motor driven gear pump with a built in flow control valve. It will be valued that the lubrication unit additionally incorporates a pressure switch and low-level option to monitor events of pump cycle and low oil levels in reservoir. The lubricator unit may additionally incorporate an inherent clock to control the working cycles of the lubricator.In the favored exemplification, the reservoir incorporates three distinct limits i.e. 2 liters, 3 liters or 4 liters and the reservoir is made of materials, for example, ABS or metal.

In the favored configuration, the electrical circuit framework interfaces four important parts, i.e. sensors, measuring modules, test controller and actuators. As needs be, the electrical circuit framework gives signals which are sent from thermocouples fix to universal unit; and this module forms temperature errors from servo motors that touch in the test controller. It will be valued that the segment of the favored exemplification is a programmed for controlling data input from the sensors and to send yield to the actuators. As per favored encapsulation of the present innovation, the lubrication control unit (LCU) is outfitted with modules and test controller to obtain and break down information with a default provider testing program. Appropriately, the LCU sends required signs to the actuators and monitoring unit, wherein the LCU can be changed in accordance with some default setup. Ideally, the default setup incorporates operation sensors limits, type of sensors to be utilized, color and kind of curve to be shown in observing or monitoring unit. In the favored framework, the modules incorporate universal measurement unit and temperature measurement unit.

This temperature measurement unit has eight isolated analog inputs for thermocouple. A program has been developed using NI LabVIEW V.13. This program can be detected real time temperature and then it compares with reference or critical temperature as indicated by researcher based on atmospherically condition. This present configuration is suitable for manual and automatic mode. This invention includes some assumptions and change in the original drawings of the parts. It is understood that changes are made without moving out from the scope of project.

III. EXPERIMENTAL DETAILS

The experiment is conducted on MIDAS 4i turning machine for MRI value 15seconds. Specification of LM guides is kept confidential. The slots on LM guides are done using EDM as shown in the figure 1.1.

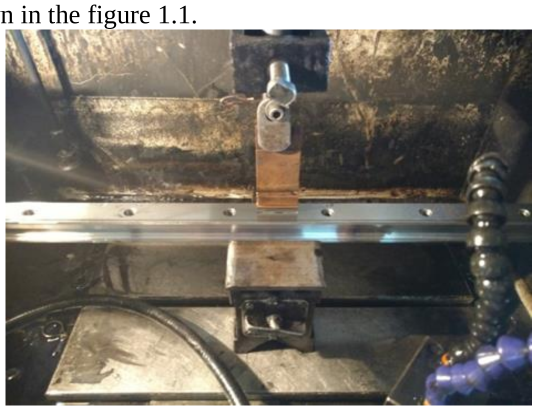

Fig. 1.1: Slot on X axis using EDM machine

A. Specification of K Type Thermocouple:

Power Supply	10 up to 30V DC
Power Consumption	Approx... 2W
Accuracy	±0.1%, typical
Linear deviation	0.1% full scale
Repeatability	0.003% typical
Isolation Voltage	100V DC
Effect of temperature on sensitivity	<0.01%/ 10k

Table 1.1: Specification of Thermocouple

B. Servo 68 Grade Oil / Sae Grade 20w:

In this project, servo 68 grade oil is used; it can also be called as SAE grade 20W and ISO grade 68. The detailed specification of the oil is shown in below table1.2.

	SAE 20W / ISO grade 68 oil @ 40°C	SAE 20W / ISO grade 68 oil @ 100°C
Kinematic Viscosity	68centistrokes	8.7centistrokes
Flashpoint	210 °C	210 °C
Viscosity Index	95	95
Density	865kg/m^3 or 0.0313lb/ m^3	865kg/m^3 or 0.0313lb/ m^3

Table 1.2: Specifications of Servo oil

Specific heat @100°C (cp) = 1950 J/kg °K. Thermal conductivity @100°C (k) = 0.134 W/mK

C. Calculation for Cooling Rate:

Let us assume that atmospheric temperature is at time t=0 is Ta = 30°C

Lube oil temperature at time t=0 is T0 = 26°C

To find the time required to cool down by 1 degree of LM guides. This is found out using Newton's Law of Cooling and making some assumptions.

T (t) = Ta + (T0 – Ta) * e (k*t) (1)

28 = 30 + (26 - 30)* e (-k*15)

15k = ln (0.5)

k= -0.0462, where K is constant (2)

Now, using (2) and substituting in (1), we get required time to cooldown by one degree -

29= 30+ (26-30) e-0.0462*t

ln (0.25) = -0.0462 * t

t = 30.0063 minutes

Therefore time required for ambient temperature to cool down by 1°C i.e. from 30°C to 29°C is around 30 minutes.

IV. ANALYSIS OF RESULTS

A. Fully Manual Mode:

It is the condition where automatic lubrication system is not on. Experiments were performed to see condition. Here two initial conditions are considered that is related to initial temperature of the four thermocouples, are having different initial temperature. Second one is, two of the thermocouple is having same temperature that is Z axis A&B, X axis C&D.

In all the experimental readings were taken for every 30minutes.

Observing the graph one can see same behavior of temperature growth up to 210minutes. Generally heat is generated on X and Z axis mainly due to the weight acting on them. This creates friction between carriage and linear guides. Obviously any change in the top as observed.

The thermocouples after 210minutes reaches to 33degree at this time, initial temperature of all thermocouples were different. Gentle slope of thermocouple in the graph is observed.

When the machining is carried out for 8 hours and critical points are taken at every 30 minutes and the resulting graphs are shown in figure 1.2 and figure 1.3.

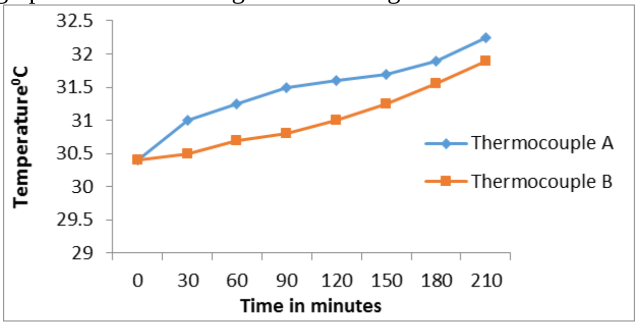

Fig. 1.2: Change of temperature in Z axis (Manual Mode)

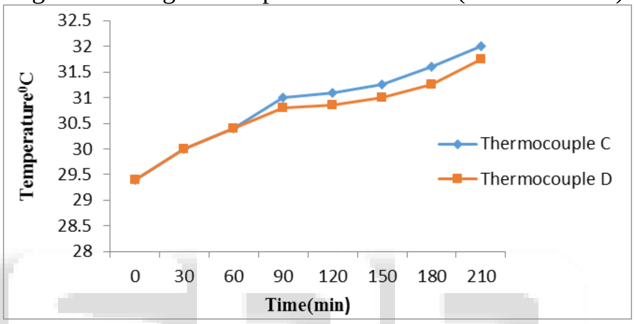

Fig. 1.3: Change of Temperature in X axis (Manual Mode)

B. Automatic Lubrication Mode:

In this mode critical temperature time and MRI are considered. The figures 1.4 and 1.5 show experimental data. The graph shows that temperature increase rates and declining slope after reaching critical temperature. From 90 minutes temperature increased linearly and thermocouple A reaches critical point lubrication system gets on. MRI=15seconds, oil will be injected at 150minutes. Temperature starts falling down at 180minutes that is it took around 30 minutes to cool down. Machining time was considered to be for 8 hours; in this duration lubrication system is triggered three times consuming just 81 ml of oil.

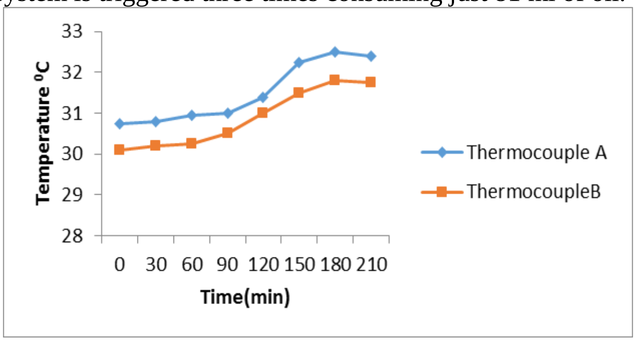

Fig. 1.4: Change of Temperature in Z axis (Automated Mode)

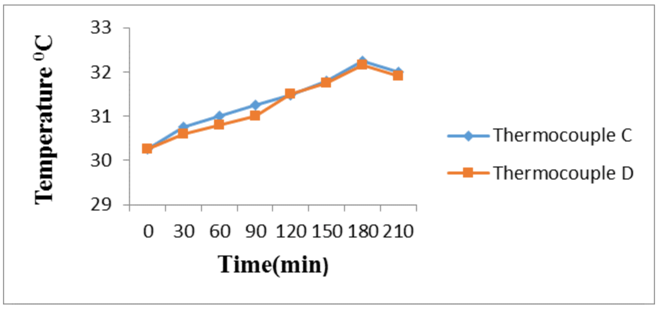

Fig. 1.5: Change of Temperature in X axis (Automated Mode)

Lubrication unit discharge volume = 108ml/min
Lubrication unit discharge volume per second = 1.8ml/sec
Motor Response Interval MRI=15seconds
Lubrication pipe discharge value-
Ball screw lubrication pipe 0.4ml*2 =0.8ml
LM guides lubrication pipe 0.1ml*8=0.8ml
Therefore total amount of oil injected in one cycle is 15*1.8=27ml

In this porotype approach, lubrication system is triggered 3 times per 8 hours i.e. 27*3= 81ml

In industrial practice, lubrication system gets on every 30minutes for 15 seconds consuming lubricant of 27ml. For 8hours oil consumed is 27*16= 432ml.

	Reservoir capacity	For 8 hours oil consumed	Reservoir empty after	For 46 hours oil consumed
Industry approach	2500ml	432	46 hours	2500
Prototype approach		81		486

Table 1.3: Result Table

The table shows that we can save large amount of oil in machining process.

V. Conclusions

In this project work, designed closed loop control system for thermal and flow feedback in CNC turning machines. In usual practice lubrication system is time domain basis. That is, lubrication system will be on for the particular interval of time at regular interval say every half an hour. But in this project, Lubrication system is temperature domain basis. That is lubrication system will be on only when measured temperature is more than set temperature or critical temperature. By practicing this approach we can save so much amount of lubrication oil and also in the long run efficiency of the LM guides will be increased and maintained constantly.

According to reports different Motor Response Interval (MRI) are considered for injecting suitable amount of oil to be injected into the guideways. Best one is considered based on number of times the temperature reaches critical temperature and also amount of oil required for injecting during machining time. Among all MRI =15seconds seems to be best choice for saving oil as it reaches critical temperature only 3 times and injects oil of 27ml*3=81ml.

It will be good if each thermocouple have independent critical value and alarm sensors. Lubrication system should be improved by injecting oil only at that particular LM guide which crosses critical temperature. Thermocouples can also be mounted on a ballscrew and monitored in the same way as done for LM guides which may improve the performance of machine.

References

[1] M. Sparaham et.al. "Designing and manufacturing an automated lubrication control system in CNC machine tool guideways for more precise machining and less oil consumption", University of Malaya, Faculty of Mechanical Engineering, Manuf Technol (2014) 70:1081–1090.
[2] N. J Georgea, et.al. "Lubricating and cooling capacities of different SAE 20W – 50 engine oil samples using specific heat capacity and cooling rate", University of Calabar, Nigeria Faculty of Physics, Archives of Physics Research, 2010, 1 (2):103-111, ISSN 0976-0970.
[3] Hu Shi et.al "Investigation into effect of thermal expansion on thermally induced error of ball screw feed drive system of precision machine tools", of University, Xi'an China, School of Mechanical Engineering, International journal of machine tool and manufacture 97 (2015) 60-71.
[4] Kuniaki DOHDA1 et.al. "Tribology in metal forming at elevated temperatures" of Northwestern University, Department of Mechanical Engineering, (2015) ISSN 2223-7690.
[5] Chao Jina et.al "Thermal characteristics of a CNC feed system under varying operating conditon"of University of Science and Technology, Wuhan 430074, Hubei, China. Precision Engineering 42 (2015) 151-164.