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AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

ANALYSIS OF AUTOMOBILE ENGINE NOISE
AND METHODS OF ITS REDUCTION

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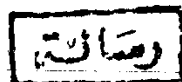


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A B S T R A C T

Mufflers of expansion chambers , resonators , and combined mufflers are tested with respect to their effect on the attenuation of the exhaust noise of a petrol engine installed on a sedan car . Also the change of the back pressure in the exhaust pipe is measured for each type of mufflers with different values of parameters . A comparison between the obtained experimental results and the theoretically calculated values are carried out for examining the validity of the used theories in muffler design .

The expansion ratio and the chamber length of the expansion chamber are changed . The resonator is tested with different values of its cavity volume and acoustic conductivity . The acoustic conductivity is changed in two conditions , the first is by changing the number of the connecting holes , while the second is by changing the connecting holes diameter . The results are also taken when the resonator cavity is filled with glass wool. The combined muffler is tested with the two possible arrangement of its chambers , once when the resonator is leading the expansion chamber and the other when the expansion chamber is the leader.

The noise spectra of the unmuffled engine and when it is muffled with the tested mufflers are obtained by using the third octave/octave automatic analyser . The attenuation spectra and its weighted value " A " which is correlated to the annoyance caused by the traffic noise are investigated .

The results show that the attenuation increases by increasing the expansion ratio of the expansion chambers, the cavity volume of the resonators and its acoustic conductivity . The frequency at which the maximum attenuation occurs increases by decreasing the expansion chamber length , decreasing the cavity volume and increasing the acoustic conductivity of the resonator connecting holes . When the resonator cavity is filled with glass wool the attenuation increases with no change in the resonance frequency .

The inspection of the weighted " A " attenuation at different values of the muffler parameters shows that the increase of the attenuation by increasing the parameters values is limited with a certain value of each parameter . Increasing the parameters value than this limit, the attenuation starts to decrease again . This limitation is due

to the effect of increasing of the parameters values in changing the muffler phenomena which makes it to work as another type and the generation of the radial noise waves which pass through the muffler without attenuation .

The results show also that the simple expansion chamber is characterised with a negative attenuation at low frequency region which makes it unsuitable for use in passenger car noise attenuation when it works at low speeds cities . This negative attenuation could be eliminated by using a combined muffler composed of an expansion chamber followed by a resonator tuned at this low frequency region .

The inspection of the effect of the different mufflers on the rise of the back pressure in the exhaust pipe shows that the maximum rise is produced by the combined muffler while the minimum is produced by the simple expansion chamber .

S Y M B O L S

A	Noise reduction	dB
C	Sound velocity	m/sec
C _o	Acoustic conductivity	m
D ₁	Exhaust pipe diameter	m
D ₂	Chamber diameter	m
d	Connecting holes diameter	m
d _t	Tailpipe diameter	m
f	Frequency of the sound wave	Hz
f _c	Cut-off frequency	Hz
f _r	Resonance frequency	Hz
F _m	Panning friction factor	
K	Wave length parameter = $2 \pi f/C$	m ⁻¹
L _e	Chamber length	m
l _t	Tailpipe length	m
l _c	Connector length	m
m	Expansion ratio = $(D_2/D_1)^2$	
N	Engine speed	r p m
n	Number of connectors	
P	Exhaust gas pressure	N/m ²

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S_1	Exhaust pipe cross-section area	m^2
S_2	Chamber cross-section area	m^2
V	Chamber volume	m^3
V_p	Piston displacement	m^3
v	Exhaust gas velocity	m/sec
λ	Wave length	m
ρ	Average density of the conducting medium	kg/m^3
μ	Average coefficient of viscosity of the conducting medium	$kg/msec$

Any other symbols used will be indicated in the text.

CHAPTER 1

INTRODUCTION

Noise holds an especially negative position among the environmental factors which affect man's comfort today. It reduces the working capacity, increases the level of errors and disturbs intellectual-creative activity.

Furthermore, high noise level results in physical damages. Hardness and loss of hearing due to high noise levels become the most frequently acknowledged occupational disease.

The most important noise source affecting the human ear in our daily life is the motor-car noise. This noise was found to be emitted from the following sources :-

- a - Engine exhaust
- b - Engine suction
- c - Moving elements
- d - Ventilation system
- e - Road and tyre friction
- f - Body and air friction

It was found that the engine exhaust is the most dominant source. It is generated due to the high

velocities of the exhaust gases through the valves and the pipes as air-born noise , and from the exhaust system to the surrounding as structure-born noise , then again as air-born noise.

Different silencing techniques are used to reduce the noise level of the motor cars so that the attenuated exhaust noise may not exceed the safety limits for the human ear .

Many theoretical studies were dealt with determining the attenuation results from different types of mufflers. In those studies , some assumptions were used for simplifying the derivation of the governing equations . The theoretical values obtained deviates from those of the actual due to neglecting some important factors and conditions in the assumptions .

In the following study the experiments were carried out on a wide range of different mufflers installed on a motor vehicle . The actual attenuation would be measured to study the actual effects of the muffler parameters on the noise attenuation . Also the effect of these parameters on the back pressure in the exhaust pipe were tested .

The best muffler which gives the required noise attenuation from the point of view of its type and parameter were obtained . A comparison between the actual obtained attenuation and the theoretically calculated values showed to what extent the theoretical calculations could be used in mufflers design and in judging their performance.

The inspection of the back pressure in the exhaust pipe due to muffler insertion will show if the muffler affect the engine performance with a considerable value or not .

CHAPTER II

REVIEW OF THE PREVIOUS WORK

In recent years the general idea is that a healthy exhaust is a sign of engine efficiency . Many researches and development work have been done to obtain the most suitable way to reduce the exhaust noise with a least effect on the engine performance . These work have been done on the fundamentals of sound filtration.

Norris (1) showed that the exhaust noise is the most important cause of the motor car noise . In that discussion he assumed that the exhaust noise is a sound wave having the frequency of the engine firing , neglecting other modes at which sound may be transmitted.

An early study has been done at Sulzer (2) for measuring the noise level as a function of time for a Diesel Engine with and without silencing device . The change of the noise level with the frequency (noise spectrum) was not available without the use of the sound analyser which was not in hand at that time. An imperical relation between the engine parameters and the volume of the silencer was suggested for

different types of engines . For the high speed engines the relation is given in the form :-

$$V = R V_p / N \sqrt{r z}$$

where:

R = 3 for the passenger car engine to
give the volume in liters

r = 1 for 4-stroke engines

= 2 for 2-stroke engines

z = No of cylinders

In this formula the type and the construction of the
silencer have not been taken into consideration .

The acoustic theory and muffler literature were
studied with the aim of obtaining a method of predicting
muffler characteristics by Stewart(3) . The theory
of acoustic filters based on the change of the wave
front area and the transmission of the sound through a
conduit with an attached branch were used in designing
the expansion chamber and resonator mufflers as shown
in fig. (1) . Experimental studies demonstrate that
this theory is reasonably accurate for small filters ,
with stationary air at room temperature as sound conduc-
ting medium . When the equation of the acoustic filters