國立中興大學機械工程研究所

碩士論文

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單缸二行程引擎排氣管設計
對引擎性能與排氣噪音的影響

The Effects of Exhaust System Design on the Performance and the Exhaust Noise for Single Cylinder Two Stroke Engine

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中文摘要

本文主要是進行引擎在穩定運轉時的性能與排氣噪音計算，探討各種不同排氣管設計對單缸二行程機車引擎性能與噪音的影響。二行程引擎的排氣管主要是由數個膨脹室與管子的組合，構造相當複雜，而排氣管的設計不僅會影響排氣噪音，同時也會影響引擎的性能，本研究則是探討排氣管的設計參數對引擎性能與排氣噪音的影響。

研究排氣噪音的方法主要可分成兩類，第一類是以線性聲學理論為基礎，探討消音器的聲學特性；第二類則是以非線性氣體動力學為基礎，利用排氣管出口的瞬時流率來計算排氣噪音量。本研究主要是以第二種方法來進行。本文首先進行排氣管內壓力與出口流速的計算與量測，探討以這種方法計算排氣噪音的準確程度。研究中分別針對兩隻不同形式的排氣管，探討引擎在沒有點火的五種轉速下，在排氣管內的壓力變化及在排氣管出口的瞬時流量變化。為簡化計算及量測，本研究是以馬達來帶動一具單缸二行程機車引擎。在理論計算方面，本文以零維模式來模擬汽缸內驅排氣及壓縮過程，以一維模式來模擬進排氣管內的流速與壓力變化，其中進排氣管內的一維非穩態可壓縮流是以特徵線法來求解。在實驗量測方面，本研究利用壓力轉換器量測排氣管中膨脹室的壓力，而用熱線流速儀來進行排氣管出口速度的量測。比較計算與量測結果，發現壓力與流速的變化趨勢非常吻合，但平均流量則有一些差異。這說明了以一維非線性氣體動力學來分析排氣管是非常可行的。

接著是進行引擎的循環模擬分析與量測比較，目的是要建立一個足以代表真實引擎行為的數學模式，以作為將來變更排氣管設計參數的基本模型，這部份工作是利用 WAVE 軟體來進行的。WAVE 同時具有引擎循環分析與進排氣計算的功能，其在進排氣管內的計算，則是以有限控制體積法來解一維非穩態可壓縮流。本文針對一款市售 50c.c. 二行程機車引擎，說明了如何使用 WAVE 建立引擎循環模擬分析的模式，以及其進排氣系統的模式，並說明了如何調整 WAVE 中的引擎參數，包括燃燒、熱傳、驅氣、摩擦模式的參數，使得模擬的結果能與量測結果相符合，如此引擎循環模擬分析才能反映出引擎的真實行為。比較結果發現，調整燃燒模式中的參數可使氣缸壓力的計算值與量測值吻合，加上調整摩擦模式的參數會使 IMEP 的變化趨勢一致；而調整燃燒模式或驅氣模式中的參數，就可以使模擬與量測的引擎性能較為接近。

最後針對上述建立好的引擎及排氣管模式，在不改變外型的前提下，以原來的排氣管設計為基準，改變排氣管內部的設計參數，分別從聲學以及非線性氣體動力學兩種不一樣的角度來探討這些參數的影響。本文的重點著重在膨脹室體積，連通管直徑、數目和長度，以及觸媒轉化器的溫度。結果發現，在不降低引擎性能而又能減少排氣噪音，最佳的方式是減少連通管的有效流道面積，如減少管數或管徑，然後是增加膨脹室二與膨脹室三的體積，其他的方法不是沒有效果就是會影響引擎性能。

英文摘要

The noise radiated from the tail pipe plays an important role in the total noise emitted for small two stroke engines. The exhaust pipes of two stroke engines are usually of complicated geometry. They are composed of several short straight pipes and expansion chambers. Studies in the past have shown that the design of the exhaust pipe has significant influence on the engine characteristics. In this paper , engine performance and exhaust noise were calculated to study the effect of exhaust pipe on the engine characteristics.

There are two ways of analysis that have been used widely for the design of engine exhaust pipe. One is based on the linear acoustic theory, and the other is based on the nonlinear gas dynamics in the exhaust pipe. This paper was implemented mainly by the latter method in which the exhaust noise was calculated by means of instantaneous exhaust flow. In this paper, comparisons of the results of measurements and calculations of the instantaneous exhaust pipe pressure and tail pipe velocity were first executed to verify the validity of the engine and the exhaust pipe model. Two types of commercial exhaust pipe were considered. They were individually connect to a single cylinder two stroke engine which was driven with an electric motor. Different engine speeds could be obtained by using pulleys of different diameters. Five engine speeds were used in this paper. In the part of calculation, the one dimensional unsteady gas dynamic model was used, and the spatial and the temporal variations of the velocity and the pressure in the pipe were obtained through the model calculations. As in the part of measurement, the

pressure variations in the pipe were obtained with pressure transducers inserted at several different locations on the exhaust pipe, while the instantaneous velocity of the tail pipe was obtained with a hotwire anemometer located at the center of the exit of the exhaust pipe. For both types of exhaust pipe, comparisons of the pressure and velocity variations showed that the results of model calculation agreed quite well with those of the measurements. This illustrated that the one dimensional nonlinear gas dynamics is a useful tool for analyzing the exhaust pipe.

In the second part, comparisons between the results of engine cycle simulation and measurements were carried out in order to build up an engine model that was reasonable enough to represent a real engine. This part of work was executed with the WAVE code. Engine cycle simulation and intake/exhaust gas analysis are the main functions of the WAVE code. In calculating the intake and exhaust gas behavior, WAVE uses the finite control volume method for solving the one dimensional unsteady compressible flow. In this paper, a commercial 50 c.c. two stroke engine was used to illustrate how to build an engine model in WAVE. Besides, this paper studied how to modify parameters in the engine model, including the combustion model, the heat transfer model, the scavenge model and the friction model, to match the simulated results to the measured results. An engine model which can response the behavior of a real engine could be obtained after the adjustments mentioned above. It was found that adjusting parameters in the combustion model would trim the calculated cylinder pressure to be close to the measured results, and adjusting parameters in the friction model would make the calculated IMEP vary in the same trend as the measured data. Furthermore, adjusting parameters in the heat transfer and the scavenge model could make the calculated engine performance close to the measurement.

In the final part, design parameters of the exhaust pipe were varied to study the effect of each parameter on the engine performance and the exhaust noise. This work was conducted based on the previous engine model. The diameter and the length of connecting tubes and the volume of expansion chambers in the exhaust system were considered in this paper. Results of calculations show that the diameter of the connecting tubes is the most significant factor, because it could decrease the exhaust noise and keep the engine performance unaltered. Other parameters either had no effects on noise reduction or would drop off the engine performance.

目錄