ANALYSIS CHARACTERISTICS OF PREMIX INJECTOR INVOLVE (DIESEL, WATER, AND AIR) IN BURNER SYSTEM USING ANSYS CFX

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ABSTRACT

Diesel fuel combustion produce hazardous toxic and be harmful for health. However, by using Premix injector with different percentage of diesel fuel, water, and air will reduced air polution. Diesel fuel is the main element which are more economical and safe for the users. It were tested with three types volume fraction for W0 (0% water), W10 (10% water), and W20 (20% water). Every types of diesel fuel consist different percentage of fuel and air. For all parameter such as velocity and pressure are determine by using ANSYS CFX as Computational Fluid Dynamic (CFD) with k-epsilon turbulence method. Spray pattern with different characteristic of parameter such as density, viscosity etc for W0, W10, and W20 have discovered. Premix injector model was drawn in Solidworks.Simulation in the premix injector was carried out with different length of mixing chamber, inlets, and spray chamber for each type of diesel fuel. The inlets of air, diesel fuel, and water have been set in velocity. Velocity contours and pressure contours determined by using ANSYS CFX. The high values of pressure that involved in the premix injector have lower velocity and the pressure is inversely proportional to the velocity. The spray pattern can be observed in spray chamber and determine the maximum and minimum values of parameters. W20 have higest pressure(50.4 kpa and 53.31 kpa) in different lenght and diesel velocity is 0.0035 m/s and 0.04 m/s. The lowest pressure is W10 with 49.005 kpa to 49.076 kpa and diesel velocity is 0.197 m/s to 0.981 m/s. Some improvements that can be done such as minimize the diameter of nozzles and design the larger spray chamber to see the clear contours.

Keywords: Diesel, Water, Mixture Formation, Spray Characteristics, Emissions.

1.0 INTRODUCTION

The problem of environmental in the world nowadays become increasing especially for air that surround on us. It is because the increasing number of industries that using combustion as their alternative way to produce high mass of production, economical and easy in engine maintenances. Diesel engine are very good combustion for heavy industries because it produce higher torque, but disadvantages of diesel fuel combustion produce hazardous toxic and be harmful for health.

The external premix injector in burner system has designed by Y.Kidoguchi, T.Yatsufusa, and D.Nakagama (Y. Kidoguchi 2011). Premix injector involves diesel fuel, water, and air with the different percentage of fraction. The main element that important for this injector is diesel fuel (Bhikuning, A 2011). In the study for premix injector, the value of parameter cannot be measured manually, but by using ANSYS CFX through Computational Fluid Dynamic (CFD), parameter can be predicted and determined. The methodology for this study is by using flow meter to measure the pressure value. For all the parameter such as velocity, temperature, and pressure are determine by ANSYS CFX with k-epsilon turbulence method model.

Fuel-air mixing during the ignition delay period has a great influence on the combustion process on high-speed small diesel engines. It is very important to control the ignition delay in order to suppress the emission of soot, NOx and unburned hydrocarbon without decreasing the thermal efficiency. Liquid spray and atomization systems have many technological applications, including process industries. The operating principle of the swirl atomizers relies on the conversion of pressure into kinetic energy to achieve a high relative velocity of the liquid with respect to the surrounding gas, by means of a nozzle (Yao, S., Zhang, J., & Fang, T. 2012).

Swirl injector is one of the method to mix the fluids or to produced spray with high pressure. Swirl injector was used in many applications due to its better atomization and wide dispersion with lower energy relative to other commonly used pressure injectors. Swirl provides advantages for the mixing in engineering applications over a wide range of areas in energy, environmental, biological sciences, and more (Dinesh, K. K. J. R. 2012).

Spray with steady swirl gives the perfect penetration on the nozzle. Swirling flows may affect flame dynamics in two aspects. First, large scale unsteady motions arising from shear-layer instability and vortex breakdown. Second, flow swirl may alter the flame structure and combustion intensity and as a consequence influence the heat-release behaviour in a combustion chamber.

Internal fuel-water rapid mixing is an injector by mix the fluid from water, air and fuel in the injector mixing chamber and produce better spray pattern. The supplied fuel and water are rapidly mixed in the mixing chamber with support of atomizing air. The atomizing air is pressurized and introduced into the mixing chamber through four slits of swirled. The advantage of using this injector is to make the water supply available in combustion without emulsification process. External fuel water rapid mixing was implement in this research as an injector that produces the spray pattern from the liquid immediately to the nozzle without using mixing chamber. This injector needs emulsified fuel when water is introduced (Y. Kidoguchi 2011).

2.0 Methodology

The concern of this study is to get the data calculation prediction which is needed to analyse characteristics of premix injector involve diesel, air, and water in burner system using ANSYS CFX. The procedure to get the important data of premix injector from stoichiometric equation calculation is carried out step by step to make sure that the accomplishment will follow the guide line to achieve the objectives of this study. Moreover, the progress method have discovered by determine the fluid properties, study of premix injector, define types of spray pattern, and calculation combustion preparation.

Premix injector model is drawn by using Solidwork. The exact design of outer dimension is shown in figure 1. This injector has six components; Part A is main body, the importantmain parts are part B and part C (swirler), Part D is mixing chamber, Part E is connecting part and Part F is air connector. Air pressure (0.1 bar) will go through the groove and bottom of swirler. Water-Fuel emulsions will flow at the bottom of part B with diameter 1.8 mm, and then go through the swirler with 0.5mm tolerances shown in. figure 1. In the mixing chamber will mix water, fuel, and air depending on the air fuel ratio.

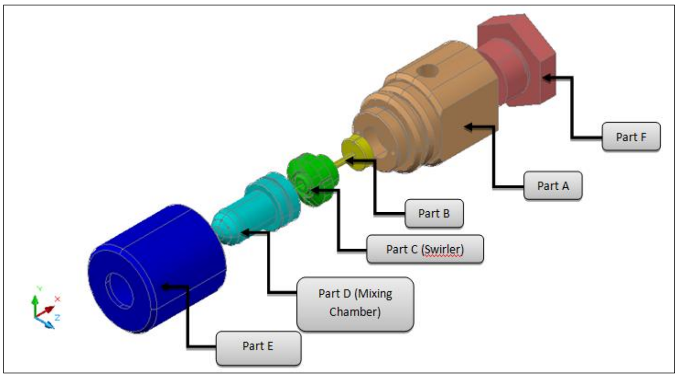

Figure 1: Assembly drawing for premix injector

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The external geometry has been saved in IGES format. It then used as geometry modelling in ANSYS CFX. After modelling process done, the model should being meshed using CFX-Mesh in ANSYS V14.0. The premix injector model is meshed in three types, which are geometry mesh, connection mesh, and default mesh. For geometry mesh, divide the solid bodies for premix injector at 11 bodies. The connection mesh is setup between head of mixing chamber and spray chamber. Use sweep mesh for default mesh. Figure 2 shows the setup for the default meshing setting.

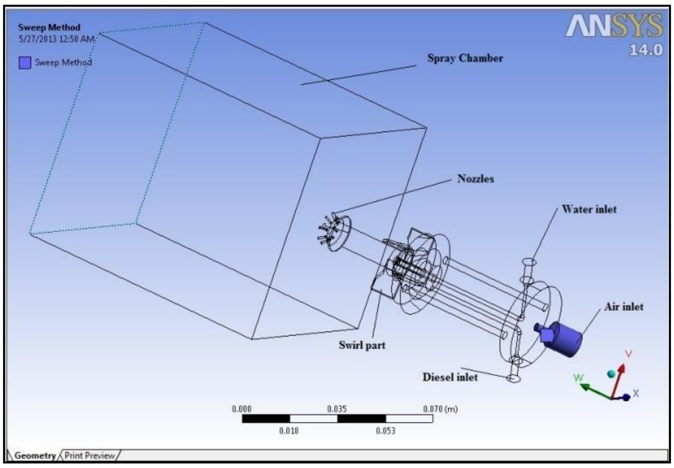

Figure 2: Sweep meshing at the air inlet part.

The boundary conditions have been selected based in the premix injector specifications. The boundary condition for W0 diesel type has shown in Table 1.

Table 1: Boundary Condition for W0 diesel fuel

Boundary Condition		
Analysis Type	Steady State	
Inlet	**Flow Regime**	**Subsonic**
Air	Mass and Momentum	**12.37m/s**
Diesel	Mass and Momentum	**0.021m/s**
Water	Mass and Momentum	**0m/s**
Opening	**Flow Regime**	**Subsonic**
	Mass and Momentum	0 Pascal
Walls	Wall Roughness	Smooth Wall
Turbulence	k-Epsilon	Scalable

There are three velocities for the inlets involve air, diesel fuel, and water which 12.37m/s, 0.021m/s, and there is no velocity involved in W0 diesel fuel. The outlet set up as the opening zero Pascal for the flow domain. The turbulent model has been set as k-Epsilon. The simulation of multiphase injector could be determined as the volume fraction that involved in the mixing chamber before it spray out from the nozzle. The design of fluid flow can be effect of the parameters such as pressure and velocity because it did not same with the fluid flow of pipe and complicated part. Table 2 shows the volume fraction in each types of diesel fuel.

Table 2: The volume fraction in the mixing chamber

	Volume Fraction		
Type of Fluids	**W0**	**W10**	**W20**
Air	0.9	0.999	0.999
Diesel Fuel	0.1	4.34E-02	4.73E-04
Water	0	4.98E-03	9.46E-05

3.0 Results and discussion

According to the result of injector analysis, pressure and velocity contours will form when the fluid injected in the fluid flow through the model. The flow field in the premix injector has been simulated. The analysis will be categorized into three different parts. First is pressure contours, second is velocity contours, and spray flow pattern in the spray chamber.

3.1. Pressure in Fluid Flow

The value of pressure can be determined in three part of the design which at the inlet of fluid and mixing chamber. The maximum and minimum values of pressure at different length are shown in figure 3. The graph shows the different pressure in the mixing chamber when all the fluids mix after pass through the swirled part to complete its mixing. From the graph can conclude that the maximum pressure acting on the mixing chamber is almost the same for all diesel fuel type. Types of W20 are the highest pressure acting (53.40kPa to 53.31kPa) in different length. The important for this simulation process is to determine the parameters which have higher and lower values that acting in the premix injector model. The graph shows that the pressure for each types of diesel is same from the initial mixing until the end before it spray out from the nozzles.

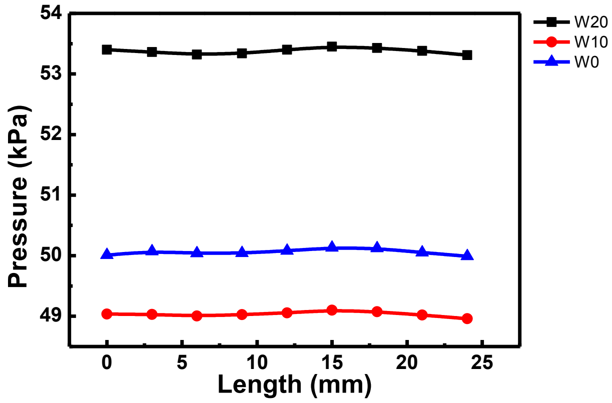

Figure 3: Pressure in the mixing chamber.

3.2. Mixing Fluid in the Mixing Chamber

Mixing chamber is the most critical part in the analysis of premix injector. The result of analysis shows the different velocity of each fluid when mixing and it is not constant for each of the diesel type. Figure 4 shows the same patterns of the air velocity when it is mix. The problem for this project, the air density is lower than the diesel and water, so it is difficult to get the accurate result because when the velocity inlet of air is higher. The pressure of air will pull out the other fluids and disable to mix. The diesel fuel velocity for W10 is the highest among the other types. The presence of water gives the impact for the fluids especially for the diesel fuel. In the mixing chamber, the pressure and velocity are not constant because of swirling.

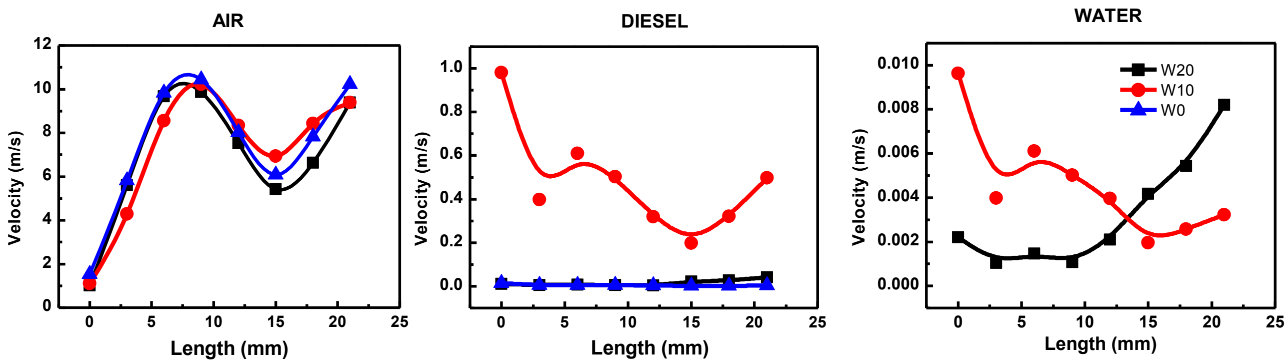

Figure 4: Fluid velocity in the mixing chamber

3.3. Velocity in Fluid Flow

Velocity of internal fluid flow of premix injector has a different value to balance the volume fraction in the chamber. The unit for velocity is metre per second for this project for all inlets. The design of injector is complicated and need to determine the velocity values of each diesel fuel types carefully before run ANSYS CFD simulation software. This injector fluid flow did not same with pipe fluid flow because it involve many diameters of small pipe that have higher dimensional design. All types of inlet involve air, diesel fuel and water should be determine as mass flow rate (kg/s) to get the accurate result for each parameter. Unfortunately, the software will stop running when using mass flow rate for air. This problem will effect through the result analysis to measure all the parameters. We have divided the length of the injector part to measure the velocity in the fluid flow. Figure 5 shows the velocity along the inlet part.

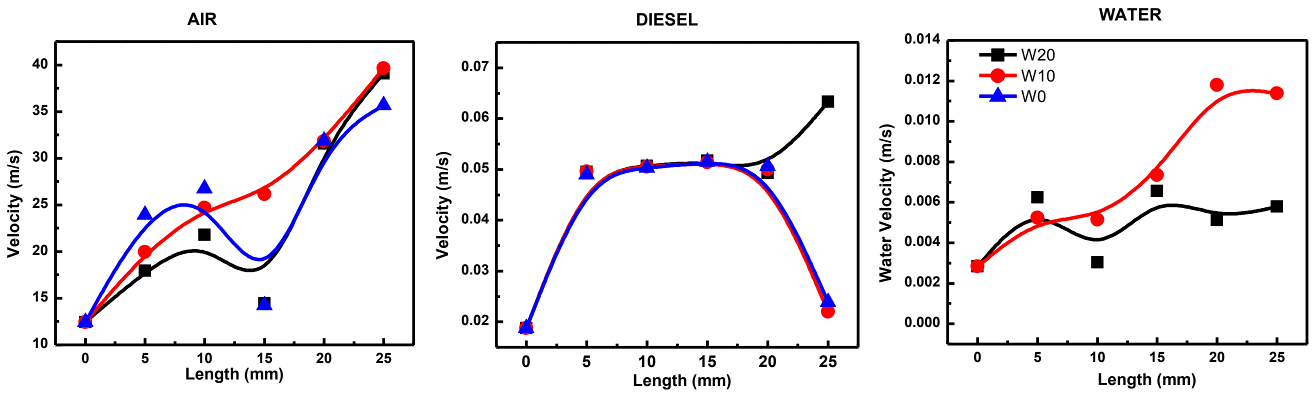

Figure 5: Fluid velocity along the inlet part

3.4. Velocity Contours result

The maximum velocity and minimum velocity in different length is shown at table 4. From the table below, we can conclude that the velocity for diesel type W10 have higher than the other that acting in the chamber (0.197m/s to 0.981m/s) in different length. The minimum value velocity acting in the premix injector is at diesel type W0 in range 0.00588m/s to 0.0145m/s. The minimum and maximum value for the velocity is recorded. The Figure 7 (W0 diesel) shows the high velocity (red region) acting upper part of nozzles in the spray chamber model. The maximum value acting in the model for diesel W0 type is 1.644m/s. The value for minimum velocity (blue region) acting in the spray chamber of the premix injector is 0.00865m/s. The contour velocity for W0, W10 and W20 diesel fuel in different length are shown figure 6 to 8.

The fluid flow process in the premix injector between air, diesel, and water has been realized in the simulation ANSYS software. The different particles size between liquid and air show the velocity of air flow faster than the liquid. The suitable parameter for the air in the premix injector is velocity (m/s) and for liquid is flow rate (kg/s). The design of spray chamber and injector fluid flow is referable in one part one body to get the best result of the project. Swirl part in the premix injector is important to mix the fluid in the chamber and give good performance in spraying velocity and pressure of diesel, air, and water at the inlet give the multiple results. When the value of water in diesel mixing is high, the velocity for the air and diesel inlet is slower. The result might be smooth or pulscefation . Meanwhile, the value of mass flow rate from the experimental between three different fluids are not suitable when setup in the k-epsilon turbulence model. As the result, the value of air at the inlet part is higher than the diesel and water inlet.

This research, velocity and pressure were used as the main parameter at the inlet. Other those, the parameters that involve in the premix injector such as pressure, velocity, and spray flow pattern have different values for each types of diesel fuel. In the combustion system, presence of water gives effect of advantages for environment that getting worst. The density of air is lower than the liquid phase, so the particles move faster and have higher pressure to reach to the nozzle chamber.

Table 4: Diesel velocity W0 diesel type in different length of chamber

DIESEL VELOCITY (m/s)			
Length	W20	W10	W0
0	1.11E-02	0.981	1.45E-02
3	5.32E-03	0.398	4.60E-03
6	7.30E-03	0.61	5.88E-03
9	5.40E-03	0.502	4.54E-03
12	3.51E-03	0.319	2.88E-03
15	2.09E-02	0.197	1.70E-03
18	2.72E-02	0.321	2.00E-03
21	4.10E-02	0.498	3.30E-03

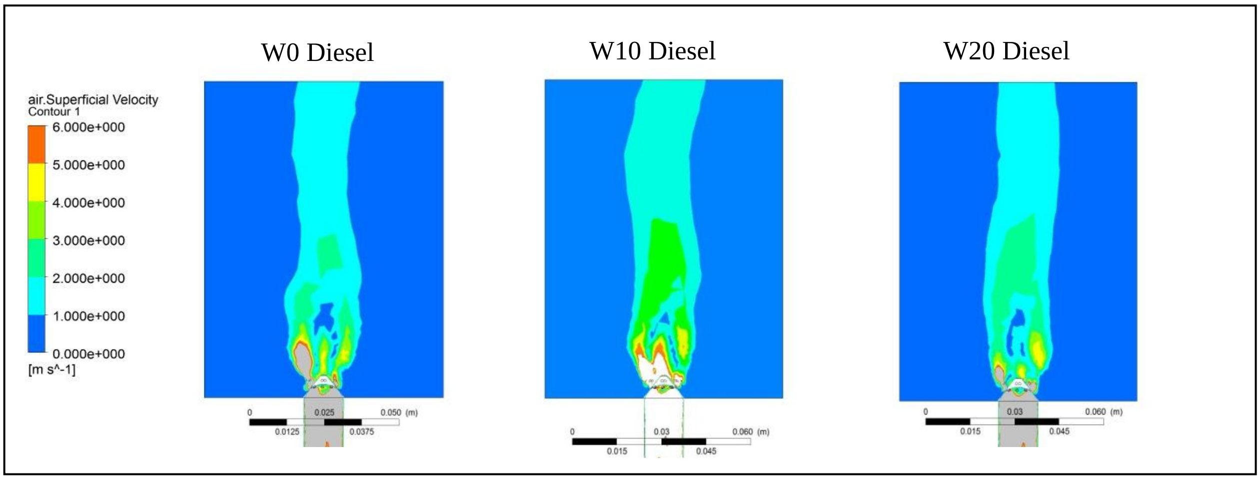

Figure 6: Air velocity in spray chamber

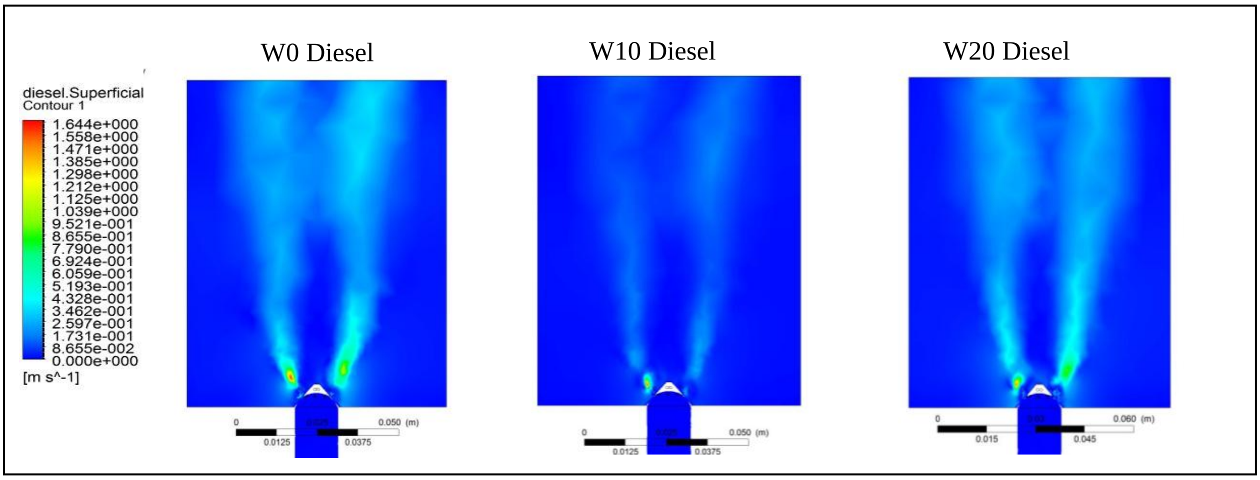

Figure 7: Diesel velocity in spray chamber

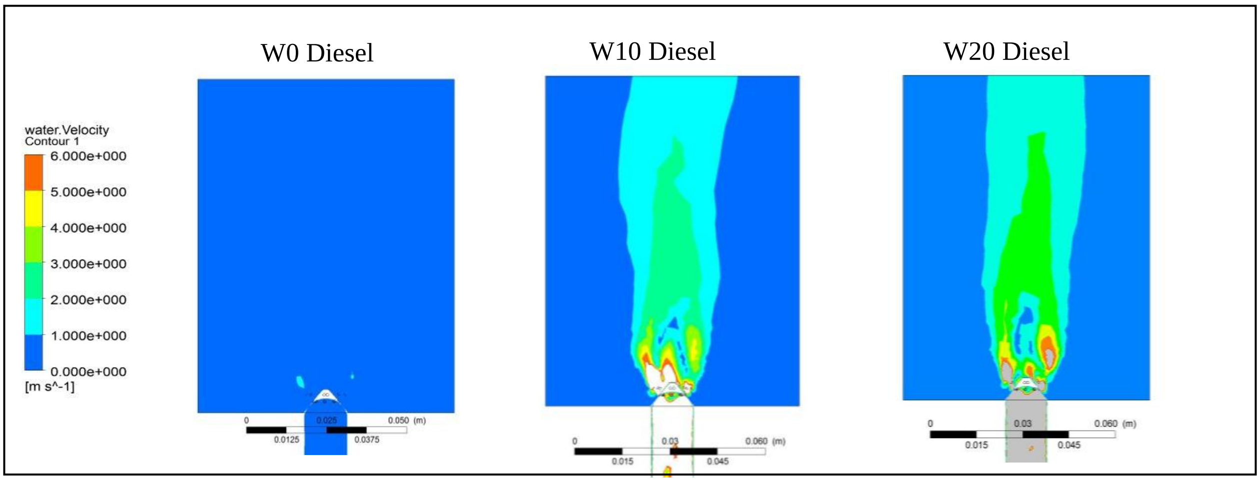

Figure 8: Water velocity in spray chamber

4.0 Conclusion

This project has been achieved to study the external spray pattern of Diesel burner system injector, analysis characteristics of premix diesel, water, and air in the injector, and measure the value of parameter involve such as velocity and pressure in the injector by using Computational Fluid Dynamic (CFD). Premix injector is the improvement research to save the environment that becomes worst nowadays by reducing the Carbon on the atmosphere. The previous version of injector consists of fuel and air. Swirling in premix injector is important to make the perfect mixing of the fluids, but the level of pressure should be high to produce the swirl movement. The drawing of the fluids flow should be exact in dimension to measure by using CFD software. The boundary condition of premix injector should be determined to select the inlet, wall and outlet. Meshing after determined the boundary condition much easier to know the number of nodes and elements. For the domain in this premix injector, there are three different of fluids that have different density which air, diesel and water. The inlets of the fluid are from different sources. The swirled part in the injector moved by the air that the function is to mix the fluids in the mixing chamber. The pressures for water and diesel fuel inlets have higher value than in the fluid flow because of its densities. However, the results of the contour between air, diesel, and water have different pattern of spray because of its parameters.

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Biography

Farid Sies is an Instructor Engineer in Mechanical and Manufacturing Engineering at University Tun Hussein Onn Malaysia. Mr Farid holds a Bachelor of Science degree in Mechanical Engineering from University Technology Malaysia and Master of Science in Mechanical and Manufacturing Engineering from University Tun Hussein Onn Malaysia.His experiences in industries were worked at Thomas and Betts, Kulai for 1 year and Shimano Component (M) Sdn Bhd for 9 years. During, he worked in Shimano Component (M) Sdn Bhd, he studied part time in Degree in Mechanical Engineering at UTM within 5 years (2002-2007). Upon graduation, he worked as a Project Engineer at Southen Lion (M) Sdn. Bhd., Malaysia. He then enrolled at the Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia in Faculty of Mechanical and Manufacturing Engineering in 2008 as an instructor engineer. He is member of BEM.

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