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DSP Implementation of Active Noise Control Systems
以數位信號處理器實現主動噪音控制系統

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Abstract

This thesis describes the DSP implementation of active noise control (ANC)system of ducts, fans and hands-free communication in car cabins. It is divided into three main parts. The first part presents an active noise control system for broadband cancellation of noise in ducts, where non-acoustical reference is unavailable and thus the ANC structure is “spatially feedforward.” In this structure, acoustic feedback that is known to be detrimental to system stability and performance must be taken into account in control design. In this case, difficulties generally arise in implementing the ideal controller, or the zero spillover controller due to plant uncertainties. Alternatively, the controller is implemented through an equivalent approach based on the optimal model matching principle. The algorithm is implemented on a digital signal processor, using FIR, IIR and hybrid filters. Experimental results indicated that the proposed controller was effective in suppressing periodic noise and random noise source, without and with airflow. In addition, directional transducers were shown to be useful in mitigating the adverse effect of acoustic feedback and thus simplifying controller synthesis. An application of broadband active noise control for engine exhaust systems using spatially feedforward structure also is described in this section. Experiments are carried out to evaluate the proposed system for reducing the noise at different engine operating conditions.

The second part of this thesis describes two configurations of adaptive feedforward ANC technique for reducing blade passing frequency (BPF) noise in centrifugal fans. In one configuration, the control speaker is installed at the cutoff region of the fan, while in the other configuration at the exit duct. The proposed ANC system is based on the filtered-x least mean squares (FXLMS) algorithm with multi-sine synthesized reference signal and frequency counting technology. The system is implemented by using a digital signal processor. Experiments are carried out to evaluate the proposed system for reducing the noise at the BPF and its harmonics at various flow rates. The results of experiment indicated that the ANC technique is effective in reducing the blade passing noise for two configurations by using the feedforward adaptive control.

In the third part of this thesis describes the background noise reduction for hands-free communication systems of car cabins using adaptive feedforward noise

control algorithm. For hands-free telephone system, the quality of communication usually is effect by background noise such as engine noise and aerodynamic noise. In the present study, a design for reducing car cabin periodic background noise from engine and broadband random noise using adaptive feedforward control are investigated. The algorithm is based on the well-known FXLMS with multi-sine synthesized reference signal and frequency counting technology is implemented on a DSP platform. Experimental results indicated that the proposed design was effective suppressing 15 dB in periodic engine noise and 2-3 dB in broadband random background noise.

The ANC system presented in the first part is essentially a fixed controller. To enhance the practicality of the technique, future research will be focused on the development of robust adaptive controllers to accommodate perturbations as well as uncertainties in the system. Along the same line of the preliminary results, future research will be focused on the following aspects. The robustness should be optimally accounted for by using more sophisticated algorithms, e.g., H¥ in stead of direct truncation of filters. Adaptive version of the ideal controller should be developed to cope with ANC problems of time-varying systems.

Key words：Active noise control;DSP

中文摘要

本論文主要是描述以數位信號處理器(DSP)實現管路、扇葉噪音及車廂內免持聽筒行動電話之主動式噪音控制。在論文的第一部份主要是描述管路寬頻噪音的控制方法，在此部份採用空間前饋架構 (spatially feedforward structure)為發展基礎。在此一架構中，聲學回授效應(acoustic feedback)在設計控制系統時必須納入考慮，否則經常會造成控制系統的不穩定，且造成在實現理想控制器或零溢出控制器 (zero spillover controller)上的困難。 在設計此控制器時並採用 最佳化匹配原理(optimal model matching)的原理，並利用有限脈衝響應濾波器 (FIR), 無限脈衝響應濾波器 (IIR) 及混合式濾波器(hybrid filters)來實現所設計的控制器。實驗的結果顯示此一控制器可有效降低週期性(periodic noise)及隨機噪音(random noise)。在另一方面也利用麥克風及控制喇叭的方向性來消除聲學回授的不良影響。接著並將此一發展的控制系統應用到實際的引擎排氣系統的噪音上，以評估在不同的引擎轉速狀況下的衰減效果。

論文的第二部分則描述利用適應性前饋(adaptive feedforward) 控制的方法來降低扇葉的通過頻率噪音(blade passing frequency noise)。在控制結構上除驗證傳統的管路形式外，並提出另一種在鼓風機接合處(cutoff region) 安置控制噪音源的架構，並利用多輸入參考訊號的的最小均方根演算法(FXLMS) 及頻率計數法(frequency counting)來得到實際扇葉的瞬間轉速，並產生多正弦函數波 (multi-sine) 來當做參考輸入以達噪音控制之目的。在此階段並利用實驗的方式去評估此二種控制架構在不同流速下的控制效果。

由於安全的考量，近幾年來車內免持聽筒行動電話已逐漸普及，而其通話品質則經常受到外界雜音的干擾。在本論文的第三部份則企圖將前述發展的適應性前饋控制法及多正弦函數法等技術應用在此問題上，以減少免持聽筒行動電話接收器的雜音。其主要原理乃利用主動式噪音控制的技巧減少由引擎所產生的週期性噪音及由駕駛室外傳來的氣流噪音。

在本論文的最後並提出一些未來在主動式噪音控制的研究方向，及針對上述系統的一些改善及更週詳的考量，如發展較具強健性的控制器以應付較複雜的時變系統。

關鍵字：主動式噪音控制; 數位信號處理