國立臺灣大學工學院機械工程學系

碩士論文

Department of Mechanical Engineering

College of Engineering

National Taiwan University

Master Thesis

線上預測銑削加工之切削力

Online prediction of cutting force in milling

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中華民國 109 年 7 月

July 2020

doi:10.6342/NTU202004067

摘要

加工過程中的切削力可被用於分析刀具磨耗、偏擺、加工精度與表面粗糙度等。一般量測切削力主要是利用價值百萬元的動力計，除了價格昂貴外，動力計也無法達到線上量測與監控的目標。本研究提出線上估測切削力的方法(Online Prediction of Cutting Force Technology, 以下使用 OPCFT 簡稱)，這項技術可以在透過直接量測 CNC 控制器內部訊號，並不額外外加感測器的情況下，達到線上估測切削力。

這項技術具有三個主要的創新點。第一，由於加工中引發的雜訊或是振動並不適合用於切削力參數鑑別，因此透過比較動力計測量的訊號與本研究建立的切削力模型之模擬結果，發現實際加工中所擷取的訊號因為包含了雜訊而不能直接使用，所以使用了零相位濾波器去除了高頻雜訊，傅立葉濾波器濾除大小刃引起的周期性變化，必須透過這些特殊的濾波方法才能得到與切削力模型相符合的訊號。第二，透過整合切削力學與伺服模型，將伺服訊號中由切削力與摩擦、慣量引起的訊號分離，得到主軸電流和伺服軸電流與切削力之關係。由於切削力並非直接施加於馬達驅動的干擾力，而是作用於平台上的工件，因此透過敲擊實驗將傳動系統的特性加入預估模型。第三，透過數學方法將追蹤誤差與伺服軸電流還原平台之軸向切削力，主軸電流還原切線方向切削力，並使用切削周期法鑑別切削力係數，透過切削力模型模擬各方向的切削力。

本研究在立式加工機(MV66A)進行了 29 筆實驗，同時擷取動力計量測之切削力訊號與本研究提出 OPCFT 這項技術的模擬結果比較，結果顯示 X 方向的平均 RMS 誤差為 12.3 %，Y 方向的平均 RMS 誤差為 14.0 %。實驗結果驗證了本論文提出的技術可以在不外加任何感測器的情況下，達到線上估測切削力的目標。

關鍵字：線上切削力預測、切削力模型、切削力係數鑑別、整合切削力之伺服模型、銑削加工、虛實整合

doi:10.6342/NTU202004067

Abstract

The cutting force during machining can be used to analyze tool wear, run out, machining accuracy and surface roughness. The general measurement of cutting force mainly uses a dynamometer which costs about one million NT dollars. In addition to its high price, the dynamometer cannot achieve the goal of online measurement and monitoring. This research proposes a method for online prediction of cutting force technology (Online Prediction of Cutting Force Technology, hereinafter referred to as OPCFT). This technology can estimate the cutting force online directly through the signal of CNC controller without any additional sensors.

This technology has three main innovations. First, comparing the signal measured by the dynamometer with the simulation results of the cutting force model established in this study, it is found that the noise or vibration induced during machining is not suitable for the identification of cutting force coefficient. Therefore, a zero-phase filter is used to remove high-frequency noise. The Fourier filter filters out periodic changes caused by large and small edges. Both filtering methods are required to obtain the cutting force. Second, by integrating the cutting force and servo model, the signals caused by the cutting force, friction and inertia in the servo signal are separated to obtain the relationship between the cutting force, the spindle current and the servo axis current. Since the cutting force is not directly applied to the motor drive, but to the workpiece on the platform, the characteristics of the transmission system are added to the prediction model through the impact test at the workpiece. Third, through the mathematical methods, the tracking error and the servo axis current are used to restore the axial cutting force of the platform, and the spindle current are used to restore the tangential cutting force, and Instantaneous method is used to identify the cutting force

doi:10.6342/NTU202004067

coefficient which is to simulate the cutting force in each direction through the cutting force model.

In this study, 29 experiments were conducted on a vertical processing machine (MV66A). The cutting force signal measured by the dynamometer was compared with the simulation results of OPCFT proposed in this study at the same time. The results showed that the average RMS error in the X direction is about 12.3 % and the average RMS error in the Y direction is about 14.0%. The experimental results verify that the OPCFT technology proposed in this paper can achieve the goal of online cutting force estimation without any additional sensors.

Keywords: online cutting force prediction, cutting force model, identification of cutting force coefficient, servo model integrating cutting force, milling processing, virtual and real integration

doi:10.6342/NTU202004067