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Journal of Materials Processing Technology 166 (2005) 364–371

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Use of electrical power for online monitoring of tool condition

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Received 30 January 2004; received in revised form 22 July 2004; accepted 22 July 2004

Abstract

A universally applicable and reliable method for online monitoring of tool condition is presented. This method is based on monitoring the differential electrical power consumption. In this technique the power for running spindle motor is nullified and only the power required for actual drilling process is recorded. Therefore, unlike other conventional electrical power monitoring systems, this technique can be used for both small and big motors. A three-level-three variable (drill diameter, speed, and feed rate) factorial design experiment was conducted on mild steel to asses the sensitivity of detecting tool wear for drilling process based on this method. The results show that the differential electrical power is a better indicator of tool wear than conventional mechanical power method. The findings were also verified using composite materials such as carbon, Kevlar, and glass fiber reinforced plastics. This method can be effectively used to verify and/or determine the maximum permissible wear in drilling materials.

Keywords: Online monitoring; Machining power consumption; NC Machining; Tool wear

1. Introduction

The concept of online monitoring of tool condition has gained considerable importance in the manufacturing industry. This is mainly attributed to the transformation of the manufacturing environment from manually operated production machines to CNC machine tools and the highly automated CNC machining centers. For modern machine tools, the downtime attributed to tool failure is estimated between 10% [1] and 20% [2]. A reliable monitoring system can reduce this downtime and allow optimum utilization of the tool life.

During a machining process, such as drilling, the cutting edges are subjected to forces, high-temperature and sliding wear. The cutting edges become progressively blunt as the machining time increases. The quality of the work piece also deteriorates [3]. In general, the failure of the twist drills occurs in one of two modes: (1) fracture or chipping and (2) excessive wear. Under normal cutting conditions, failure due to fracture is observed with small size drills (less then 3 mm in diameter), while excessive wear is the dominant failure mode with large size drills (greater than 3 mm in diameter). These defects are of particular importance for high-speed precision drilling [4].

Untended automation of machining operations requires the development of reliable methods for online-sensing of cutter breakage and wear. Tool wear depends on the type of tool, work material, cutting conditions and lubricant selected. Traditionally, tool wear is measured with the toolmakers microscope under laboratory conditions. This requires a human inspector to determine the worn region based on the textural differences between the worn and the unworn surfaces. Flank wear is determined by measuring the maximum distance between the top of the tool edge and the bottom of the worn surface. The complex nature of the tool wear complicates the task of defining the flank and crater wear boundaries manually.

A variety of experimental sensing techniques have recently been applied to the automated tool wear monitoring problem. The sensing techniques can be broadly divided into two types, (1) direct measurement, and (2) indirect measurement. In a direct method, the tool wear is measured under a microscope or using machine vision sensors [2,3,5]. This method is complex and is time-consuming [3].

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0924-0136/$ – see front matter © 2004 Published by Elsevier B.V.
doi:10.1016/j.jmatprotec.2004.07.104

Table 1
Comparison of different tool wear sensing techniques

	Direct measurement	Cost	Reliability	Flexibility	Sp. testing setup	Time-consuming
Optical systems	√	low	Very high	√	×	√
Mechanical power	×	high	High	×	√	×
Acoustic emission	×	high	Low (30%)	√	√	×
Vibration signature	×	low	High	√	√	×
Neural networks	×	high	Low	×	√	×
Vision sensors	√	high	High	√	√	√
Electrical power	×	low	High (80%)	√	×	×

Indirect sensing methods have predominantly been implemented, employing such varied technologies as cutting force [6–8], acoustic emission [9–11], spindle current [12,13], vibration sensors [4], and neural networks [14,15]. A critical comparison between different monitoring techniques is given in Table 1. A comprehensive review of the methods applied to condition monitoring in drilling was compiled and reported recently by Jantunen [16].

Previous work in current sensing was done by monitoring spindle and feed motor current [12]. The current of three-phase induction drilling machine motor was monitored to detect tool failure rather than tool wear [13]. Power or current monitoring is reported to be approximately 80% successful in detecting drill conditions [4]. However, this method was only used with lower power motors due to the low resolution of the machining power to the total motor power in conventional machining motors. For this reason, an innovative Differential Power Detector Box (DPDB) was designed in the proposed method, which circumvents this difficulty. The spindle and feed motor powers are nullified prior to the measurement. Thus, only the machining power is recorded. The machining power is measured more accurately than in the mechanical power. In the mechanical power, the force and torque are transmitted to the work piece and some of the power is lost due to heat, vibration, and chip removal mechanism. However, the electrical power is directly converted to machining power.

2. Experimental setup

To verify the concept of online tool condition monitoring through power differential device, the following experimental setup was prepared. A DPDB was connected to one of the three phases of Bridgeport series-II N/C milling machine. A schematic diagram of the experimental setup consisting of the test machine and data acquisition instrumentation is shown in Fig. 1. A parallel measurement of the axial and torque forces was done through a dynamometer. The drilling experiments were performed dry. The diameters of the drills used for the experiments were 6.35 mm, 9.525 mm, and 12.7 mm. The

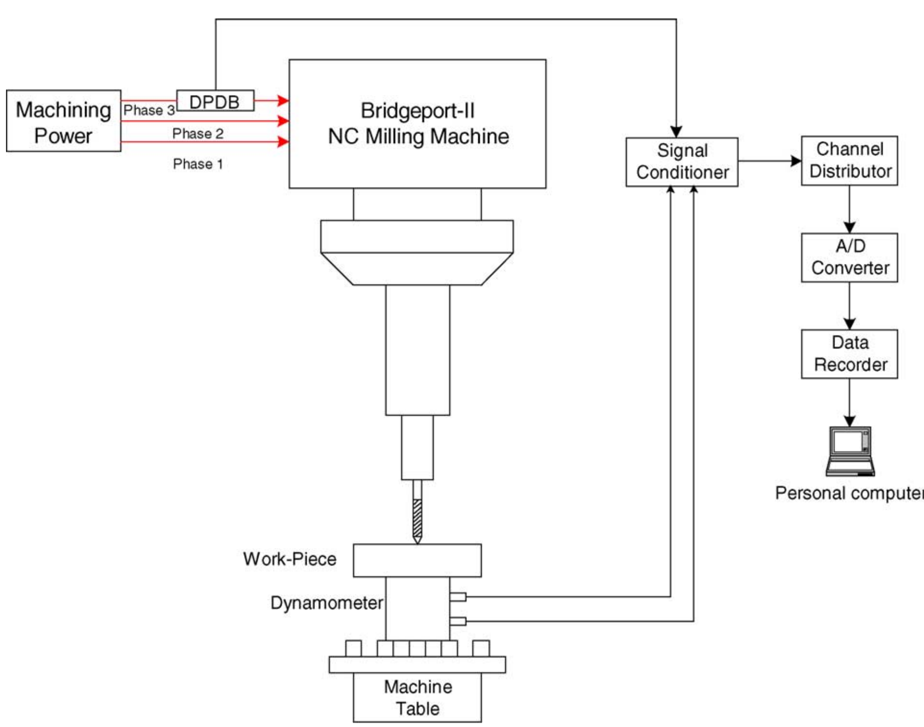

Fig. 1. Schematic diagram of experimental setup.