SYSMEAS PROGRAM FOR ACOUSTICAL MODELLING OF MUFFLER SYSTEMS

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1. INTRODUCTION

A computer program called SYSMEAS has been developed for Acoustical Parameter Estimation and System Modelling of muffler systems. Siemens Automotive is currently using this program as a predictive tool for the preliminary design of intake resonators. SYSMEAS is a Matlab^{TM} based program that combines both theoretical and measured data to predict various acoustical performance parameters such as insertion loss (IL) and transmission loss (TL). This paper outlines the theory behind SYSMEAS, describes the features of the program, and illustrates the accuracy of the computer model's parameter estimation.

2. THEORY

The SYSMEAS program utilises the Transfer Matrix Method as described by Munjal [1]. This method describes the input/output relationships between acoustic pressure and velocity across different types of elements. Each element is characterised by a two-by-two 'four-pole parameter' transfer matrix. These parameters are based on the element's physical and acoustical properties. The resultant system transfer matrix can then be used for the calculation of insertion and transmission losses of an acoustic muffler. In order for the model to better approximate the effects of flow on the acoustic performance of the system, an aeroacoustic formulation of the transfer matrix, also described by Munjal [1], is applied. The formulation is valid up to the cut-off frequency of the system, defined by the largest lateral dimension above which modes other than the fundamental plane wave mode begin to propagate.

The transfer matrix of each element may be derived theoretically or through measurement. Measurements of muffler components and the resulting analysis used in SYSMEAS are based on the method developed by Chung and Blaser [2]. This method uses two pairs of microphones (one pair upstream and one pair downstream of the element) to get the sound intensity on each side of the element. A minimum of two loads with known termination impedances is needed to estimate the four-pole parameters for the transfer matrix.

3. SYSMEAS PROGRAM

Matlab^{TM} was chosen as the application language for this program because of its ease with manipulating matrices. SYSMEAS runs on any PC computer with a Windows O/S and a current version of Matlab^{TM} installed. The latest version of the program operates under Matlab^{TM} Release 12.

3.1 System Design

Muffler systems designed in SYSMEAS can be comprised of any combination of ten types of elements (listed in Table I).

Table I. SYSMEAS supported element types.

Uniform straight tubes	Conical tubes	Extended-tube resonator	Concentric hole-cavity resonator	Full expansion chamber
Helmholtz resonator	Overlap tuner	Quarter-wave resonator	Simple area discontinuity	Measured element

There are also various system parameters than can be selected, including the inlet source type, outlet termination type, and fluid parameters such as the fluid temperature and flow rate. Source and termination impedances can be modelled as ideal (open, closed, or anechoic), or measured impedance data can be used. Similarly, measured source strength spectral data can be used if an estimate of absolute radiated sound pressure is required, or the source may be considered 'white'.

3.2 Analysis

Once the system has been modelled, SYSMEAS can analyse its various performance parameters. The program can estimate the TL and IL of any subset of elements as a function of frequency. The pressure at a junction between two elements or radiated into the far field can be estimated, as can the pressure distribution along any straight tube. Finally, the pressure drop across a series of elements can be calculated.

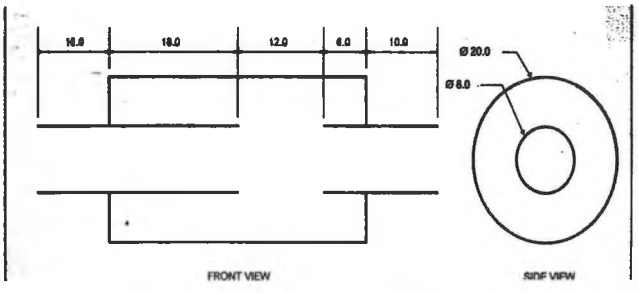

Figure 1. Dimension diagram (in cm) of expansion chamber.

3.3 Data Acquisition and Evaluation

SYSMEAS utilises a modular formulation for data acquisition. Data can be acquired directly from Matlab^{TM}-supported DSP cards, GPIB equipped analysers, or read from a variety of different file formats according to user requirements (this module may be customised for each user). After a measurement has been acquired, it is saved to a file. The element's characteristics can then be calculated from the measured data files. These characteristics are then saved in a separate element library.

3.4 Optimisation

The optimisation module allows the user to simultaneously optimise some of the parameters of theoretical elements located within the system. This optimisation uses constrained minimisation techniques. One of three different cost functions can be selected: maximisation of TL, maximisation of IL, or minimisation of radiated pressure from the system outlet. These functions are optimised over a selected frequency range.

4. RESULTS

The SYSMEAS program can be validated by comparing measured TLs for a given muffler system to the TLs predicted by SYSMEAS.

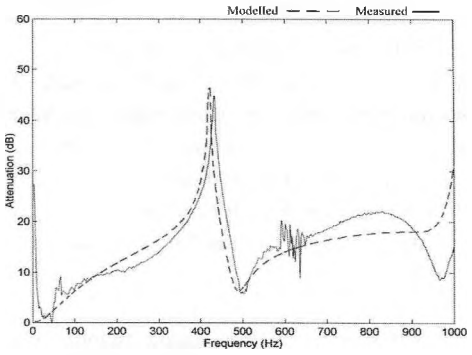

Figure 2. Transmission losses for expansion chamber.

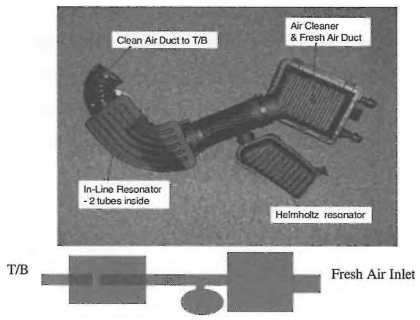

Figure 3. Daimler Chrysler LH 3.5L induction system.

A simple expansion chamber, with extended inlet and outlet tubes, was modelled and then measured to evaluate the accuracy of SYSMEAS. The dimensions of the expansion chamber are shown in Figure 1. The results of the comparison, illustrated in Figure 2, show a good correlation between theory and experiment.

A more complex muffler system was also tested. The muffler shown in Figure 3 is in current production for the Daimler Chrysler LH (Intrepid) 3.5L induction system. The measured and modelled TLs are shown in Figure 4. Again, a reasonably good correlation is shown.

REFERENCES

[1] Munjal, M.L. Acoustics of Ducts and Mufflers. New York: John Wiley & Sons (1987).

[2] Chung, J.Y. and Blaser, D.A. *Transfer function method of measuring in-duct acoustic properties*, Engineering Mechanics Department, General Motors Research Laboratories, June 5, 1980.

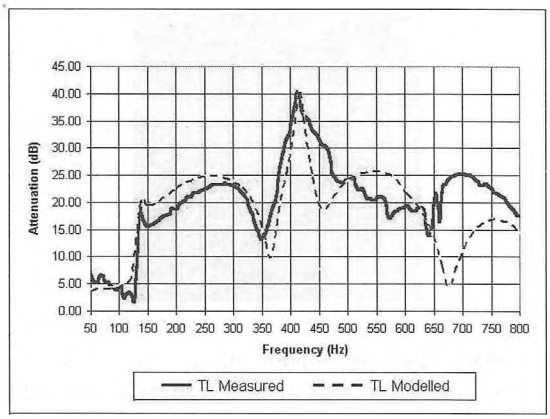

Figure 4. Transmission losses for Daimler Chrysler LH 3.5L induction system