Development of Computer Software for Predicting Fuel Consumption Rate of an Automobile with a Leaked Exhaust System

P.K. Oke, B. Kareem

Abstract—**Most of the exhaust systems were manufactured to cater for incomplete combustion of gasoline. Some improvement on the mixing of the air and fuel to get complete combustion had been achieved through research efforts. Investigations on effects of leak of exhaust system on fuel consumption rate of an automobile were scanty. In this study, experimental data obtained from exhaust system of CRV Honda with holes/leakages of different diameters located at different distances from the exhaust manifold was modeled. The models obtained were computerized. The results of fuel consumption rates from the model and computer software developed were compared. The finding shows that there is good agreement between the model and the computer software developed. The computer software (called FUCON+) has accurately predicted fuel consumption rate of CRV Honda with respect to leakage on the exhaust system.**

Index Terms— **Traffic, leakage, exhaust, computer, software, maintenance.**

I. Introduction

In the operating principle of an automobile, an engine nebulises a fuel and mixes the nebulised fuel with air, so as to create an explosion in a cylinder, and the pressure of expansion is converted into a rotary force that drives the wheels to rotation [1,2]. The mainstream of automobiles is a 4-cylinder engine with a design of driving the pistons repeatedly to move up and down for two times [3]. In other words, four actions including an air inhaling, a compression, an expansion, and a discharge are preformed when the engine rotates twice, and the ignition is done by electric sparks. The total volume for the pistons in the cylinders to move up and down is called exhaustion capacity, which is also an index of an engine power [4].

In normal conditions, if the engine is running at a low speed, then the exhaust pipe will produce an appropriate discharge pressure to assist the engine torque output; and if the engine is running at a high speed, the exhaust pipe will expedite the exhaustion to enhance the engine operating performance of an automobile [5].

In the 1970's when the developed and developing countries first became concerned about the effect of automobile exhaust on air quality, a great deal of research was done to define the problem [6]. If cars were perfect and burnt their fuel completely, the exhaust would consist of carbon dioxide (CO_2) and water (H_2O) [7]. Since nothing is perfect, least of all cars, the analysis of actual exhaust gasses revealed the presence of several troublesome components [8]. First, it was found that a portion of the gasoline that entered the engine was not completely combusted before escaped into the exhaust system. This component was labeled as "hydrocarbons (HC)". Another result of this incomplete combustion was "carbon monoxide (CO)". The third major component was "nitrogen oxides (NOx)" [9]. Air is actually composed of over 70% nitrogen which when subjected to the high temperatures and pressures inside an automotive engine combines with some of the oxygen in the air to form the aforementioned compounds. The exhausts have other components but, those mentioned are the main elements that the automotive industry focused on [10].

The increasing density of traffic in developing countries such as Nigeria necessitates a greater control of emissions from combustion engines. Most of the exhaust components were created as a result of incomplete combustion of gasoline. Some attempts have been made in literature to minimize the effects of the toxic emissions from the automotive exhaust systems [11]. Many exhaust systems' manufacturers experimented with engine and fuel systems before coming out with optimal designs. The modified exhaust systems are designed based on optimal proportions of fuel to air ratio that brought out complete combustion. Meanwhile, fuel injection systems had been developed as a good replacement to carbureting systems for precise control of the flow of fuel in engine [12]. All of these efforts had some degrees of success but still air quality has gone below the standards in some areas because of pollutants, ejected from exhaust systems.

Vehicles powered by internal combustion engines normally have exhaust systems for expelling exhaust gases from the engine. The exhaust system of a conventional automobile often includes an exhaust pipe connected at one end to the exhaust manifold of the engine and coupled at the opposite end to a muffler. Muffler is used to lessen the noise and deaden the vibration accompanying the ejected hot exhaust gases [12]. Catalytic converters are now being interposed between the engine and the muffler to reduce hydrocarbon and carbon monoxide pollutants from the exhaust stream. The outlet of the muffler is typically connected to a tailpipe which directs the exhaust gases toward the rear periphery of the underside of the automobile

Manuscript received March 18, 2011. This work was supported by the Industrial and Production Engineering research group of the Federal University of Technology, Akure, Nigeria, under Grant IPE000061.

P.K. Oke is with the Federal University of Technology, P.M.B. 704, Akure, Nigeria (e-mail: okekayode2002@yahoo.com).

B. Kareem is with the Federal University of Technology, P.M.B. 704, Akure, Nigeria (phone: +234-803-373-7251, email: karbil2002@yahoo.com, bkareem@futa.edu.ng).

to prevent exhaust fumes from converging below the vehicle [2]. The tailpipes of some known models of automobiles also included a resonator to provide for optimum tuning characteristics of the exhaust system [3].

More recently, emission control devices such as catalytic converters have been interposed between the engine and the muffler to reduce hydrocarbon and carbon monoxide pollutants from the exhaust stream [6]. It was on this note that the concept of the catalytic converter began to be seriously considered. Some of the effects of these exhaust gases on humans are mental acuity, throbbing headache, formation of acid rain, cancer-enhancing, death, etc. The effects of exhaust fumes on vehicles, include change in fuel consumption rate, change in efficiency of the vehicles' engines, change in power, and increased back pressure. Back pressure sometimes happens when there is a leak on the exhaust systems [7].

Back pressure developed by the exhaust gases within the exhaust system can result in a reduction in the efficiency of the expulsion of exhaust gases from the combustion chambers of the engine [2]. Thus, increased back pressure may result in a decrease in engine performance and a decrease in fuel economy. Based on this, manufacturers of automobiles and other vehicles usually attempt to design such exhaust systems so as to minimize, as much as possible, the back pressure from the engine. However, despite the attempts by such manufacturers to reduce the back pressure associated with automotive exhaust systems, the systems continued to develop back pressure for reasons which may be attributed to leakages.

The thermal conditions of the engine are also very important. Excessive cooling causes the engine to lose heat rapidly, and this reduces the dedicated efficiency of the engine. Besides, some of the fuel admitted into the cylinder in atomized form is not always combust completely; therefore increase in fuel consumption results [5,13].

However, efforts on fuel consumption economy have since continued but still, the effects of exhaust systems' leakages on fuel consumption rate have been scantily investigated. This study will develop a computer software for fast prediction of fuel consumption rate with respect to leakage hole diameter and distance from the exhaust manifold. The outcome of this study is expected to predict diameter and length of leakage location that will maintain economy fuel consumption in automobiles.

II. METHODOLOGY

The experimental results, from a new exhaust system (comprising resonator, catalytic converter, muffler and its pipes), was used for the research (Fig. 1). The fuel consumption rates' results obtained for four trials of leakage diameters 5mm, 10mm, 15mm and 20mm on the following locations of the exhaust system: between the exhaust manifold and catalytic converter (43.7cm from the exhaust manifold outlet); between the catalytic converter and silencer (138.40cm from exhaust manifold); very close to the silencer outlet (233.70cm from exhaust manifold); and muffler mouth (355.60cm from exhaust manifold) (Table 1) were used to formulate their respective multiple linear regression models. Flowchart, algorithm and coding using Visual Basic 6.0[R] were developed from the formulated models. The developed computer software was verified and validated with further data obtained from the same experiment.

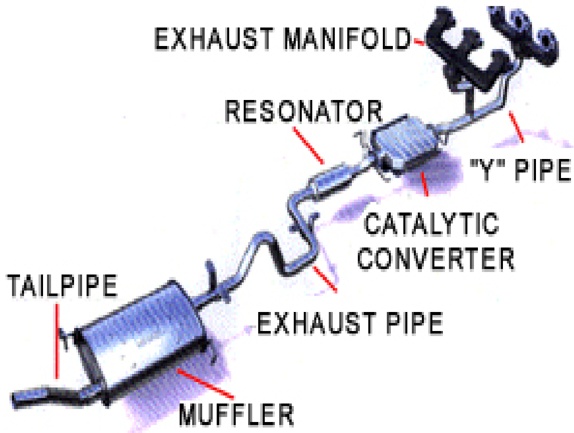

Fig. 1. Diagram showing a complete exhaust system

III. RESULTS AND DISCUSSION

The summary of the experiment's results for the four trials is presented in Table 1. The modeling results using multiple regression analysis [14] are shown as Eqns (1-4):

$$\lambda_1 = 2.190000 + 0.084000\alpha - 0.00000282\psi \quad 1$$
$$\lambda_2 = 0.920000 + 0.0894000\alpha + 0.00000578\psi \quad 2$$
$$\lambda_3 = 3.510000 + 0.128400\alpha - 0.00000414\psi \quad 3$$
$$\lambda_4 = 2.630000 + 0.135000\alpha + 0.00000811\psi \quad 4$$

Where,

α = the diameter of the hole/ leak on the exhaust system.

ψ = the location (length from the exhaust manifold outlet) where the hole/ leak occurs.

λ = the fuel consumption rate, for the respective first, second, third, and fourth experimental trials, with $R^2 \geq 0.9$, and showed a good agreement with the experimental data.

Table 1: Experimental Results for Modeling

Fuel Consumption Rate, λ_1, where leak location , ψ is 43.7 cm.	2.60	3.20	3.46	3.89
Fuel Consumption Rate, λ_2, where leak location , ψ is 138.4 cm.	1.59	1.69	2.04	2.78
Fuel Consumption Rate, λ_2, where leak location , ψ is 233.7 cm.	4.15	4.86	5.43	6.10
Fuel Consumption Rate, λ_2, where leak location , ψ is 355.60 cm.	3.31	3.92	4.64	5.29
Diameter of Leak, α	5.00	10.00	15.00	20.00

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

The development of software for these models is highly needful for effective verification and validation. Besides, it enhances information technology compliant and adequately fitted into the present day technological advancement (as manual validation is tedious, time consuming, inconsistent and archaic) [15]. The FOCON+ software was designed and written using Microsoft Visual Basic 6.0^R [16]. The software has been designed in such a way that a fuel consumption rate report is automatically generated, which can be printed out for evaluation. The flowchart/algorithm is step-wisely developed for the FUCON+ software that gave interface outputs with enhanced simplicity and user-friendliness. The software generated a printable fuel consumption rate reports automatically.

In verification and validation of FUCON+ software, it was applied to real life problems utilizing series of experimental data from exhaust systems from selected brands of vehicle including Honda CRV. The results obtained form the testing exercise, are in good agreement with the ones from the models. The software provides an easy and convenient approach to fuel consumption rate analysis. The steps of implementation of FUCON+ software (with its features and interface) based on the developed flowchart/algorithm is presented as follows:

Step 1: Installation of software: double click on the setup icon and respond appropriately to the installation wizard provided.

Step 2: After installation, open the software by clicking on it. At this, the initialisation and loading page is displayed, and completed.

Step 3: Register as a new user (for the first time), after which you will only have to re-enter the username and password used to register. Proceed with the usage by clicking OK (Fig. 3a,b).

Step 4: Select the make and model of the vehicle and proceed by clicking continue (Fig. 4a, b).

Step 5: Enter the parameters for the analysis of fuel consumption rate and click evaluate. This is followed by a thank you message (Fig. 5a, b).

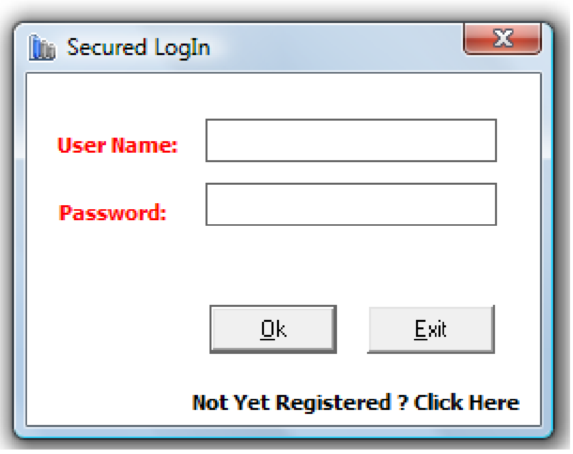

Fig. 3a: Output Sample for User Registration

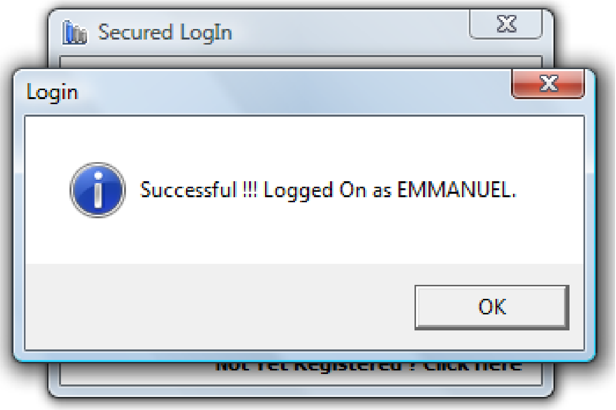

Fig. 3b: Output Sample for User Registration

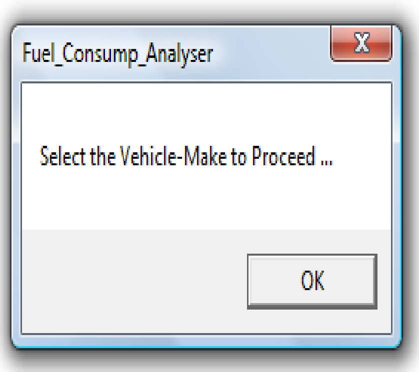

Fig. 4a: Output Sample for Vehicle Brand Selection

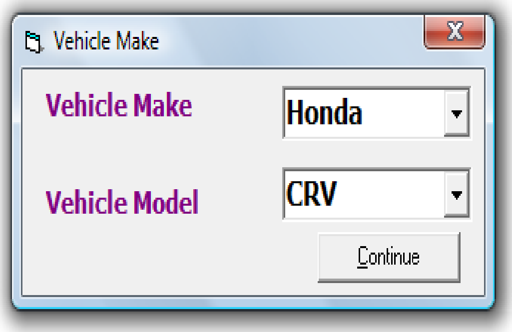

Fig. 4b: Output Sample for Honda CRV Selection

Fig. 5a: Output Sample for Data Input/Results

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

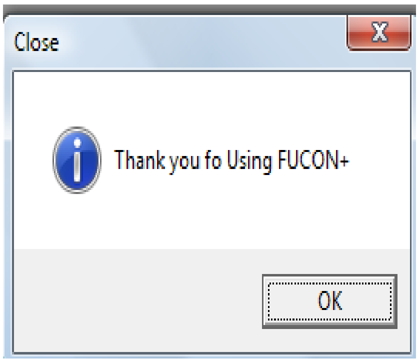

Fig. 5b: Output Sample for Friendliness

The FUCON+ software requires an hardware comprises keyboard, mouse and monitor, printer, and central processing unit of 350 G Hard-disk and memory of 2.0 G ram.

IV. Conclusion

The knowledge of the effect of a leaking exhaust system on the rate of fuel consumption will help car owners and drivers to make better choices of maintenance policies for their exhaust system. The modeling/software results would help the vehicle owners in monitoring and controlling their fuel expenses. It would also help vehicle designers to look into some design considerations at the points where the effect of leak is disastrous. This will promote better fuel economy and cleaner exhaust output. Having known the size of leaks and the locations, the rate at which fuel is consumed can be quantified using the developed FUCON+ software. The FUCON+ software is recommended for use in automobile design outfits, automobile research institutes, car marketers, specialized repair centers, and individual automotive maintenance shop. The software was meticulously designed that it can generate printable fuel consumption rates' reports automatically. The cost of the software is cheaper than similar proprietary software.

Acknowledgment

P.K. Oke thanks the management of the Federal University of Technology, Akure, Nigeria for providing an enabling environment for carrying out this study.

References

[1] M. A. Taylor & T. M. Young, Developing a set of fuel consumption and emissions models for use in traffic network modelling. *Proc. of the 13th International Symposium on Transportation and Traffic Theory*, pp.289-314, 1996.
[2] W.T. Tong, and C.S. Cheung, A Modal Approach to Vehicular Emissions and Fuel Consumption Model Development. *Journal of the Air and Waste Management Association.* Vol. 55, pp. 1431-1440, 2005.
[3] SAE Surface Vehicle Emissions Standards Manual, *Society of Automotive Engineers,* Inc., Warrendale, PA, 1993.
[4] P.K. Oke and P.K. Farayibi, Investigations into the impact of leak exhaust system on fuel consumption rate of Automobile, *International Journal of Engineering,* 4(3), 397-406, 2010.
[5] J. P., Roumégoux, M. André, R. Vidon, P. Perret, and P. Tassel, Fuel consumption and CO2 emission from the auxiliary equipment: air conditioning and alternator. *in French, Bron, France: INRETS, report LTE0428*, 28p. 2008.
[6] E.F. Obert, *Internal Combustion Engines and Air Pollution*, 3rd ed. Harper & Row, New York, pp. 97- 106, 314- 317, 1973.
[7] K. Owen, and T. Coley, Automotive Fuels Reference Book, 2nd ed. Society of Automotive Engineers, Inc., Warrendale, PA, 1995.
[8] T. Huai , S.D. Shah, J.W. Miller, T. Younglove, D. Chernich and A. Ayala, Analysis of heavy-duty diesel truck activity and emissions data. *Atmos. Environment,* Vol. 40, p. 2333-2344, 2006.
[9] Information on http://www.wikianswers.com/ *how_will_a_hole_in_the_exhaust_affect_fuel_consumption* retrieved, January, 2011
[10] M. Barth, T. Younglove, G. Scora, C. Levine, M. Ross and T. Wenzel Comprehensive Modal Emissions Model (CMEM), version 2.02: *User's Guide. University of California, Riverside Center for Environmental Research and Technology,* 2007.
[11] N.A. Henein, Emissions from Combustion Engines and Their Control. Ann Arbor Science Publishers, Ann Arbor, MI, 1972.
[12] Highways Agency, Scottish Executive Development Department, Welsh Assembly Government and the Department for Regional *Development Northern Ireland, Design Manual for Roads and Bridges, Volume 11, Section 3, Part 1, Air Quality, Highways Agency, Scottish Industry Department,* The Welsh office and the Department of Environment for Northern Ireland, Stationary Office London, 2007.
[13] Information on http://peugeot.mainspot.net/fault_find/index.shtml retrieved, January, 2011.
[14] A.A. Aderoba, *Tools of Engineering Management, Vol 1, Engineering Project Management*, Ondo: Besade Publishing Press, Nigeria, 1995.
[15] M. Kerman, and R. Brown, Computer programming fundamentals with applications in Visual Basic 6.0. Reading, Massachusetts: Addison-Wesley, 2000.
[16] G. S. Byron, *Schaum's Outline of* Theory and Problems of Programming with Visual Basic, *University of Pittsburgh* Schaum's Outline Series, McGraw-Hill Inc., 2001.