

# COMPUTATIONAL INVESTIGATION OF AIR-FUEL MIXING SYSTEM FOR NATURAL GAS POWERED MOTORCYCLE

Yeap Beng Hi\*, Azeman bin Mustafa, Zulkefli bin Yaacob,

Gas Technology Center (Gasteg)  
Faculty of Chemical Engineering and Natural Resources Engineering  
Universiti Teknologi Malaysia  
813100 Skudai, Johor, Malaysia

## ABSTRACT

The idea of incorporating a newly designed mixer into the existing carburetor of conventional motorcycle is the main objective of the development of natural gas motorcycle fuel system. In a bi-fuel motorcycle, the carburetor still plays a vital role in switching from fuel gas to petrol mode operation and vice-versa. The carburetor is the most important part of the fuel system of a motorcycle. All motorcycle engines carry variable venturi jet carburetors. The basic operation of the carburetor mainly depends on the restriction barrel called the venturi. When airflows through the venturi, its speed increases and its pressure decreases. Gasoline in its liquid state does not burn readily in the combustion chamber; only gas does. That is where the carburetor plays its part by atomizing the gasoline into mist in the air stream in order to burn efficiently in the combustion chamber. The decisive advantage of the prototype mixer now under development is that it does not require any atomizing process as the inlet fuel is in gas form. The main challenge focuses on designing a mixing device which mixes the supplied gas with the incoming air at an optimum ratio. In order to surmount the identified problems, the way fuel gas and air flow in the mixer have to be analyzed. In this case, the Computational Fluid Dynamics or CFD approach is applied in the design of the prototype mixer. The present work is aimed at further understanding of the air and fuel flow structure by performing CFD studies using a commercially available FLUENT code.

**Keywords:** Carburetor, mixer, natural gas motorcycle, venturi, Computational Fluid Dynamics.

## INTRODUCTION

Natural gas is particularly suitable for fueling internal combustion engines. Many systems using natural gas for fueling internal combustion engines have been proposed and some are presently in use in particular applications such as for service trucks, small tractors, lift trucks and taxis [1]. It has also been proven to successfully power an existing conventional gasoline-powered motorcycle without undergoing major engine and fuel system modifications. The prototype natural gas powered motorcycle is a *KRISS 110*, four-stroke model [2].

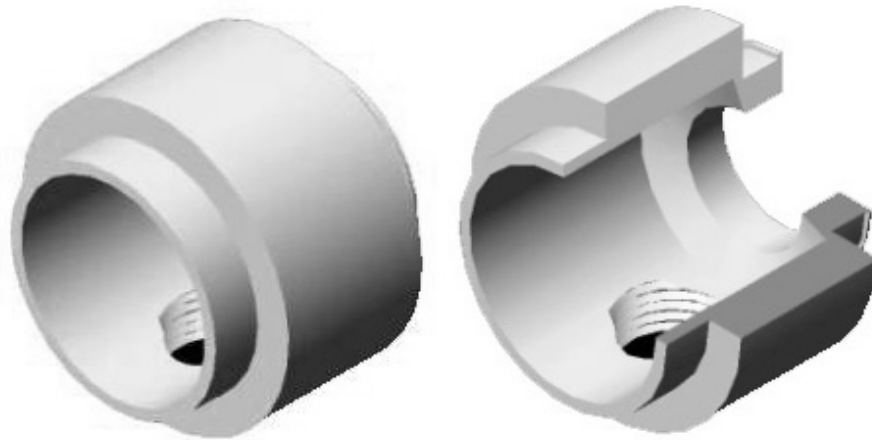
There has been ongoing research on the motorcycle's performance running on gaseous fuel. As the combustion efficiency is directly proportional to the degree of homogeneous mixing, it is important to make sure that the air and natural gas are homogeneously mixed prior to entry to the combustion chamber. The present work is aimed at analyzing the flow behavior of methane and air in the prototype mixer to determine its feasibility. The computational modeling approach has been applied.

## THE PROTOTYPE

The basic principles which govern mixing gaseous fuel with air are:

- Obtaining gaseous fuel flow rate from the regulator outlet at near atmospheric pressure in correspond to specific power output of motorcycle.
- Inducing air through an air intake system of the internal combustion engine, the air intake system having an air inlet for receiving the air and an air intake conduit for transporting the air from the air inlet to an air filter.
- Introducing the gaseous fuel at atmospheric pressure into the air intake system upstream from the air filter through a fluid channel mounted in the air intake conduit to obtain proper air-fuel mixing.

The prototype under development relates to a system and method for mixing gaseous fuel with air for subsequent combustion in a dual fuel internal combustion engine. The cylinder shape mixer, with its outlet diameter reduced, comprises of a mixing chamber with a fuel inlet duct inserted perpendicularly to the airflow direction. The gaseous fuel mixer is mounted to the air intake system of an ordinary internal combustion engine at the position immediately after the air filter. The filtered air flows past a fuel line outlet which is in communication with a gaseous fuel.

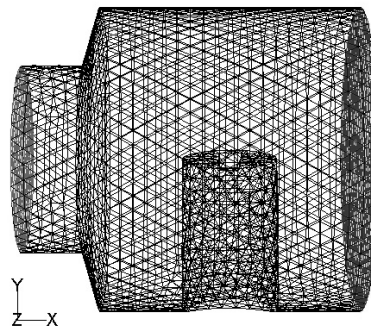


**FIGURE 1: Prototype Mixer For Natural Gas Motorcycle**

#### THE MODELLING SOFTWARE

Computational Fluid Dynamic (CFD)'s modeling predicts important performance characteristics such as pressure loss, flow and temperature uniformity and heat transfer rate. By using modeling, the impact of alternate design ideas on these performance parameters can be studied to improve the efficiency of final design. CFD techniques involve the numerical solution of the fundamental equations of conservation of mass, momentum, energy and individual species, closed by some turbulence model on computational grid or mesh fitted to the geometry of interest.

The pre-processing stage consists of the input of a flow problem to a CFD program by means of an operator-friendly interface and the subsequent transformation of this input into a form suitable for use by the solver. The prototype is meshed in *GAMBIT* using a hybrid mesh as shown in Figure 2.



**FIGURE 2: 3D Meshing In *GAMBIT***

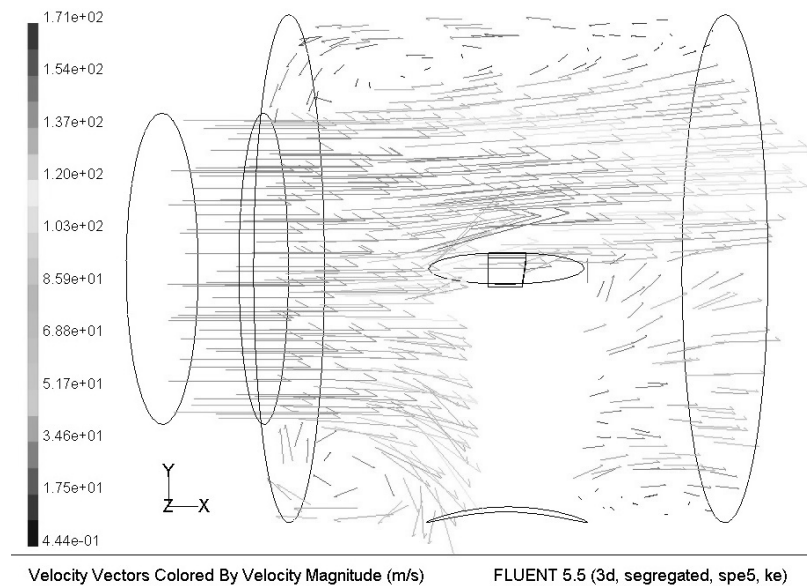
The fully turbulent flows in the prototype prompted the application of standard  $\kappa$ - $\epsilon$  model. It is a two-equation model in which the solution of two separate transport equation allow the turbulent velocity and length scales to be independently determined. Robustness, economy and reasonable accuracy for a wide range of turbulent flows of the standard  $\kappa$ - $\epsilon$  model in *FLUENT* explain its popularity in industrial flow and heat transfer simulation.

For the convenience of analysis and visualization, surfaces in the domain are needed to display results in a 3D model. Although *FLUENT* creates surfaces for all boundary zones automatically, a self-defined 2D plane at the center of the mixer is created and further analysis is based on it.

## RESULTS AND DISCUSSION

The fluid flow characteristic in the prototype mixer is initially being investigated on air only. The airflow pattern is expected to be prerequisite feature on the mixer's efficiency when methane is injected through the fuel inlet. In operation, air flows into the mixer by suction pressure as the engine's piston moves downward in the intake stroke.

From the preliminary result, it is clearly observed that two prominent re-circulation zones exist at the upper and lower region of the mixer, which are attributed to the obstruction of air flow by the fuel injector, that has been positioned perpendicularly in the air jet mainstream. These regions of stagnation, particularly the upper re-circulation, will trap fuel when fuel is being injected and therefore, a considerable amount of fuel is wasted and engine performance is compromised in long run.



**FIGURE 3: Velocity Vectors of Air Flow Through Mixer**

### Air-Fuel Mixtures

An engine is generally operated at different loads and speeds. For this, proper air-fuel mixture should be supplied to the engine's cylinder. Fuel and air are mixed to form 3 different types of mixtures:

- i) Chemically correct mixture
- ii) Rich mixture
- iii) Lean mixture

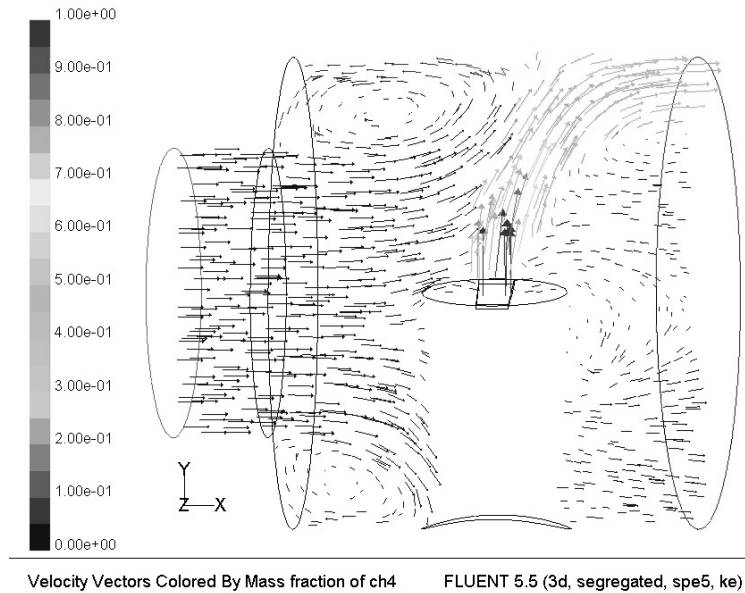
Chemically correct air-fuel ratio for methane ( $\text{CH}_4$ ) is 16.31 : 1. The mixer should provide an air-fuel ratio in accordance with engine operating requirements and this ratio must be within the combustible range.

### Mixture Requirements At Different Loads and Speeds

The air-fuel ratio at which an engine operates has a considerable influence on its performance. The prototype mixer is modeled on a free gear load. For idling at normal operating temperature, the engine still demands a fairly rich mixture, for which the air-fuel ratio is usually in the range of 11:1 to 13:1 [4]. In this case, an excess of petrol is required, owing to the comparatively small amount incoming fresh charge becoming diluted by unscavenged and inert exhaust gases.

When fuel is injected into the mixer, it produces a mixture with air-fuel ratio of 9.77. Although this ratio is within the combustible range, it is slightly too rich for idling speed compare to the ideal 11:1 to

13:1 range. In practice, it becomes necessary to deviate from the ideal mixture, in order to compensate for certain shortcomings inherent in engine operation. As a consequence, suitable provision must be made for an excess of either air or fuel in the mixture, according to engine requirements.



**FIGURE 4: Mass Fraction of Methane**

Due to the greater velocity of entraining fuel comparing to the suction air, the fuel jet momentum swaps directly into the mixer's exit boundary. The surrounding airflow is decelerated on the upstream side of the jet, creating a region of stagnation pressure while a low-pressure region develops in the wake of the jet, which subsequently leads to flow re-circulation [5].

The re-circulation zones, which are initially identified on airflow, are eventually intensified by the fuel injection, especially the upper region. Instead of diluting the supplied fuel to meet engine's requirement, the mixer is creating an adverse effect as air stream is distorted by the fuel due to unstrategic point of injection. When the fuel jet hits the upper wall of the mixer, as a consequence of momentum exchange between the jet and surroundings, fluid is entrained into the re-circulating stream within the two jets' shear layers. As the result, part of the fuel is trapped there, which to remain stagnant during operation.

#### **Air-Fuel Ratio Across Mixer**

Figure 5 shows the air-fuel ratio at different cross section. Datum at the y-axis is set at air inlet boundary while the x-axis' datum is set at the bottom of the mixer. As shown in Figure 5, at  $x=34\text{mm}$ , the mixture is basically very lean at the bottom of the mixer as the result of fuel swapping. Furthermore, the poor air-fuel ratio of 1730.93 as compared to mean equivalence ratio of 9.77 was caused by the slow air and fuel mixing in this low turbulence region between the jet shear layers. The re-circulation zone due to the wake of fuel jet at the center of the mixer diffuses much of the fuel molecules to mix with air, as can be seen from the graph in Figure 1, the air-fuel ratio is reduced gradually towards the upper wall of the mixer.

The mixing result at  $x=46\text{mm}$  shows a marked improvement, where the lowest air-fuel ratio obtained, though very rich, is 2.27, a relatively better mixture compared to the downstream of 2.04, 1.70 and 1.33 at  $x = 43\text{mm}$ ,  $x = 40\text{mm}$  and  $x = 37\text{mm}$  respectively. The average results show that concentration of the species is not uniformly distributed across the mixer. Mass fraction of methane is most concentrated at the upper region while the air circulates at the lower part of the mixer's exit.

## CONCLUSION

Through the analysis of CFD's modeling, the design of this prototype does not create a suitable mixing environment to replace the existing carburetion system, as it does not conform to the aerodynamic of flow structure. Therefore, the newly proposed mixer, based on the analyzed results of the prototype, is to incorporate the below criteria's to promote better mixing:

- i) Any mixer for mixing a gaseous fuel with air prior to gas engine has a nozzle which opens into an air inlet path through a venturi in a direction across the axial line of the air inlet path in order to permit an appropriate amount of fuel to enter the air inlet path and to reduce mixture loss.
- ii) A mixer for a gas engine must be configured to have a large expanding angle at the downstream of the venturi in a substantially parallel orientation relative to the flow of the inlet air to reduce the ventilation resistance caused by a boundary layer and make a uniform mixture of the gaseous fuel and the air.

## ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi Malaysia for financially supports the research through IRPA Vot 72231, as well as Mr. Wee Kim Hor Amir and Mr. Wang Junhong from CFD Research (S) Pte Ltd for their continuous advices and assistance with technical information.

## REFERENCES

1. Bradney, D. (1996). "Methane As an Engine Fuel." *ImechE* Seminar Publication. **2**. 9-16
2. Zulkefli Yaacob, Zulkifli Abdul Majid, Martin Philip King Ik Piau and Ong, Hua Long (1990). "A Study on Exhaust Performance and Lubricating Oil Effects on Natural Gas Motorcycle." *Jurnal Teknologi*, 31 (F)
3. Fletcher, C. A. J. (1991). "Computational Techniques for Fluid Dynamics." Berlin: Springer-Verlag.
4. Nunney, M. J. (1975). "The Automotive Engine." London : Butterworth & Co (Publishers) Ltd. 187.
5. Beer, J. M. (1996). "Combustion Aerodynamics." London: Applied Science Publishers Ltd. 21.