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論　文　内　容　要　旨

報告番号	甲　先　第　164　号	氏　名	リ　ジンシャン 李　靖祥
学位論文題目	Characteristic analysis and suppression strategy of the valve impulse exhaust noise（バルブ衝撃排気音の特性解析と抑制法）		

内容要旨

Pneumatic systems widely exist in the industrial productions, using high pressure compressed air as power source. The air charging and discharging processes of pneumatic cylinder through valves are recurrent to generate aerodynamic noise, especially the venting exhaust to atmosphere directly. In order to suppress this kind of impulse exhaust noise, the characteristics of such noise and the suppression strategy are presented. The aerodynamic properties of impulse exhaust are studied firstly. Based on the analysis of aerodynamic parameters during the exhaust process, the sound sources are discussed. Then the radiated noise of exhaust with a typical sintered bronze silencer is predicted both in time-domain and frequency-domain. A noise suppression strategy of controlling the opening process of valve is proposed. Finally the experiments based on a modeled pneumatic exhaust system and a pneumatic friction clutch and brake system of mechanical press are carried out to verify the validity of the presented model and the suppression strategy.

In Chapter 1, the impulse exhaust noise will be introduced briefly, including the definition, characteristics and harm to the environment. Then the research background of pneumatic exhaust, the progress of classical exhaust noise control and the purpose of this study will also be introduced.

In Chapter 2, analysis of aerodynamic properties of impulse exhaust will be presented in details. The typical pneumatic exhaust systems will be introduced firstly. Then based on some basic assumptions, the mathematic model of aerodynamic properties of pneumatic exhaust will be described. A

one-dimensional thermodynamic model is used to describe the transient exhaust process. So the aerodynamic parameters during the exhaust can be obtained, such as cylinder pressure, mass flow rate. In addition, the movement equation of piston in the cylinder of typical pneumatic friction clutch and brake system will be introduced to describe the whole systems. In practice, some classical porous materials are used to reduce the impulse noise. The aerodynamic model of porous material with rigid frame, such as sintered bronze used in muffler devices normally, will also be obtained.

In Chapter 3, the sound sources of impulse exhaust noise will be introduced according to the Lighthill's general theory, as the impulse exhaust noise is a kind of aerodynamic noise. The impulse exhaust noise is mainly composed of monopole sources related to the mass flow and quadrupole sources generated by the turbulence. Based on a piston sound source assumption, the noise radiation characteristics of the exhaust with sintered bronze muffler will be predicted. The mass flow considered as a monopole source is related to the sound pressure of impulse exhaust noise. And the sound pressure level (SPL) at a far-field observation point is predicted by the piston acoustic source approximation.

In Chapter 4, the control strategies of impulse exhaust noise will be presented. There are three approaches to control the noise from the sound source, the propagation path and the receiver, respectively. Muffler devices are used to reduce the aerodynamic jet noise classically. The features and disadvantages of various mufflers in the industrial applications will be introduced firstly. Unlike the steady noise or period noise, the evaluations of impulse noise are introduced. Then a semi-active control strategy to change the sound source of impulse exhaust by controlling the opening process of exhaust valve is presented. The principle and specific control method will be introduced.

In Chapter 5, experimental study will be presented. The experiments were based on a pneumatic friction clutch and brake (PFC/B) system of mechanical press and also a simplified cylinder exhaust system. In order to test the presented

semi-active noise control strategy, a modified pneumatic valve was designed, which can adjust the poppet valve by a servo motor. The experimental results will be shown to verify the validity of the presented aerodynamic model and the radiated noise predictions. The noise was analyzed to study the effect of presented suppression strategy comparing to the direct exhaust.

In conclusion, the aerodynamic properties of impulse exhaust based on typical pneumatic exhaust systems have been investigated. According to the aerodynamic models, the flow parameters during the impulse exhaust were obtained. The sound sources of impulse exhaust noise were studied based on the Lighthill's general theory of aerodynamic noise. The radiated noise of exhaust with a typical sintered bronze silencer is predicted both in time-domain and in frequency-domain. In addition, a semi-active noise control strategy has been presented to suppress the impulse exhaust noise especially to reduce the peak SPL.

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論文審査の結果の要旨

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学位論文題目

Characteristic analysis and suppression strategy of the valve impulse exhaust noise

(バルブ衝撃排気音の特性解析と抑制法)

審査結果の要旨

多くの工業製品で用いられる，駆動源として高圧空気を使った空気圧システムの給排気過程に発生するバルブ衝撃音についての解析とそれを抑制するための方法について検討した研究である．始めに衝撃排気についての空気力学的特性を調べた．1次元の熱力学が，過渡排気過程を表すために用いられた，加えて，空気圧摩擦クラッチおおびブレーキシステムのシリンダー内のピストンの運動方程式が，系全体を表すために導入された．そして，剛体壁空間中に穴あき構造を有する一般的な焼結した青銅の消音器を用いた際の排気騒音の放射について，時間領域および周波数領域で予測した．衝撃排気騒音の音源について，空気力学的騒音の1つの種類として，Lighthillの一般理論に従い導いた．それらの解析結果から，騒音を抑えるための方策として，バルブの開放過程を制御することを提案した．ここでは，音源，伝搬経路および受音部に対しての対策の3つの手法が用いられた．工業的な応用としての定常雑音および周期雑音についての消音器ではなく，衝撃音についての評価方法を導入して，排気バルブの開放過程を制御することで衝撃排気音の音源を変化させるセミアクティブ制御法を提案した．最後に，モデル化された空気排気システムおよび空気圧摩擦クラッチおよびブレーキシステムを用いた実験が，与えられたモデルと騒音抑制方法の有効性の確認のため実行された．その実験では，サーボモータでポペットバルブの調整を行う，改良された空気圧バルブが設計された．提案した抑制法による効果を直接排気音との比較により騒音の解析を行い，衝撃排気音のピーク音圧レベルを低下させるためのセミアクティブ騒音制御法が与えられる．衝撃排気騒音の発生機構の提案とそれらを低減するための制御方法の提案が本論文の主な提案内容である．

以上本研究は，上記について独創的であり価値のある内容であると判断する．よって，本論文は博士（工学）の学位授与に値するものと判断する．

なお，本論文の審査には，徳島文理大学石原国彦教授の協力を得た．