Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 56 (2016) 321 – 325

www.elsevier.com/locate/procedia

9th International Conference on Digital Enterprise Technology - DET 2016 – "Intelligent Manufacturing in the Knowledge Economy Era

Cutting tool condition recognition in NC machining process of structural parts based on machining features

Nanhong Lu[a], Yingguang Li[a,] *, Changqing Liu[a] and Wenping Mou[a,b]

[a]*College of Mechnacial and Electrical Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China*
[b]*NC Machining Workshop, Chengdu Aircraft Industrial (Group) Co. Ltd, Chengdu, China*

* Corresponding author. Tel.: +0086 25 84895835; fax: +0086 25 84895906. *E-mail address:* liyingguang@nuaa.edu.cn

Abstract

Cutting tools are direct performers in material cutting processes of NC machining, while the degree of cutter attrition and breakage directly influences the quality of production. Meanwhile tool condition recognition is a key technique in automatic and unmanned machining process. Aimed at this problem, the recognition of tool-condition based on machining feature in real-time is stated. Machining features are used to build relationships between geometry, processing technology and monitoring signals in order to provide the basis for cutting tool condition identification. A feature database is established with experimental results and a cutting tool condition recognition system is established based on this database. Experimental results suggested that the proposed method solves the problem of tool condition monitoring, especially for production with multi varieties and small-batches.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: Structural parts; Cutting tool condition; Condition recognition; NC machining

1. Introduction

With the increased application of high-performance numerical control machines, NC machining has got fast development, and lots of structural parts are processed by them. NC machining processing is the key factor affects quality of workpiece which also impacts machining cost [1]. During a machining process, we have to keep an eye on the equipment situation when it's running and change the tool if find it broken. Actually, cutting tools wear during the machining processes, and will not satisfy the machining requirements [2]. However the judge of tool condition mainly depends on experiences of workers at present. So if we want to reduce the number of workers and implement automated production, we have to guarantee the cutting tools wear in a permissive range.

As we all know, the cutting tools experience three stages from a new one to a scrapped one: initial worn stage, normal worn stage, acutely worn stage, as shown in Fig.1 [3]. In order to avoid the problems of processing quality and safety, cutting tools must be changed when it reaching segment of acutely worn [4]. At present, a cutting tool is changed based on the amount of using time in most manufacturing companies, which cause resource waste or machining quality decline [5]. Moreover many aircraft structural parts have thin-walls and large size, which led to more complex machining conditions, and more difficulties in the monitoring of cutting tool condition [6].

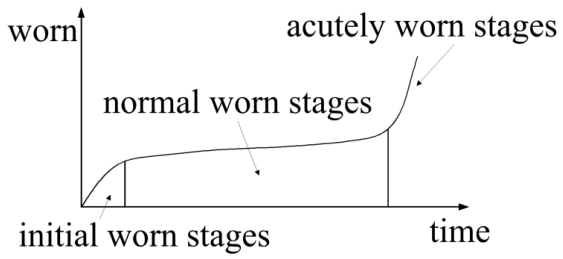

Fig.1. stages of tool wear

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production
doi:10.1016/j.procir.2016.10.028

In conclusion, a method should be presented for cutting tool condition recognition, which could remind workers to change cutting tools according to the real operation. The down time of cutting tool malfunction will also be shortened to get higher machining efficiency. At the same time, the implementation of tool condition recognition is the base of intelligent manufacturing.

2. Literature review

To deal with tool condition recognition problems, there are two methods, forecasting method and monitoring method. And the monitoring method includes direct ones and indirect ones.

A forecasting method is a technology that extrapolates tool-failure time by scientific methods when a tool is under normal condition [7]. The purpose of this method is telling people when we should replace a cutting tool. The forecasting method builds a tool life prediction model by simplify a cutting process [8]. It is under an ideal condition. So, its biggest problem is that it only applies to specific condition. The prediction model failures when the cutting parameters change.

A direct monitoring method judges tool condition by measuring the wear of a tool directly. This method is the most direct and most accurate one. It includes contact monitoring method, radiation detection method and computer image processing method. Among them, the contact monitoring method uses contact sensors. It measures the cutter diameter before and after a machining process when a machine tool is stopped. And it uses the differences of cutter diameter to judge the tool condition. This method must stop a machine tool and cannot find out suddenly damages. A radiation detection method uses radioactive substances which are harmful to humans and the environment, and it is no longer been used. A computer image processing method uses optical instruments to get images of tool wear zones [9]. It uses these images to judge the tool condition by pattern recognition technology. This method seriously affects by chips and coolant [10]. In general, a direct monitoring method cannot detect suddenly damages and can only be used in specific conditions.

An indirect monitoring method judges a tool condition by indirectly signals which related to tool wear. The signals used by this method include cutting force signals, vibration and acoustic emission signals etc [11, 12]. Scientists use time-domain analysis method and frequency-domain analysis method or time-frequency analysis method for handling the signals we get, like averages, Fourier transform and Wavelet transform etc [13]. After the original data acquisition, signal processing and time-frequency domain analysis, scientists judge the tool condition in pattern recognition [14].

An indirect monitoring method is mainly suitable for tool condition judgment in large quantities production and is not suitable in small quantities production or single piece production. The methods that are designed to work for different cutting conditions need some sort of training before the actual cutting process. If any process variables change, system retraining becomes necessary.

Currently there are some commercial products available for tools and machine condition monitoring. Factories can choose these products to improve machine utilization and reduce production cost.

ARTIS system is a system which used in all kinds of metal cutting machine tools and production lines for monitoring process and machine condition. Its task is to protect tools, optimize cutting process, reduce cost and optimize production and quality. It has different sensors for different monitoring signals. This system is very suitable for turning process. But in milling process, it encounters problems of wrong alarms.

Forecasting Method only applies to those specific conditions. There are a lot of limitations because the prediction model failures when the cutting parameters change. A direct monitoring method cannot detect suddenly damages and can only be used in some certain machining conditions. The indirect monitoring method and the commercial product cannot deal with tool condition recognition very well in small quantities production or single piece production. So there is necessary to find out a method of tool condition recognition in small quantities production or single piece production.

3. The overall of the proposed method

Normally, NC machining parts have the characteristics of large size, complicated structure etc. But even the most complex parts can still be decomposed as a combination of multiple features through analyzing (feature—geometry with a certain engineering semantics) [15, 16]. In STEP AP224, ISO has defined some typical geometric feature structures including pocket, boss, hole, step, profile etc. For example, the complex structural part in Fig.2 can be decomposed as a combination of several pockets, holes, ribs and profiles.

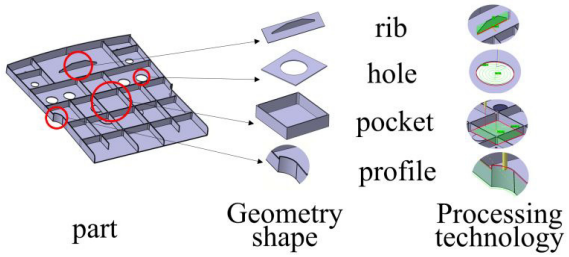

Fig.2.Complex parts can be decomposed as a combination of features

The process technology of a part is complicated, but for a certain geometric feature, the processing technology is relatively fixed. The right part of Fig.2 is the processing technology of some typical features like rib, hole, pocket and profile. For a particular structure, its machining parameters can be fixed and inherited because of factories' standard production and processing.

The above two points can provide a new idea for cutting tool condition recognition in a NC machining process of aircraft complex structural parts, which is the method of tool condition recognition based on feature in this article. The