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碩士論文

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單膨脹室內軸對稱周期性流場分析

Analysis of the Periodic Flow in An Axisymmetric Single-Expansion Chamber

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摘要

過去引擎排氣噪音研究的方法主要有兩種，第一種是以傳統的線性聲學理論為基礎，主要注重在消音器的聲學特性；而第二種方法則是採用一維非線性氣體動力學理論來計算排氣管內的壓力與流速變化，並以排氣管口的瞬時質量流率來計算排氣噪音。這種做法固然能掌握一些排氣噪音特性，但因真實的排氣管形狀十分複雜，一維理論有其限制。本研究的主要目的即是希望能改進第二種做法，將其擴展到三維的流場計算，以彌補一維計算在高頻部份會低估的缺點。這是以計算流體力學為工具，來模擬排氣管內的三維流場，以計算排氣管口的瞬時質量流率，進而得到引擎的排氣噪音。

本研究主要分成兩部份，第一部份是以數值方法來計算排氣管內的流場及排氣管口的瞬時流量，第二部份則進行引擎排氣管口瞬時流量的量測。為簡化計算及實驗量測，在本研究中以一隻軸對稱單膨脹室的簡化排氣管來進行分析。

在數值計算的部份，本研究主要的做法是以有限體積積分法來解排氣管內的非穩態連續性方程式、動量方程式和能量方程式，並配合 $k-\varepsilon$ 雙方程紊流模式，及SIMPLE法則來求解。計算結果顯示100 Hz固定周期均勻分佈的入口速度，對於所模擬的單膨脹室管大約

在 0.1 秒才達到周期性的穩定狀態，並且在入口速度逐漸增加的過程於膨脹室的突張與突縮段會有兩個迴流區域的產生，隨著時間的增加，入口速度減小的影響，這兩個迴流區會合併形成一個繞著整個膨脹室的大迴流，如此不斷地循環著。

在實驗量測部份，本研究主要是利用應變規式的壓力計與熱線流速儀，來進行排氣管冷流場管壁的壓力與出口速率的量測。在瞬時速率量測方面，雖然熱線流速儀無法判定速度的方向，但卻是簡便又有效率的量測工具，由本研究的實驗確實知道出口區域會有逆流的現象發生，而且愈靠近出口端及管壁面量測的逆流程度會愈大。本研究並以一維流場的計算結果與量測值作一比較。在管壁壓力量測方面，前端壓力變化的幅度範圍在 0.2 巴左右，並且在低轉速時高頻壓力波明顯，大約是引擎轉速的 7 倍，而在膨脹室的壓力相較於前端降了 0.1 巴左右，同時變化的幅度也要來的小，隨著轉速的增加高頻現象較不明顯。

Abstract

In the past there are two methods to study the noise of engine exhaust are as follow： one used traditional linear acoustic theory to analyse the acoustic characteristics of the muffler, and the other used one dimensional nonlinear gas dynamic theory to calculate pressure and velocity variations in the exhaust pipe, and the mass flow rate from the open end of the exhaust pipe is used to calculate exhaust noise. Although these methods have in hand some properties about exhaust noise, one dimensional theory can be limitted because complicated exhaust pipe. In this paper, we try to improve the second method and expand three dimensional calculation, in order to remedy low prediction on high frequency with one dimensional method. We can simulate three dimensional flow in exhaust pipe by computational flow dynamics model and the mass efflux at the end of the exhaust pipe obtained is used to calculate the noise level of engine.

The study was conducted in two parts. In the first part, the flow field in an exhaust pipe and the mass flow rate at open end was claculated with numerical method. In the second part, the instantaneous velocity at the exit of the pipe was measured. With the purpose of simplifing calculation and experiment, an axisymmetric exhaust pipe with single-expansion chamber was analysed.

In numerical calculation, the flow in an exhaust pipe was simulated by employing finite volume integrating method to deal with unsteady continuous equation, momentum equation, energy equation, $k-\varepsilon$ two equation turbulent model and blend SIMPLE algorithm. Results of calculation showed that the inlet oscillating uniform distribution velocity was at the frequency of 100 Hz, can reach periodic stable state about 0.1 sec in simulated single-expansion pipe. Besides, the growth of two recirculation zones can be observed in the expansion chamber during increasing inlet velocity. These two recirculation zones merged into a main recirculation around whole chamber followed decreasing inlet velocity. Repeatedly circulating.

In experimental measurement, using the strain-gauge pressure sensor and hot wire anemometer to measure tube pressure and exit velocity of exhaust pipe. Though hot wire anemometer can't judge the direction of velocity, it still was a convenient and efficient measurment instrument. Results of experiment showed that the exit part of exhaust pipe happened countercurrent and the measured degree was more strong more near the exit end and wall. The measured value also was used to compare with the results of one dimensional calculation. The amplitude of pressure variation was about 0.2 bar in the front of pipe. There was high frequence pressure wave being about seven times frequency of engine revolution. The pressure in the chamber compared to the front part of pipe dropped 0.1 bar and the amplitude of variation was smaller. The high frequence condition was not obvious followed quicker revolution.

目　錄