Journal of Fluids and Structures 82 (2018) 134–153

Contents lists available at ScienceDirect

Journal of Fluids and Structures

journal homepage: www.elsevier.com/locate/jfs

Prediction of the transmission loss in a flexible chamber

A.J. Torregrosa [a], A. Gil [a], L.M. García-Cuevas [a], P. Quintero [a,*], F.D. Denia [b]

[a] *CMT-Motores Térmicos, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain*
[b] *Centro de Investigación en Ingeniería Mecánica, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain*

ARTICLE INFO

Article history:
Received 24 November 2017
Received in revised form 27 March 2018
Accepted 6 July 2018

Keywords:
Silencer
Muffler
Expansion chamber
Finite element method
Finite volume method
Flexibility
Deformation
Acoustics
Vibroacoustics
Fluid–structure interaction
2 way FSI

ABSTRACT

Acoustic components have been extensively studied supposing perfectly rigid behavior. Although some works have been performed for the radiated sound in the case of a flexible element, an important lack of information exists concerning transmission loss analysis. The current investigation proposes the study for a generic flexible expansion chamber. The analysis has been performed using two different methods: a resolution in the time domain, using a Finite Volume discretization for the fluid domain and a Finite Element discretization for the solid domain, and an approach in the frequency domain, using a Finite Element discretization for both fluid and solid. After studying the rigid case in order to tune up the simulation, the study of the flexible case shows a good agreement among both methods. The comparison of rigid and flexible expansion chambers shows the importance of accounting for these phenomena when the frequency content of the acoustic signal excites the natural modes of the structure.

1. Introduction

Reduction of noise emissions is currently an important area of interest because of its practical importance. A document of the *World Health Organization for the European Union* (W.H.O., 2010) showed that near 40% of citizens of the EU experience road noise of about 55 dB(A). A 30% of European population experiences road noise over 55 dB(A) during night.

Recent regulations focus their application on an effective reduction of noise (Union, 2014). In order to comply with regulation without jeopardizing engine performance, various noise control methods have been developed. These kind of control methods can be categorized as passive or active systems (Hansen, 2003).

Active noise techniques allow obtaining a very high reduction of observer perceived noise. However, this kind of control is associated with some issues of cost and reliability. Currently, their application on the transport industries is not approachable. For instance, Linus et al. (2017) demonstrated that the performance of active-noise canceling headphones is dependent on the noise environment. Under some circumstances, they showed how its performance could be unacceptable. In the automotive field it is necessary for a control mechanism to be useful on the whole range of operation making the use of this kind of devices currently out of scope.

Due to these limitations, passive noise control is nowadays the principal engineering solution. A general categorization of passive elements can be split as dissipative or reflective. Dissipative noise control allows a high noise reduction. For example, Hwang et al. (2017) showed how using dissipative viscoelastic materials allows an effective noise control. However, porous absorption materials lose acoustic performance for low frequencies. When the frequency is low, the thickness of a porous absorber is less than one quarter of the acoustic wavelength and absorption becomes inappreciable (Munjal, 2014).

* Corresponding author.
E-mail address: pedquiig@mot.upv.es (P. Quintero).

https://doi.org/10.1016/j.jfluidstructs.2018.07.003
0889-9746/

Nomenclature

ρ	Density
$\vec{w}$	Solid displacement
$\underline{\boldsymbol{\sigma}}$	Solid Stress tensor
$\vec{b}$	Solid volume forces
$\vec{f}_m$	Fluid volume forces
Q	Fluid volume heat generation
ϕ_v	Viscous dissipation
ε	Solid strain
λ	1st Lamé parameter
μ	2nd Lamé parameter or viscosity (according to context)
E	Young modulus
c_p	Specific heat
ν	Poisson ratio
u	Fluid velocity
τ	Fluid stress tensor
p	Pressure
T	Temperature
h	Enthalpy
c_p	Specific heat
$\vec{n}$	Surface normal vector
t	Time
a	Sound speed
k	Thermal conductivity
k_0	Wave number
j	Imaginary unit
R	Radius or gas constant (according to context)
δ	Thickness or Dirac Delta (according to context)
$[A]$	Transfer matrix
TL	Transmission Loss
VR	Velocity ratio
f	Frequency
h	Enthalpy
T_S	Sampling time
$[M]$	Mass matrix
$[C]$	Damping matrix
$[K]$	Stiffness matrix
ω	Angular frequency
L_{muff}	Expansion chamber length
m^*	Mass ratio
D^*	Stiffness parameter
v	Velocity at the boundary conditions

Subscripts and superscripts

0	Unperturbed case
ref	Reference data
in	Inlet
out	Outlet
$*$	Non dimensional variable

For reactive noise abatement techniques, part of the sound wave is reflected towards the source, or back and forth among the elements. Some examples of these elements are: expansion chambers, Helmholtz resonators, Herschel Quinke tubes, etc. These elements allow dealing with low frequency noise (Aydemir and Ebrin, 2009).

Traditionally, reactive elements have been extensively considered as infinitely rigid, i.e. wall displacement and/or velocity is supposed to be negligible from the fluid behavior point of view. This is effectively true in most of the current applications in the automotive industry. However, very low density–low rigidity materials are becoming of interest. As an example it could be useful to refer to the works of Aydemir and Ebrin (2009), Nunes et al. (2001) and Hu et al. (2003).