STUDY OF THE TRANSMISSION LOSS OF VARIABLE DIAMETER, CONCENTRIC, PERFORATED TUBE, CAVITY RESONATOR

A THESIS SUBMITTED
IN FULFILMENT OF THE REQUIREMENTS OF
THE DEGREE OF
DOCTOR OF PHILOSOPHY

BY
LOKESH CHANDER MALHOTRA

TO THE
DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY, 1982

TO MY PARENTS

CERTIFICATE

This is to certify that the thesis entitled, "Study of the Transmission Loss of Variable Diameter, Concentric, Perforated Tube, Cavity Resonator", being submitted by Mr. Lokesh Chander Malhotra, to the Indian Institute of Technology, New Delhi, for the award of the degree of 'Doctor of Philosophy' in Mechanical Engineering, is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

K.K. Chaudhry

(DR. K.K. CHAUDHRY)
Assistant Professor
Applied Mechanics Department
Indian Institute of Technology
Hauz Khas, New Delhi-110016

K.K. Pujara

(PROF. K.K. PUJARA)
Mechanical Engineering Deptt.
Indian Institute of Technology
Hauz Khas, New Delhi-110016

New Delhi

27.7.1982

ACKNOWLEDGEMENT

It is with great pleasure that the author wishes to express his profound gratitude to Prof. K. K. Pujara and Dr. K. K. Choudhry for supervising the work on this thesis. Their inspiring guidance, valuable discussions and constant encouragement helped the author to accomplish this work.

The author is thankful to the Head, Applied Mechanics Department for providing facilities to perform the experiment in the Gas Dynamics Laboratory. Sincere thanks are due to Mr. T. R. Bhogal, Mr. I. N. Anand, Mr. Harbhajan Singh, Mr. H. R. Sharma, Mr. Mukesh an other supporting staff of the Gas Dynamics Laboratory, and Mr. Sham L. Mr. Hardit, Mr. Sharma and Mr. Chandan of the departmental Workshop, for their sincere efforts and help in making the experiment a great success.

The author is thankful to M/s Ahuja Radios, for their valuable help in getting frequency responses for the driver unit and the microphones.

The author is also thankful to the staff of the Vibration and Instrumentation Laboratory, Instrument Design and Development Center, Sheet Metal Shop of Central Workshop, Computer Center and Library for their help and co-operation.

The financial support, for the present work, provided by the Ministry of Education, Government of India, under Quality Improvement Programme, is gratefully acknowledged. The author is also grateful to the Principal, Motilal Nehru Regional Engineering College, Allahabad, for sanctioning him study leave, under Quality Improvement Programme, for completing the Ph.D. work.

A special word of thanks for Mr. B. L. Tuli, Mr. K. K. Pathak and Miss Neelam for typing the thesis, for getting the tracings made and for typing the mathematical portion of the thesis respectively.

The author's heartfelt thanks are also due to his friends and well wishers for their direct or indirect assistance during his Ph.D. Programme.

Last but not the least, the author wishes heartiest thanks to his wife Shashi, daughter Shanchli and son Shalok who, by virtue of being his own, have been kept neglected from his side during the research programme.

LCMalhotra

New Delhi-110016 (L. C. MALHOTRA)
27.7.1982

ABSTRACT

Exhaust noise which may reach levels as high as 155dB(A) is a dominant component of overall noise in many situations. This thesis reports study of transmission loss of one of the various kinds of mufflers that can reduce this noise viz. the variable diameter, concentric, perforated tube, cavity resonator. The concentric, uniformly perforated tube, cavity type of acoustic resonator is one of the best available. This resonator has an outer rigid shell around uniformly perforated center tube of diameter equal to that of the inlet (and outlet) tube. The annular space in between is known as cavity and the perforations in the center tube become the communication between the cavity and the gas passage tube. This configuration of muffler provides relatively narrow bands of attenuation ranging from 50 Hz to 4,000 Hz approximately. Beyond this frequency, this configuration provides little attenuation.

A major part of the work reported in this thesis deals with modified configuration of the concentric, perforated tube, cavity resonator, with variable diameter of the perforated tube in the cavity. This modified configuration amounts to the silencer having two concentric perforated tubes- one having diameter equal to that of inlet (and outlet) pipe and the other having larger diameter (lying between the inlet pipe diameter and the outer cavity diameter) with 100% porosity of the inner perforated tube. The above configuration results in two cavities of the shell. Taking one dimensional differential control volumes for the center tube and both the cavities of the shell; a mathematical model, consisting of closed form solution of the transmission loss, has been derived from the

mass and momentum conservation equations taking appropriate assumptions and boundary conditions. This solution has been obtained, assuming zero mean flow in the center tube. It is further assumed that there exists wave motion in both the cavities and the coupling between the two cavities and between the inner cavity and the center tube through the impedance boundary of the perforate. This provides a mathematical model wherein the diameter of the second perforated tube can be changed from minimum to maximum diameter of the cavity, without disturbing the inlet (and outlet) tube diameter. The computer programme incorporating the above solution is developed and run on ICL 2960.

The existing unmodified configuration of a muffler described earlier is a special case (with 100% porosity of the outer perforated tube and a finite porisity of the inner perforated tube) to the more general modified configuration dealt with in this thesis. The values of the transmission loss, in the frequency range of 100 - 10,000 Hz, have been calculated, for the muffler of unmodified configuration of different cavity lengths, outer cavity diameters, diameter of the inlet and outlet tubes having perforated tube of different porosities, for air as medium at 20°C. The results thus obtained upto the second place after decimal point are compared with the existing results. The two results agree very closely within the range of 0.0 - 0.1 dB for the whole frequency range except at some of the peaks where the results have a difference of about $\pm$ 1.0 dB

A number of mufflers, of modified configuration, of different lengths, outer cavity diameter, diameter of the perforated tube and porosity, have been computed for air as medium at 20°C, for the number of cosine terms required for convergence of series. The transmission loss, thus calculated, is seen to increase, with the increase in diameter of the perforated tube from the minimum to the maximum cavity diameter, keeping other dimensions constant, in the frequency range from about 2500 Hz to 10,000 Hz. The sharp peaks become higher and wider at the base and shift to the high frequency side because of the widening of the base. Hence, the broad peaks inbetween reduce in their width, but with higher transmission loss. For mufflers of smaller lengths the number of broad and sharp peaks in the whole frequency range is less as compared to the longer mufflers.

The theorteical results of transmission loss of the modified configuration are verified against experimental results obtained by measurements of transmission loss for a number of resonators with modified configurations in the laboratory. The noise signals taken up by microphones at the inlet and outlet of the resonator are fed to the measuring amplifier, which gives the amplitude of the noise signals in dB. The transmission loss is then calculated from already existing formula. The experimental results are then plotted and compared with the theoretical results. The experimental results are seen to fall with in $\pm$ 1.25 dB of the theoretical results except at sharp peak points where the experimental results are lower than the theoretical results by 5.0 dB to 8.0 dB.

It is concluded that the modified configuration gives higher transmission loss for larger diameters of the perforated tube than that given by unmodified configuration for the least diameter of the perforated tube equal to that of the inlet (and outlet) pipe. The existing unmodified configuration gives little or no transmission loss in between the short and very sharp peaks after about 3500 Hz frequency But the modified configuration gives broad peaks in between the large and broad based sharp peaks.

CONTENTS

Page

Page

Page