Int J Adv Manuf Technol (2014) 70:1081–1090
DOI 10.1007/s00170-013-5325-y

ORIGINAL ARTICLE

Designing and manufacturing an automated lubrication control system in CNC machine tool guideways for more precise machining and less oil consumption

Mahdi Sparham · Ahmed A. D. Sarhan · N. A. Mardi · M. Hamdi

Received: 15 April 2012 / Accepted: 23 September 2013 / Published online: 12 October 2013

Abstract Machine lubrication systems are a very important portion of manufacturing and production workshop maintenance. Automatic lubrication systems eliminate the need for often careless manual lubrication, providing a safer, more frequent, and opportune monitored approach to machine lubrication. However, traditional automated lubrication systems have inherent environmental and technical–economic problems. With the goal of higher machining precision, cost-effectiveness, greater reduction in oil consumption, and more flexible performance, an automated lubrication control system is introduced in this research work. The new automated lubrication control system in computer numerical control machine tool guideways is a novel approach in machining technology; failure detection/correction in the lubrication system may be identified by temperature signals from sensitive temperature sensors installed in the machine tool guideways, with the signals reflecting the friction, wear, and loading conditions. Data collected via temperature sensors, data analysis, and preparation of commanding signals are analyzed by a lubrication control unit (LCU). The LCU transmits signals to actuators to trigger oil injection by the oil pump. The display unit presents real-time measured temperature variations along with the pump's operation state.

Keywords Automatic lubrication control · CNC machine tool · Machine guideways

1 Introduction

Although computer numerical control (CNC) machines offer great precision and versatility in the fabrication of complex parts, machining is an innately slow and expensive process. Attempts to improve the efficiency of machining processes must be tempered by the call for maintaining part accuracy and avoiding dynamic instabilities that may incur damage to the moving parts, cutting tools, workpieces, or machine drive systems [1]. Machine accuracy entails how well the tool point is positioned anywhere in the envelope and comprises three aspects. The most common is positioning accuracy or how precisely the carriage and cross slide place the tool tip in the desired location. For roughly 80 % of all turning jobs, an accuracy of 0.013 mm (0.0005 in.) is acceptable and most machines currently available can easily achieve this. Precision is not only inherent to the machine, but also depends on how the machine is handled. To allow a new or existing CNC machining center to attain its potential precision, it is advisable to implement these techniques [2].

Precision CNC machining is majorly concerned with attention to detail especially at the micron level. This process is exciting for people because they get to deal mostly with scientists and telecommunication developers. In addition, if cutting objects becomes boring, precision CNC machining may be the next step to take. There are several types of precision in CNC machining, one of which employs appropriate linear guideways to improve the way carriages travel and cut during machining. This is also known as exact difficult

M. Sparham · A. A. D. Sarhan · N. A. Mardi · M. Hamdi
Centre of Advanced Manufacturing and Material Processing, Department of Design and Manufacturing, Engineering Faculty, University of Malaya, 50603 Kuala Lumpur, Malaysia

M. Sparham
e-mail: eng_sparham@yahoo.com

N. A. Mardi
e-mail: azizim@um.edu.my

M. Hamdi
e-mail: hamdi@um.edu.my

A. A. D. Sarhan (✉)
Department of Mechanical Engineering, Faculty of Engineering, Assiut University, Assiut 71516, Egypt
e-mail: ah_sarhan@yahoo.com

machining because of the low tolerance it has for error [3]. As problematic as it may sound, experts have made it a point to become successful at this level. At a specific point in the machining stage, no contact takes place between the machine and product, being considered a stress-free process (i.e., electric discharge machine (EDM), wire cut EDM CNC, etc.)

Linear slide rail is a type of rolling guide, run by the power formed between the infinite scroll circulation steel balls in the slider and the slippery course. Along the slippery course load platform, the ball screw can easily perform high-precision linear movement. Compared with traditional sliding guide, the rolling-guided friction coefficient can drop to as low as 1/50 of the original, greatly decrease less invalid movement, and therefore effortlessly achieve *micrometer*-class feed and positioning. Moreover, the bound unit design between the slider and slippery course allows the linear slide rail to withstand loads from all directions. Not only can a traditional sliding guide not match the above-displayed characteristics, but the machine being able to cooperate with the ball screw and use a linear slide rail for guidance will greatly improve the accuracy and efficiency of the mechanical equipment (Fig. 1).

Enhancing CNC machine tool accuracy is permanently the most important pursuit for researchers in the precision manufacturing field. Ribeiro et al. expressed that the economic context has led industries to make effort to diminish equipment failure or unexpected breakdowns [4]. Consequently, this effort stresses the need for a user-friendly, knowledge-based fault diagnosis system for CNC machines.

CNC machine accuracy and precision are influenced by a variety of errors categorized as four major sources. Displacement caused by thermal expansion is by far the greatest source, sometimes contributing as much as 70 % of the total error. Mechanical deviation is around 20 % and comes in the form of errors introduced by wear and tolerance of the various machine components. Forces acting on the parts as well as tool error and wear collectively constitute the remaining error percentage.

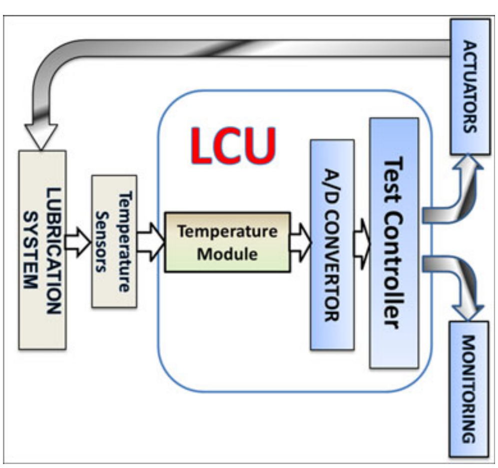

Fig. 1 Schematic of the automated lubrication system

The guideway is among the most critical elements in machining tools, as it guides the tool or workpiece along a predetermined path [5], usually in a straight line or a circle [6]. Guideway wear along with thermal and vibration errors are the largest contributor to positioning and dimensional workpiece errors in precision machining. For instance, machine tool carriages typically operate on slideways under high loads and slow speeds; thus, they must be able to get into motion quickly and smoothly and then carry on at a constant speed.

Friction between contact points in linear guideways and carriages is problematic for achieving machining precision and accuracy. Temperature will increase due to friction; consequently, friction is usually considered in motion control design for the sake of simple implementation [7–12]. However, the slideways generally used in the feed drive servomechanisms of CNC machine tools often induce significant static friction [13, 14]. The static friction cannot be ignored in practical applications because it can significantly deteriorate the reversal motions of feed drive servomechanisms.

Excessive frictional resistance at startup compared to that in motion can cause undesirable erratic or jumpy motions, commonly referred to as machine tool chatter or stick–slip. Effective lubrication is important to prevent stick–slip problems. Extreme lubrication pressure properties are also required to prevent scoring of slideways and guides. Other benefits of using lubrication oil include decreasing friction, saving energy, and preventing rusting and corrosion. Lubricants are employed in milling machines, lathes, planers, saw guides, grinders, and jig borers for less guideway wear, longer life, as well as better machining accuracy [15].

Furthermore, friction plays an important role in the precise position control of many modern machines such as robots, machine tools, etc. However, it is challenging to deal with the issues concerning friction in the control field due to its deterioration effect on precise tracking control and highly nonlinear performance at low velocity [16]. With respect to enhancing machine tool precision, progressively more researchers have realized that the friction influence must be carefully considered in the study of motion control of servo-feed mechanisms. Various important machining processes and control tasks have been studied in the hopes of solving these matters, including in-process monitoring and lubrication control. Such tasks require reliable and industrially adaptable sensors that can provide informative signals regarding the state of the machine process.

Since lubrication oil is meant to reduce friction, save energy, and prevent rusting and corrosion, it is crucial to the lifespan of a linear motion guide. Correct prediction of lubrication oil consumption and timely refill are extremely