ARPN Journal of Engineering and Applied Sciences

AN INNOVATIVE CONCEPT TO IMPROVE THE MUFFLER PERFORMANCE USING AUTOMATED MECHANICAL IRIS

Mohammad Ahsan Habib[1], Ahmad Syed Anwar[2,1] and Md. Anayet U. Patwari[1]
[1]Department of Mechanical and Chemical Engineering, Islamic University of Technology, Dhaka, Bangladesh
[2]Roadmaster Motors Limited, Dhaka, Bangladesh
E-Mail: mahabib@iut-dhaka.edu

ABSTRACT

With the development of modern civilization vehicle noise is become one of the main source of noise pollution to the environment. A lot of research has been done in recent times in the field of acoustic filters and exhaust mufflers in order to reduce the exhaust noise. While using exhaust muffler, a back pressure on engine is always produce. This back pressure represents the extra static pressure exerted by the muffler on the engine through the restriction in flow of exhaust gasses. The back pressure value mainly depends on the muffler design and exit diameter of the exhaust muffler. It has been found that for a constant exit diameter of an exhaust muffler the back pressure varies with the change of the engine speed. Due to this variation of the back pressure, the fuel consumption per unit distance is also varies. An attempt has been made in this study to stabilize the back pressure to a suitable value by using an automated mechanical IRIS. The function of the mechanical IRIS is to provide a variable exit diameter to the exhaust muffler. An automated mechanical system will be integrated with the IRIS, so that the exit diameter will vary automatically depending on the engine speed. It has been found through 3D based CFD simulation that the back pressure remains constant for a wide range of speed of the engine. This will ensure maximum the fuel consumption per unit distance throughout the wide range of speed variation.

Keywords: exhaust muffler, back pressure, mechanical IRIS, exit diameter.

INTRODUCTION

Practically all reciprocating internal combustion engines are fitted with mufflers. The muffler fitted to an engine is intended to reduce the pressure pulses associated with the exhaust gas leaving the cylinders of the engine. The design of mufflers has been a topic of great interest for many years and hence a great deal of understanding has been gained. Generally mufflers fitted to such engines are essentially reactive devices as opposed to being dissipative devices. The design of mufflers has been a topic of great interest for many years and hence a great deal of understanding has been gained. Hence good design of the muffler should give the best noise reduction and offer optimum back pressure for the engine. Moreover, for a given internal configuration mufflers have to work for a broad range of engine speed.

Mufflers have been developed over the last ninety years based on electro- acoustic analogies and experimental trial and error. Many years ago Stewart used electro – acoustic analogies in deriving the basic theory and design of acoustic filters [1]. Lima *et al*. shows the application of shape and parametric optimization techniques in the study of reactive silencers with extended inlet and outlet ducts. Parametric optimization is employed to evaluate the appropriate size of the inlet and outlet ducts. Shape optimization is employed to establish the proper profile of these ducts in order to improve the acoustic features of these mufflers in a specific frequency range [2]. Blanco *et al*. describes methodologies developed to reduce the noise radiated from silencers while keeping or improving engine performance; i.e. whilst minimizing the pressure loss through the silencer. This work was successfully developed to help motorcycle designers to meet the current legal noise limitations with minimum detriment to engine performance [3]. Munjal *et al*. gave expression for the attenuation of mufflers using the transfer matrix approach [4]. The expression they developed was based on the velocity ration concept. Later, Mujal modified this approach to include the convective effects due to flow [5].

A conventional muffler of internal combustion engine is mostly constructed as a mixture or combination of perforated ducts, baffle or perforated baffle, expansion chamber, etc., and the noise reduction is limited and back pressure is high hence the fuel efficiency is low. In order to solve the problems of traditional exhaust silencers with poor characteristics of noise reduction in low-frequency range and high exhaust resistance, a new theory of exhaust silencer of diesel engine based on counter-phase counteract and split-gas rushing has been proposed by Ying-Li Shao [6]. Young and Crocker used the finite element method to predict four-pole parameters and then the transmission loss of complex shaped mufflers for the case of no flow [7]. S. N. Panigrahi *et al*. attempts to exploit the speed of the one-dimensional analysis with the flexibility, generality and user-friendliness of three-dimensional analysis using geometric modeling. A code based on the developed algorithm has been employed to demonstrate the generality of the proposed method in analyzing commercial mufflers by considering three very diverse classes of mufflers with different kinds of combinations of reactive, perforated and absorptive elements [8]. Middlberg *et al*. present different configurations of simple expansion chamber mufflers,

ARPN Journal of Engineering and Applied Sciences

including extended inlet or outlet pipes and baffles have been modeled numerically using CFD in order to determine their acoustic response [9]. A three-dimensional finite element method has been implemented by Mehdizadeh *et al*. to predict the transmission loss of a packed muffler and a parallel baffle silencer for a given frequency range. Iso-parametric quadratic tetrahedral elements have been chosen due to their flexibility and accuracy in modeling geometries with curved surfaces [10]. In summary, most of the research studies are based on the formulation of mathematical equation and its virtual simulation and trial and error method. In addition, some of the research studies are based on the design modification of the muffler. However, all these design modification is limited to internal shapes only.

The scope of this work is to establish a new concept in muffler design by introducing an automated mechanical IRIS at the exit tip. With the change of the engine speed and engine load, the fuel consumption per unit distance varies, at the same time the back pressure of the engine also varies. For this reason, an attempt has been made to stabilize the back pressure of the engine by changing the diameter of the exit tip of the muffler with the help of an automated mechanical IRIS. It has been found in the study that, with the change of the engine speed and engine load, the mechanical IRIS can automatically adjusted its exit tip so that the back pressure remains constant. In this way, a constant back pressure can be achieved from this automated system for getting a maximum fuel consumption rate throughout a wide range of speed.

DESIGN OF MECHANICAL IRIS AND ITS MECHANISM

Engine muffler is one of the important part of an automobile system. Figure-1 shows cross section of some typically manufactured motorcycle mufflers. As it is stated before that these kind of locally manufactured mufflers are not able to provide better fuel consumption per unit distant for a wide range of engine speed. In order to overcome this problem, a mechanical IRIS is coupled at the exit point of the muffler. Figure-2 shows the CAD design of the engine muffler without and with the mechanical IRIS.

The details design of the automated mechanical IRIS is shown in Figure-3. The whole system will be kept inside the IRIS Enclosure, its one end is exhaust gas IN terminal which be joint with the muffler exit end and its other end an Outside Cap will be welded having the exhaust gas OUT passage. Inside of the IRIS Enclosure, there is a Rotor Housing holding the IRIS and the Rotor. The Blades of the IRIS is fixed with the Rotor Housing and the Blade Actuating ring of the IRIS is rotatable. If the Blade Actuating Ring rotates, the inner hole of the Blades increases or decreases. The rotation of the Blade Actuating Ring is controlled by a Rotor. Two types of movement is available in the Rotor, one is axial movement and another is rotational movement. As the Rotor is pass through three shafts that are connected with the blade actuating ring, the axial movement is always along the shafts. At the outer circumference of the Rotor few Key Slots are present, which are connected with the Rotor Guide of Rotor Housing. Due to the Key Slot and Rotor Guide, any axial movement of the Rotor will provide a rotational movement of the Rotor. For this reason, if the Rotor rotates either clockwise or anti clockwise, the blade actuating ring will also rotate and the inner hole of the Blades will increase or decrease. The axial movement of the Rotor will be controlled by the exhaust gas pressure. The exhaust gas will apply pressure on the cross bar of the Rotor. Due to high pressure the Rotor will move outside and when the pressure drops the Rotor will move backward due the effect of the spring. The stiffness of the spring need to be synchronized with the exhaust gas pressure. In order to change the spring stiffness, some nuts will be there on the outside cap. In brief the mechanism is the exhaust gas will pass through the IRIS Enclosure and it will hit the cross bar of the Rotor, then its start moving axially and rotationally. Due to the rotational movement the Rotor and Blade Actuating Ring the inner diameter of IRIS will change. Finally, when pressure drops the Rotor comes to its original position due to the effect of spring. The section headings are in boldface and lowercase letters.

Figure-1. Motorcycle mufflers used in this study.

ARPN Journal of Engineering and Applied Sciences

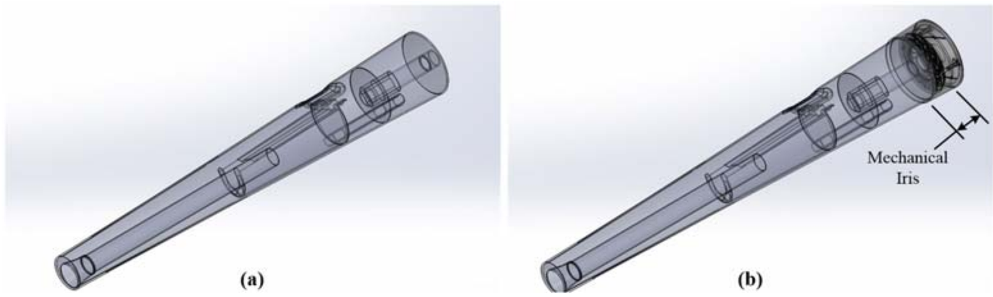

Figure-2. (a) Muffler without mechanical IRIS (b) Muffler with Mechanical IRIS at the exit portion.

METHODOLOGY AND ENGINE SPECIFICATION

In this study, three different speed of motorcycle has been used low speed (3000 rpm), medium speed (4500 rpm) and high speed (6500 rpm). Due to heavy traffic jam in local areas, it is very difficult to run any vehicle over 6500 rpm. For this reason the high speed is limited to 6500 rpm. The physical model of this test setup would be passing air at fixed mass flow rate through the muffler and measuring pressure drop across the muffler. The time conditions implemented are steady state. The Mass flow input is given as a constant number ranging from 82 gm/sec to 180 gm/sec, so the flow is subsonic flow. The solver implemented was pressure based as it is used for incompressible flows to keep the pressure field from oscillating. In order to preserve the incompressibility conditions, pressure correction algorithms are used, for pressure based solvers. For pressure velocity coupling, from the available algorithms Semi Implicit with splitting of operators (SIMPLE) is used as it provides solution without iterations, with large time steps and less computing efforts. From the various interpolating schemes are available in fluent, the second order upwind method is used for interpolating the values of these quantities so as to reduce computation effort. To determine the gradient of the variables Green –Gauss node based method is implemented. Most of the engineering flows are turbulent. Turbulence occurs when velocity gradients are high, resulting in disturbances in flow domain as a function of space and time. So, it is necessary to model the turbulence model appropriately. The Standard K-Epsilon model (SKE) is the used as it is accurately represent engineering turbulence for industrial applications. Standard K- ε (Epsilon) model is a Two-equation turbulence models and allows the determination of both, a turbulent length and time scale by solving two separate transport equations. It is based on model transport equations for the turbulence kinetic energy (K) and its dissipation rate (ε). The specification of the motorcycle engine used for this study is given below:

Table-1. Engine specification.

Engine mode	Single cylinder, 4-Stroke, Air-cooled
Displacement (cc)	120
Related Power Revolution (Kw/rpm)	6.9/7500
Maximum Torque (N.m/rpm)	7.6/8500
Transmission	5 Speed
Ignition	CDI
Starting Mode	Electric / Kick

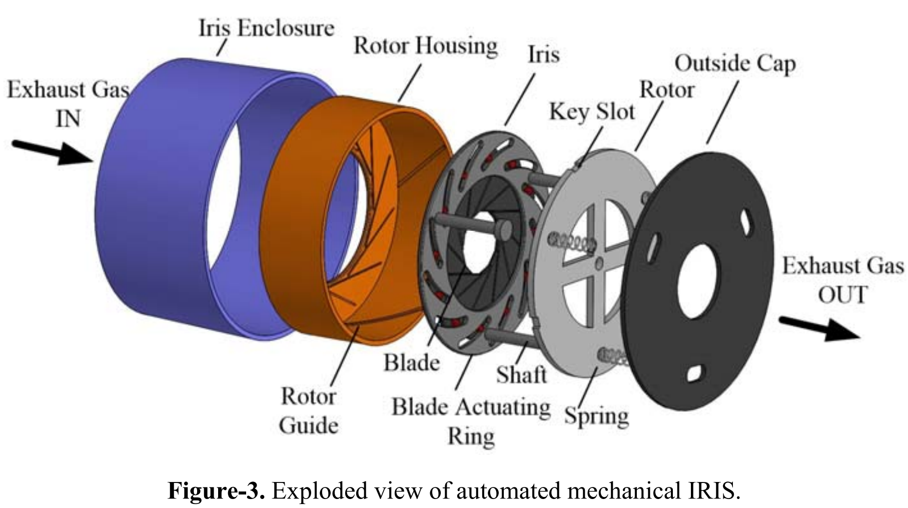

Figure-3. Exploded view of automated mechanical IRIS.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RESULTS AND DISCUSSIONS

It has been found that for this particular type of engine arrangement fuel consumption rate per unit distance is lower for medium speed compare to low and high speed. For this reason the back pressure for medium speed is assumed standard for this study. Figure-4 shows the simulation using ANSYS Fluent module of exhaust gas flow through the muffler at different speed. The exit tip diameter and the maximum back pressure for different rotational speed are tabled in Table-2.

In Figure-4 (a) the back pressure for low speed without the mechanical IRIS is 1767 Pa. However, by using the mechanical IRIS the back pressure has raised to 3445 Pa by reducing the exit diameter of the IRIS from 20 mm to 13 mm (Figure-4(b)), which is almost near to the back pressure of medium speed without IRIS. In the same way, in Figure-4 (e) without the mechanical IRIS the back pressure for high speed is 8384 Pa, which is quite high and consumes a lot of fuel per unit distance. Nevertheless, by increasing the diameter of the mechanical IRIS from 20 mm to 21 mm the back pressure has dropped to 3128 Pa (Figure-4(f)), which is close to the back pressure of medium speed without IRIS. For medium speed the back pressure without mechanical IRIS is 3366 Pa and after using it the pressure remains to 3419 Pa, which is achieved by changing the diameter from 20 mm to 15.5 mm. In this way, a constant back pressure can be maintained in engine system.

CONCLUSIONS

The performance of the muffler for any internal combustion engine is very significant for its smooth running. In order to improve the muffler performance this study presents a new concept of integrating a mechanical IRIS with an engine muffler. IRIS inner diameter is synchronized with the exhaust gas pressure with the help of a spring mechanism. Results show that by using the automated mechanical IRIS the back pressure remain stable throughout the speed variation.

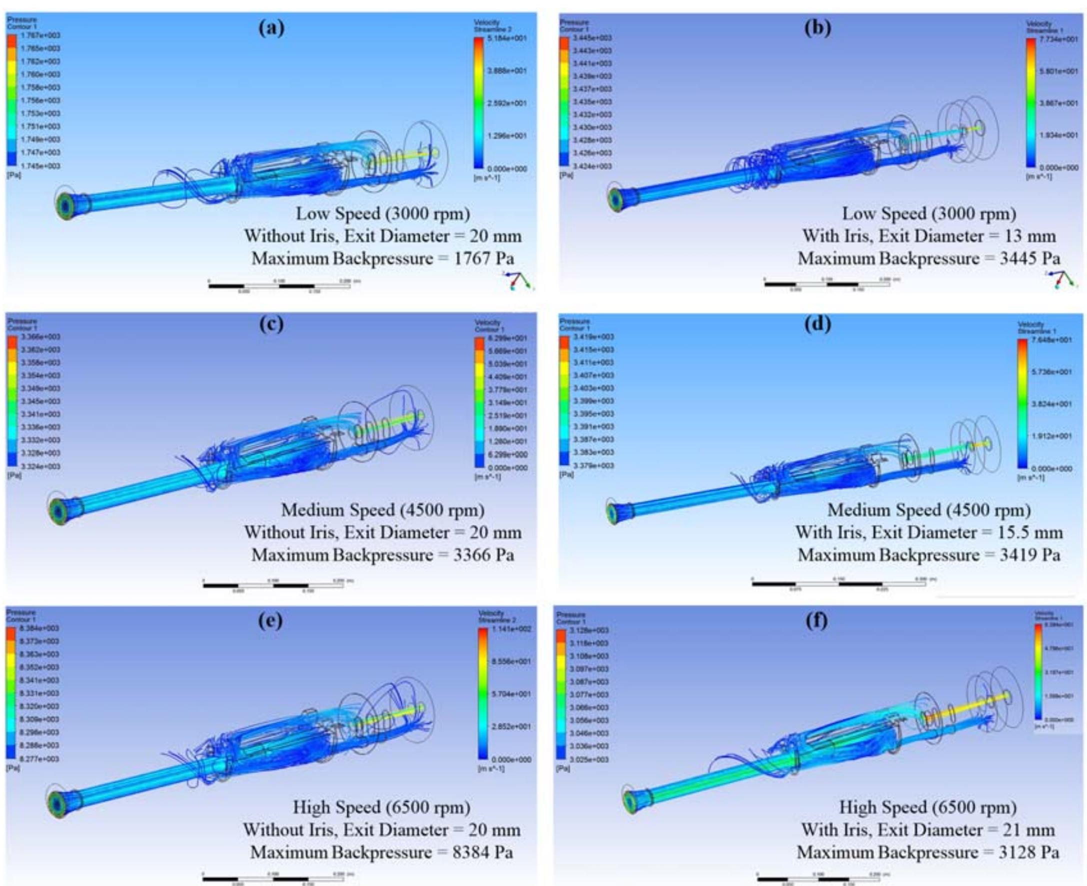

Figure-4. Flow simulation showing back pressure and exit velocity without and with mechanical IRIS for (a, b) low speed, (c, d) medium speed and (e, f) high speed.

Table-2. Summary of the simulation results.

	Rotational Speed (rpm)	Mass flow rate of exhaust gas (gm/sec)	Muffler exit diameter		Back pressure	
			Without IRIS (mm)	With IRIS (mm)	Without IRIS (Pa)	With IRIS (Pa)
Low speed	3000	82	20.0	13.0	1767	3445
Medium speed	4500	114	20.0	15.5	3366	3419
High speed	6500	180	20.0	21.0	8384	3128

ACKNOWLEDGEMENT

This research study was technically supported by Roadmaster Motors Limited (RML), Dhaka, Bangladesh.

REFERENCES

[1] G. W. Stewart. 1922. Acoustic waves filters, Physics Review. 20: 528-551.

[2] K. F. De Lima, A. Lenzi and R. Barbieri. 2011. The Study of Reactive Silencers by Shape and Parametric Optimization Techniques. Applied Acoustics. 72: 142-150.

[3] J. Blanco and A. Earnshaw. 2011. Study of the Noise Characteristics of Motorcycle Silencers. SAE 2001 World Congress Detroit, Michigan.

[4] M. L. Munjal, A.V. Sreenath and M. V. Narasimhan. 1970. Velocity ratio in the analysis of linear dynamical system. Journal of sound and Vibration. 26: 173-191.

[5] M. L. Munjal. 1975. Velocity ratio cum transfer matrix method for the evaluation of muffler with neon flow. Journal of sound and Vibration. 39: 105-119.

[6] Ying-Li Shao. 2011. A Study on Exhaust Muffler Using a Mixture of Counter phase-Counteract and Split-Gas Rushing. Advanced In Control Engineering And Information Science. Engineering. 00: 4409-4413.

[7] C. I .J. Young and M. J. Crocker. 1975. Prediction to transmission loss in mufflers by finite element method. Journal of Acoustical society of America. 57: 144-148.

[8] S. N. Panigrahi and M. L. Munjal. 2007. A Generalized Scheme for Analysis of Multifarious Commercially Used Mufflers. Applied Acoustics. 68:660-681.

[9] J. M. Middelberg, T. J. Barber and T. J. Leong. 2004. Computational fluid dynamics analysis of the acoustics performance of various simple expansion chamber mufflers. Acoustics. 123-127.

[10] Z. M. Omid, P. Marius. 2005. A Three-Dimensional Finite Element Approach for Predicting the Transmission Loss in Mufflers And Silencers With No Mean Flow. Applied Acoustics. 66: 902-918.