CNC工具機之顫振抑制策略

A chatter suppression strategy for CNC machine tools

廖運炫
國立台灣大學
機械系
教授

李忠玲
國立台灣大學
機械系

楊益群
國立台灣大學
機械系

關鍵詞

- CNC 工具機　CNC machine tool
- 自激式振動　Self-excited vibration
- 顫振抑制　Chatter suppression
- 主軸轉速調整　Spindle speed regulation

摘要

顫振(chatter)為一自激式振動，是影響工具機材料移除率與加工成本的一重要因素，其發生為動態的切削過程，可視為一結合了工具機動態結構特性與切削過程的閉迴路系統。本文針對影響最大的再生式效應導致的顫振，提出一線上顫振抑制的策略。依據再生式效應的概念，因為振動會使得未變形切屑厚度改變，因此工件表面的同一位置，在前後兩次切削間的波紋間存在著相位差，特定的相位差會導致系統的不穩定，即再生式顫振。文中以理論推導出在振動週期中能消耗最多能量的相位差，再依據主軸轉速與顫振頻率及相位差的關係，計算出最適當的主軸轉速。以電腦模擬一個二階振動系統，發現最佳相位確能使得發散的振動在最短的時間內收斂。文中並在一 CNC 銑床上進行實際切削測試，以動力計量取進給方向的切削力，做快速傅立葉轉換，得到頻率域的能量頻譜，在判斷出發生顫振時，依據求得的顫振頻率，即時將主軸調整至適當的轉速，經溝槽端銑削不同的材料，顯示出經由本文提出的策略，顫振的振幅可以急速的衰減，回復到穩定的切削狀態，驗證了文中提出之策略確實可行。本文提出之顫振抑制策略簡單，不必做系

統識別，且不必更動機械結構，容易在一般的工具機上實現，非常具實用的潛力。

Chatter is a kind of self-excited vibration, and it is one of the most important factors affecting material removal rate and machining cost of the machine tool. Chatter in essence is a dynamic machining process which is a closed loop system composed of the material removal process and the dynamic behavior of the machine tool. A strategy to suppress regenerative chatter on-line is proposed in this paper. Based on the concept of regenerative effect, the vibration occurring during the cutting process causes the variation of undeformed chip thickness, and in turn results in undulation left on the cut surface. There is phase difference between two undulations of present and previous cuts. When this phase difference falls in unstable conditions chatter takes place. The phase difference which can lead to the maximum energy removal from the vibratory system is derived. The appropriate spindle speed which can suppress chatter most effectively from energy view point can be computed according to the relationship among the spindle speed, chatter frequency, and phase difference. Numerical simulation of a single-degree-of-freedom system shows that the derived optimal phase difference can indeed lead to the reduction of vibration amplitude in the shortest time. The proposed strategy is implemented on a CNC milling machine, and millings of different materials are conducted. The cutting force in feed direction is measured by a dynamometer, and fast Fourier Transform (FFT) is carried out to obtain the power spectrum. The chatter frequency is identified when the intensity at a certain frequency other than the spindle speed and tooth passing frequency exceeds a critical value. Based on the identified chatter frequency, a new spindle speed is computed. It is found that amplitude of chatter is reduced promptly and effectively, and hence the validity of the proposed strategy is verified. The proposed strategy is very simple, no system identification of the machine tool structure is needed, and hence it has great potential in actual applications.

簡介

銑削加工在製造領域中向來是相當重要的一項技術，不論是傳統的模具製作、航太工業、汽車製造，或是電子、光電、生醫等新興的產業，在生產上對於銑削加工技術都有相當高依賴。高速銑削是銑削加工目前發展的主要趨勢，由於主軸轉速提高，使得進給速度也可以加快，因此縮短了加工時間，提昇了生產效率。除此之外，由於高速銑削具有低切削力、熱量易由切屑帶走等特性，因此具有精度高、熱變形量低等優點。所以，銑削加工技術的提昇，實爲增加產業生產力與競爭力的關鍵之一。

但在某些切削條件下，刀具和工件之間會造成劇烈的振動，振動的原因有強制式振動與自激式振動兩種。強制式振動通常爲機件或是加工過

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劃撥帳號：07188562 工業技術研究院機械所

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