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Detecting tool breakage in turning aisi 1050 steel using coated and uncoated cutting tools

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Abstract

Tool life and condition monitoring systems can be used effectively in cutting processes. Since no exact and reliable mathematical models exist for the cutting process which are able to predict tool wear, tool breakage, cutting temperature and forces, the development of tool condition monitoring systems are highly requested by industry, especially in recent years. The purpose of this research is to develop a tool condition monitoring and a real-time tool life detection system in turning processes. The software and hardware generated for this research is based on the characteristic variations of the cutting forces.

When a tool wears or breaks, cutting forces increase slightly right after the tool breakage and then decrease sharply. The change of cutting forces can itself be a good indicator to detect the tool failure. The experimental set-up developed in this research consists of a dynamometer, a pre-amplifier, an A/D converter, and a personal computer. The workpiece material is AISI 1050 steel and the tool material is coated and uncoated tungsten carbide (ISO P25). The type of insert that is used is DNMG 150608. No cutting fluid was used during the turning operations. The performance of the system has been tested experimentally for certain machining conditions and the experimental results showed that the system was being successful in tool breakage detection.

Keywords: Tool breakage; Tool life; Tool condition monitoring

1. Introduction

In this work cutting tool conditions prior to fracture in turning operations are investigated and a model to monitor the tool breakage is developed. Fracture is the catastrophic end of the cutting edge that should be avoided for the cutting tool to have a longer tool life. Tool life can be defined as the usable time that has elapsed before the cutting tool has failed to produce acceptable workpieces.

Applications of the new cutting materials, which have to perform under tougher working conditions than are usually applied, and implementation of new work materials which are difficult to machine, make tool life less predictable. Besides, difficulties in tool life predicting increase under variable cutting speed and feed. In order to avoid catastrophic tool failure, tools are usually under-utilised. Hence industry needs a system that can detect the tool fracture in real-time and stop the feed motion soon enough to avoid considerable deterioration of the production. One of the most commonly used techniques in detecting the tool failure is based on measuring of cutting force components [1].

A cutting tool requires to be changed as a result of either gradual and progressive wear reaching such proportions that complete failure of the cutting edge occurs. Two types of tool failure are encountered. Firstly the tool can reach its limit of life by gradual increase of either flank wear or crater wear, secondly after some period of gradual wear, the wear rate increases significantly during several seconds, the width of the flank wear increases by several hundred of micrometers. Sometimes this accelerated wear goes with a plastic deformation of the tool edge and the cutting edge breaks. The aim of this work is not monitoring the sudden fracturing of a tool in the manufacturing process. Many works have been done on the related subject [2,3]. The aim here is to monitor the wear development on the flank of an insert and the tool fracture as a result of excess flank wear.

It has been widely established that variations in the cutting force components can be correlated to tool wear [4–6]. Methods for correlating the measured process parameters to tool wear, fracture or chipping can be classified into three categories [7]. The first category consists of methods that can be viewed as heuristic based rules with a priori knowledge only of the process parameters, such as mathematical mod-

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elling. Second category of methods can be grouped as analytical based models, such as time series analyses and Fast Fourier Transform (FFT) peak tracking. The last category is one of example-based models with inductive learning capabilities such as pattern recognition, mapping techniques, etc. [8].

Whenever a tool breaks, a significant drop of cutting force is encountered [3]. In the event of catastrophic tool failure the cutting force rapidly increases and after about 2 or 3 ms the force drops due to the gap between the tool and the workpiece. The increase of force above the preset threshold and a sudden drop is considered to be a tool failure [1]. Tool breakage is time critical because it may induce fatal damages to machine, workpiece and operator.

Various threshold values were proposed for tool failure detection in the literature. Belmonte et al. [9] stated that threshold value of 35N for tangential cutting force guaranteed an excellent workpiece finishing with negligible cutting tool damage in turning sintered hard metal with a CVD diamond tool. In the other work, Lee et al. [10] proposed threshold values for the increase of dynamic tangential force in turning AISI 4340 and AISI 1148 steels as 83 and 107%, respectively.

The tool conditions need to be monitored in order to avoid the consequences that are resulted from the fatal damages and this usually consists of three steps. The first step is to sense some monitoring signals, such as force, vibration, sound or acoustic emission, temperature and power. The second step is to process the signals, from which a set of monitoring indices (i.e. time domain, frequency domain, time-frequency domain or wavelet indices). The last step is classification, in which monitoring indices are used to classify the current tool condition to a pre-defined tool condition [11].

There are several reasons behind the need to monitor machining processes. A detailed survey about methods used for tool condition monitoring is given in [12]. Requirements of a tool condition monitoring system are:

- Advanced fault detection system for cutting tool and machine tool.
- Check and safeguard machining process stability.
- Machine tool damage avoidance.
- Expanding of power to calculate for cutting process in machine.

2. Measuring cutting forces and determining tool fracture

In metal cutting tool faces, including the rake face, major flank face and minor flank face are subjected to both shear and normal loads due to the pressure between the chip and the machined surfaces, friction between the tool face, chip and the machined surface. The resultant force F can be expressed by three orthogonal components, tangential force F_c, feed force F_f and radial force F_p as shown in Fig. 1.

It has been reported that cutting force components are more sensitive to chipping and fracture than vibration and motor current [13,14]. Ghasempoor and Jeswiet reported that both tangential and feed forces are sensitive to the tool fracture but only the tangential force decreases consistently when the tool breaks [15]. Sudden drop in tangential force is also considered to be a tool failure in this research.

2.1. Experimental set-up and data acquisition

The experimental set up developed in this research consists of a dynamometer, a pre-amplifier, an A/D converter, and a personal computer. The personal computer is used to record the variations in cutting force components measured by a three-dimensional dynamometer, Kyowa TD-500.

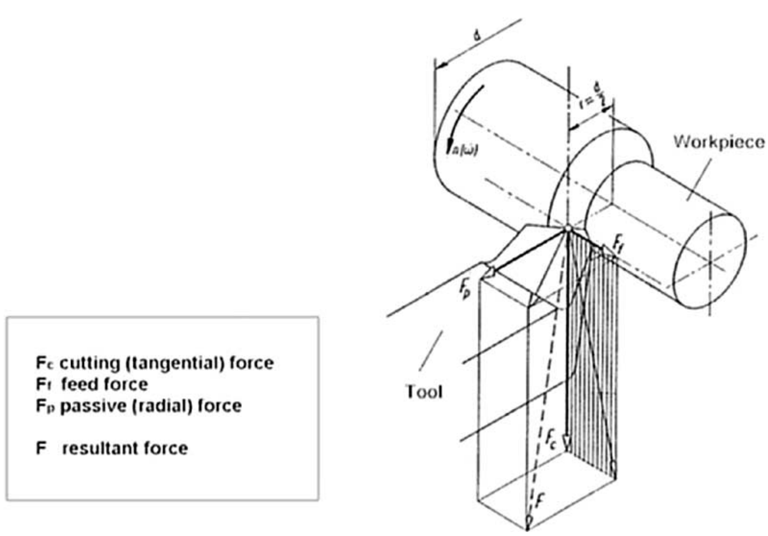

Fig. 1. Forces acting onto a cutting tool in orthogonal metal cutting [16].