Case Studies in Thermal Engineering 10 (2017) 86–94

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

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

Investigation of baffle configuration effect on the performance of exhaust mufflers

Ahmed Elsayed[a,c,*], Christophe Bastien[b], Steve Jones[a], Jesper Christensen[b], Humberto Medina[c], Hassan Kassem[d]

[a] Institute for Advanced Manufacturing Engineering (AME), UK
[b] Centre for Mobility and Transport, Coventry University, UK
[c] School of engineering and computing, Coventry University, UK
[d] School of Mathematics, Computer Science and Engineering, City University London, UK

ABSTRACT

Using baffles in exhaust mufflers is known to improve their transmission loss. The baffle cut ratio should affect the muffler performance analogous to a shell-and-tube heat exchanger. To the authors' knowledge, there is no previous assessment reported in literature of the effects that the baffle cut ratio configuration has on acoustic response and back pressure. This investigation presents a parametric study on the effect of baffle configuration on transmission loss and pressure drop predicted. The effect of (i) the baffle cut ratio and baffle spacing, (ii) the number of baffle holes, and (iii) the hole distribution for their effect on transmission loss was investigated. Results show that decreasing the baffle cut ratio tends to increase the transmission loss at intermediate frequencies by up to 45%. Decreasing the spacing between muffler plates was shown to enhance the muffler transmission loss by 40%. To assess the baffle effect on flow, the OpenFoam CFD libraries were utilized using the thermal baffle approach model. Baffles were found to cause sudden drop in fluid temperature in axial flow direction. The outlet exhaust gases temperature was found to decrease by 15% as the baffle cut ratio changed from 75% to 25%.

1. Introduction

Transmission loss (TL) is usually measured using the three point (decomposition method) or four pole methods; the four pole method is carried out by a two-source method and two-load method [1]. Several numerical approaches are utilized to model transmission loss in exhaust mufflers using finite element softwares Actran [2] and Comsol Multiphysics [3], Boundary element methods (BEM) using COUSTYX [4], and transfer matrix approach using Ricardo wave [5,6]. In the current analysis both Ricardo wave and Comsol multiphysics were utilized for predicting transmission loss.

Reactive mufflers depend on reducing the exhaust noise through a volume depending on reflection of sound noises [7,8]. Utilization of baffles in exhaust mufflers have been reported to have an improvement effect on the transmission loss of muffler by more than 50% [9–11]. Roy investigated the effect of internal baffles complete circular baffles with single centred holes on the transmission loss using harmonic BEM using LMS's Virtual Lab Acoustics module with and without extensions on baffles. The TL in the lower frequency spectrum is reduced while the mid to high frequency spectrum is greatly increased using baffles [11]. The effect of tapered connected expansion chambers has been also reported by Horoub [12] investigating the effect of connecting different sizes of expansion chambers. CFD studies for the several connected expansion chambers showed that extension on baffles helps reducing

* Corresponding author at: Institute for Advanced Manufacturing Engineering (AME), UK.

http://dx.doi.org/10.1016/j.csite.2017.03.006
Received 30 November 2016; Received in revised form 28 January 2017; Accepted 27 March 2017
Available online 28 March 2017

the pressure drop in muffler compared to single expansion chamber with same size due to the reduction in secondary flow losses and separations [13]. Recent studies investigated the effect of baffle spacing on the Sound pressure level (SPL) [14] where less spacing between baffle reduces the SPL. The effect of holes' arrangement in perforated tubes on transmission loss has been investigated by [15].

There is no investigation on the effect of baffle configuration on both transmission loss and back pressure in exhaust mufflers. This investigation highlights the effect of geometrical baffle configurations associated with four main parameters; baffle cut ratio, number of holes, holes distribution and baffle spacing.

Ricardo-Wave is a one-dimensional gas dynamics code based on finite volume method for simulating engine cycle performance. It is widely used by automotive and exhaust manufacturers such as Eberspächer [16,17] and Jugar Land-Rover [18]. Also, COMSOL Multiphysics Modelling Software is known to the capability to model transmission loss of different mufflers such as reactive, absorptive and hydride mufflers. Therefore, Ricardo-wave and COMSOL Multiphysics have been proposed for the prediction of transmission.

2. Numerical solvers and models setup

Wave has acoustics tools that enables exhaust muffler designer to calculate the insertion loss as well as radiated shell noise, tailpipe noise of exhaust system, where information about the engine as an acoustic source is needed in such cases. Model geometries are established in wave build 3D software. In the pre-processing stage, Ricardo-wave 3D build discretised the CAD model into small element standard connection such as T-element or y-element to represent one dimensional acoustic network Based on transfer matrix method (correlates the wave sound pressure and acoustic velocity at inlet and outlet of muffler), in the acoustic analysis acoustic source at inlet and anechoic termination at outlet (material that absorbing reflected sound waves such as fibre). Four microphones are placed at a ratio of 0.4 and 0.8 of the upstream and downstream pipe lengths connected to the muffler based on Ricardo wave default settings. The muffler was discretized to 20 mm in spatial co-ordinates.

In COMSOL Multiphysics, finite element approach is used solving HelmHoltz equation where volume mesh is generated and error weighting functions are solved to certain convergence tolerance.

The baffle cut ratio should affect the muffler performance analogous to a shell-and-tube heat exchanger. Fig. 1 summarizes the

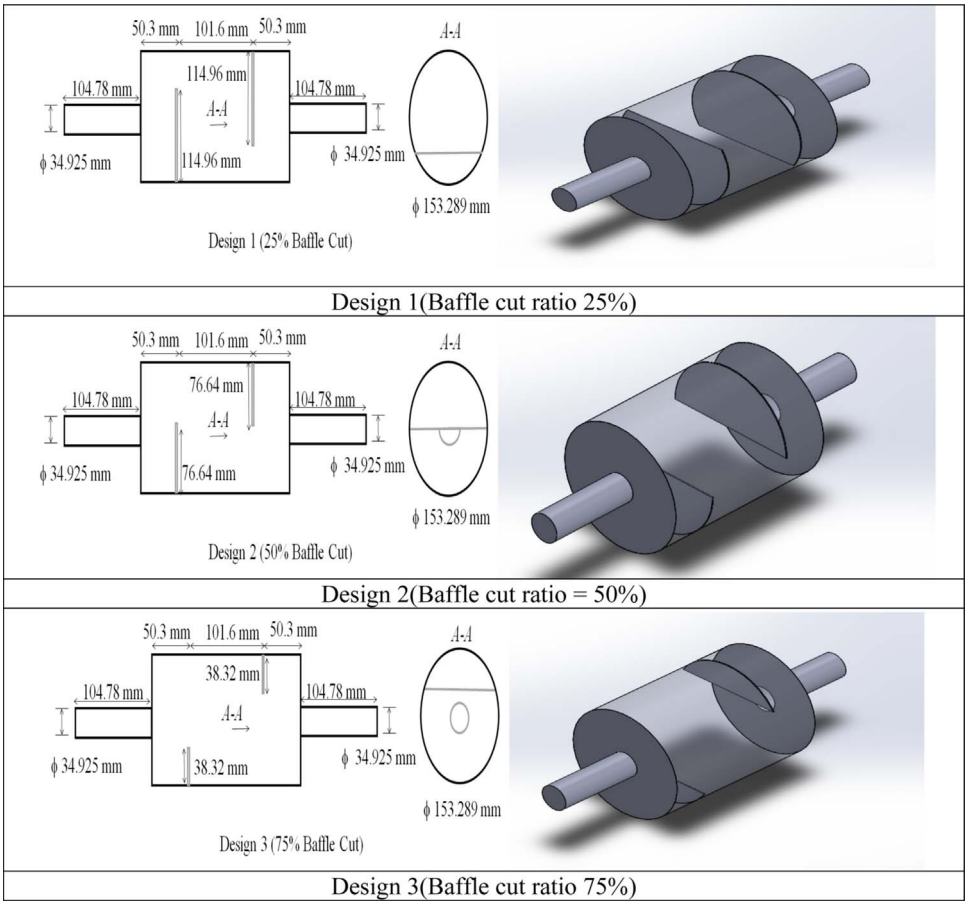

Fig. 1. Baffle cut configurations.