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# Study of Combustion Characteristics of Diesel-Hydrogen Dual Fuel Engine at Varying Load and Speed Condition using CFD

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***Abstract: The present study is about analysis of possibilities of hydrogen, could be used as a fuel in small and readily used engines as their fuel consumption is grater much in compression and Due to the depletion of fossil fuels and environmental degradation in recent years, there's a substantial world effort to make sure a continued availableness of providers of organic compound fuels and to diminish exhaust emissions from all combustion devices, significantly just in case of burning engines conjointly assigned to as IC engines. Many approaches square measure planned within the literature to seek out different transportation fuels to exchange or supplement organic compound fuels. In this concern, hydrogen gas is taken into account one in every of the foremost promising different fuels because of its clean burning characteristics and higher overall performance as compared to hydrocarbons fuel. Within the gift study, we are going to examine the (Hydrogen + Diesel) combustion model mistreatment CFD with numerous blends percentages at completely different engine speed and compare the simulation outcomes with basic of combustion efficiency and emission rate.***

***Keywords: Hydrogen fuel. Diesel, CFD, Blending, Numerical Simulation, Fluent, etc.***

## I. INTRODUCTION

Due to continued use of fossil fuels, it will have an effect on the depletion of fossil fuels and environmental degradation in recent years, there's a substantial international effort to confirm the continued accessibility of provider of organic compound fuels and to diminish the exhaust emissions from all combustion devices, notably just in case of burning engines (IC engines). Several approaches area unit planned within the literature to search out various transportation fuels to switch or supplement organic compound fuels. During this sense, hydrogen is taken iSnto account collectively of the foremost encouraging as an alternative fuels thanks to its clean burning characteristics and higher performance characteristics as compared to different hydrocarbons fuel. The hydrogen has nice combustion attributes once burned in burning (IC). Hydrogen’s composition doesn’t embody any carbon area. This implies that the hydrogen engine doesn't manufacture any noxious product, like hydrocarbons (HC), CO (CO), and carbonic acid gas (CO2); instead, its main product area unit water (H2O) and nitrogen oxide (NOx). Hydrogen incorporates a big selection of flammability as compared with all different fuels. This is the most important advantage that allows the fulfillment of associate ultra-lean mixture. Generally, fuel economies are bigger once an interior combustion engine is run with a lean mixture. Hydrogen incorporates a terribly low quantity of ignition energy. The amount of energy required igniting or burn hydrogen mixture is a smaller amount than that mandatory for standard fuels. This allows hydrogen element engines to ignite lean mixtures and assure economical ignition. Hydrogen put together incorporates a high flame speed. This implies that substance engines square measure many shut methodology of the thermodynamically ideal engine cycle. The higher flame speed leads to a high rate of pressure increase in hydrogen-fueled engines; thus, combustion is almost quick. In the case of hydrogen element, the auto ignition temperature is incredibly high (858°K). This permits hydrogen to be in addition applicable as a fuel for spark ignition (SI) engines. Moreover, hydrogen’s high motorcar ignition temperature strengthens the employment of larger compression ratios, like those current in diesel engines. Hydrogen-fueled IC engines even have negative aspects that require stressing on them and counseling the technologies for overcoming on these challenges. Increasing the equivalence ratio for a higher power demand increases NOx emissions, which are higher than those from conventional engines. Due to hydrogen’s lower ignition energy, the new gases and hot spots within the cylinder, like deposits, residual gas, exhaust valves, spark plugs, etc., Can provide as sources of ignition, generating problems of pre-ignition (undesired ignition) and backfire. The pre-ignition can be prevented by using dilution techniques, such as exhaust gas recirculation (EGR); charge dilution by inert gases, like helium (He) and element (N2); and by water (H2O) injection.

Hydrogen includes a terribly density. This result in two complications it's utilized in an internal combustion engine (IC engine): A really large volume is needed to store ample hydrogen to administer an adequate time period for the vehicle, and (2) the low energy density of a hydrogen-air mixture reduces the facility output of the hydrogen-fueled engine. Hydrogen includes a little quenching distance, smaller than alternative standard fuels.

Consequently, this permits flame propagation nearer to the cylinder walls ahead they extinguish than is feasible with alternative fuels. The smaller quenching distance may also be boosting the possibility for backfire. Hydrogen has terribly giant diffusivity. This ability to flow into inside the air is helpful for the event of a fair mixture of air-fuel, and to curb the matter of hydrogen element leaks. In hydrogen, the element area unit usually made-to-order to power every spark ignition (SI) and compression ignition (CI) engines. In SI engines, chemical element are often used directly because the sole fuel. However, within the case of a CI engine, chemical element cannot be used directly, as a result of it's terribly severe to ignite it by solely the compression method thanks to its auto-ignition temperature (858 K) being most beyond that of fuel (525 K). Therefore, some auxiliary ignition sources (spark plugs, glow plugs, or pilot fuel) ought to be used within the CI engine combustion chamber to assure the ignition of hydrogen. Hydrogen also can be employed in compression ignition (CI) under dual-fuel combustion mode with H2 supplemented into the intake air. In dual-fuel engines, the combustion of vaporized fuel with high ignition temperature like H2 is achieved with the ignition of a fuel with low ignition temperature such as diesel. Numerous experiments are established on IC fueled with hydrogen to investigated and perceive the within the engine cylinder combustion processes below fully completely different operative conditions. However, there are units severe to obtain higher data concerning the in-cylinder combustion actions and waste matter by experimentation. Also lesser the development costs and minimizing the time are needed with experimental investigations. In the past few years, varied studies centered on the way to produce AN engine model so as to get an insight into the sophisticated phenomena in-cylinder processes, and what is more optimize engines development. Today Computational Fluid Dynamics (CFD) has become a fundamental tool in the process of designing and developing engineering devices.

1.1 Reasons for mistreatment gas as a fuel –

Hydrogen may be a made supply of energy for several reasons; the most being that it's bountiful in provide. Whereas it's going to take heaps of resources to harness it, no different energy supply is as infinite as hydrogen. That why it is not possible to running out other sources of energy. _ When hydrogen is burnt to produce fuel, the byproducts is totally safe, which means that, they have no known side effects.

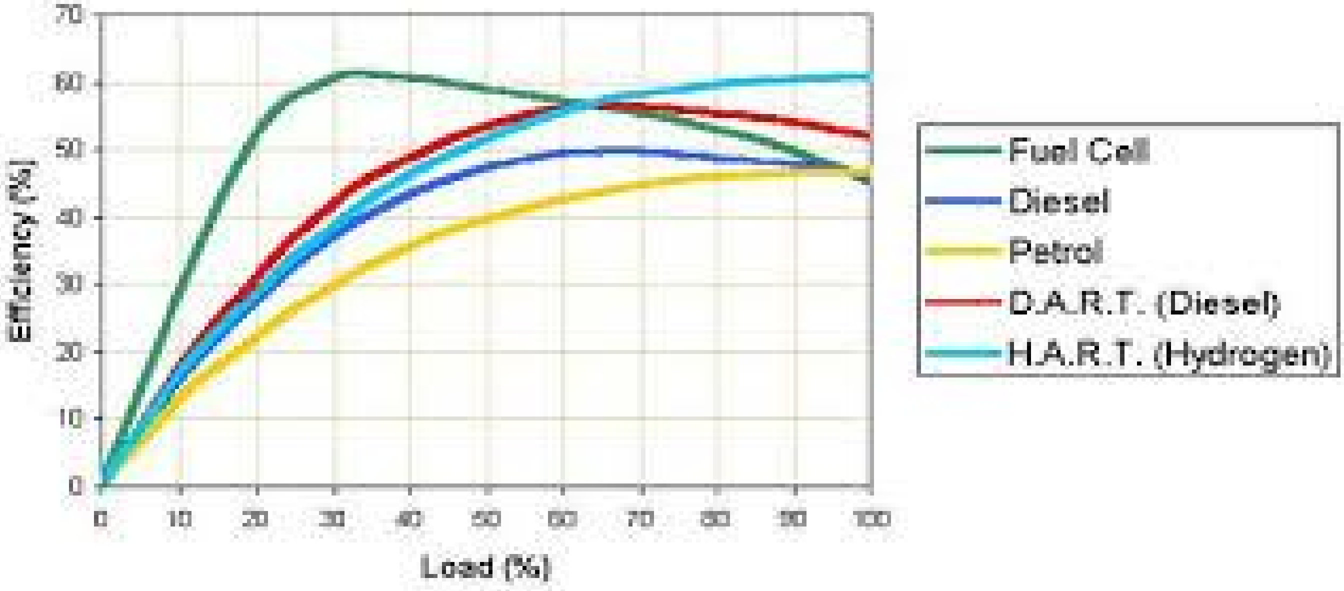

Figure 1.1 comparision of fuels

Aeronautical companies mostly use hydrogen as a source of drinking water. After hydrogen is used, it's unremarkably born-again to drinkable for astronauts in ship or house stations. This implies that it doesn't cause any harmful result or elimination to human health. This facet makes it most well-liked compared to different sources of energy like energy, current fossil fuel; it's conjointly permits that element will used several places wherever different varieties of fuel cannot be allowed.

### *A. Disadvantages*

Steam reforming and the Electrolysis is the two important process of hydrogen absorption which is extremely expensive in nature that's why this is the main reason for not using across the worldwide. Today, energy of hydrogen is mostly used most of the hybrid vehicles. So many research work and appropriate innovation is required to discover less expensive and continual ways to belt this form of energy. Until then, hydrogen energy would continue solely for the big-ticket supply of energy. The power of hydrogen cannot be miscalculate at all. While gasoline could be a very little additional dangerous than hydrogen, hydrogen is highly flammable and intermittently makes headlines for its potential dangers. Compared to gas, hydrogen absence smell, that makes any leak detection is sort of not possible. To detect leakage it's necessary to put in sensors. Blending amount of different fuel with typical fuel is a method to conserve fossil oil. Samples of low-level fuel blends embody E10 ( 100% ethanol/90% gasoline), B5(5% biodiesel/ ninety fifth diesel), and B2( two biodiesel/ ninety eight diesel), blends can even comprises two forms of different fuels, like hydrogen and compressed gas (HCNG) that is that the combination of 20% hydrogen and 80% of CNG.

## II. LITERATURE REVIEW

1) Hayder A. Alrazen , A.R. Abu Talib , K.A. Ahmad et.al- Numerical simulations were performed by employing a Ricardo Hydra diesel that's single cylinder engine and uses direct injection methodology. This analysis had been conducted by employing a two-dimensional CFD code to analysis the particular combustion characteristics and additionally emissions of a diesel in diesel CNG further as diesel H2 dual-fuel operations further as within the dieseleCNGeH2 tri-fuel operation with many air-fuel ratios. The outcomes show that the maximum in cylinder pressure & maximum temperature were raised with the addition of gaseous fuels at lower and moderate values of exceeds air. At 2.4 exceed air, the peak pressure increases by means of adding the limit value of hydrogen, such as H30eN70 and H50eN50, to CNG and it begins to decrease with H70eN30 and H2eDiesel operations . Diesel-H2 and Diesel-CNG operations decrease CO/CO2 emissions compared with Diesel-CNG operation and decrease NO emission compared with DieseleH2 operation at every exceed air. The reduction in CO/CO2 emissions was suggested at high hydrogen fraction in CNG (H70eN30) with all exceeds air whereas low hydrogen fraction in CNG (H30eN70) can repress uncontrolled hydrogen combustion and further limit the increment of NO emission.
2) Dinesh Kumar Soni , Rajesh Gupta et.al- This current study determines the two-stage technique to accomplish higher-level of emission reduction to meet more stringent emission norms. In the initial step a perfect combination of diesel wood alcohol fuel has been determined mistreatment mathematical model to convey the best level of attainable NOx additionally as smoke reduction. within the second stage, mathematical model has been conducted by 3 totally different completely different} sort of ways of emission reduction particularly through different sort of swirl quantitative relation, Variation in quantity of re circulation of exhaust gases in Exhaust Gas Recirculation (EGR) technique last however not least by suggests that of adding water in numerous amounts to the precise same optimum diesel wood alcohol mixed fuel to induce more reduction of emission. The mathematical simulation has been done on single cylinder Kirloskar diesel engine (model TV1) victimization principally offered computed fluid dynamics code AVL hearth. Within the beginning of the Simulation the optimum diesel–methanol mixed because the ideal fuel, effects of swirl ratio; one.0, 1.3, 1.6 and 2, percentage EGR varied between 10% and 20% and addition of H2O to the base fuel in the ratio of 5%,10% and 15% by quantity on emission area unit analyzed. Results show that H2O mixed method tends to decrease NOx emission by 95% and smoke by 14% with respect to emissions of ideal fuel.
3) Dulari Hansdah S.Murugana L.M.Das et.al- In this research finding the chance of utilizing bio ethanol obtained from Madhuca Indica flower as a substitute fuel in a direct injection (DI) diesel engine. There is few percentages of bio ethanol (5%, 10%, and 15%) on volume basis were emulsified with diesel proportionality with the help of a surfactant. The emulsions were designated as BMDE5, BMDE10, and BMDE15 where in actuality the mathematical value identifies the proportion of bio ethanol. The emulsions were tried as fuels within a cylinder, four stroke, and air cooled DI diesel engine having a power of 4.4 kW at 1500 rpm. In that examine demonstrates bio ethanol-diesel engine have no longer ignition delay by about 2.2 °CA than that of diesel operation at full load condition. Over-all, the nitric oxide (NO) and smoke emissions were discover to be decrease by about 4% and 20%, respectively, with the bio ethanol–diesel emulsions compared to that of diesel function at full load. The BMDE5 emulsion offered a good efficiency and decrease emissions compared to that of BMDE10 and BMDE15. It is recommended that the bioethanol made from Madhuca Indica flower can be utilized like a potential substitute fuel replacing 5% of oil diesel.
4) C.A.Harch M.G.Rasul N.M.S.Hassan M.M.K.Bhuiya et.al- Increasing curiosity about diesel engine technology and also the constant demand of discovering alternative environmentally friendly fuels as well as minimizing emissions has inspired over the years for the development of mathematical models, to provide qualitatively predictive methods for the designers. Among the substitute fuels biodiesel notably second generation biodiesel is understood as associate degree environmentally friendly

and additionally the foremost promising possibility for an IC Engine. During this analysis, associate degree engine combustion system has been made exploitation process fluid dynamics (CFD) software system, AVL Fire, which may calculate the engine overall performance, and emission characteristics for second generation biodiesel made from Australian native beauty leaf seed (BLS). This model involves simulation of fuel atomization, burning speed, combustion amount, and temperature and pressure development terribly} very combustion chamber. the subsequent model consists of a simulation of fuel atomization, burning speed, combustion time and temperature and pressure development terribly} very combustion chamber. The merchandise has been developed for oil diesel (normal diesel employed in automobiles), 5% BLS biodiesel (B5) and 10% BLS biodiesel (B10) for numerous injection timings moreover as compression ratios. The actual simulation outcomes disclosed that total B10 biodiesel provides far better performance and overall performance, and considerably reduced engine emissions. On the opposite hand, the B5 mix provides slightly increased potency and overall performance, and slightly lower emissions compared to fuel diesel.

## III.OBJECTIVE OF THE STUDY

Due to the depletion of fossil fuels and environmental degradation in recent years, there's a substantial world effort to make sure a continued availableness of providers of organic compound fuels and to diminish exhaust emissions from all combustion devices, significantly just in case of burning engines conjointly assigned to as IC engines.

Many approaches square measure planned within the literature to seek out different transportation fuels to exchange or supplement organic compound fuels. In this concern, hydrogen gas is taken into account one in every of the foremost promising different fuels because of its clean burning characteristics and higher overall performance as compared to hydrocarbons fuel.

Within the gift study, we are going to examine the (Hydrogen + Diesel) combustion model mistreatment CFD with numerous blends percentages at completely different engine speed and compare the simulation outcomes with basic of combustion efficiency and emission rate.

## IV.METHODOLOGY

The present study is done on ANSYS 14.0 with following steps

### *A. Step I Geometry Or Model Formation*

The study focuses on the to calculate the NOx percentage and the geometry used for the simulations is therefore only a part of the whole exhaust gas system in order to save computational time. The generation of the model by using ANSYS shown below:-

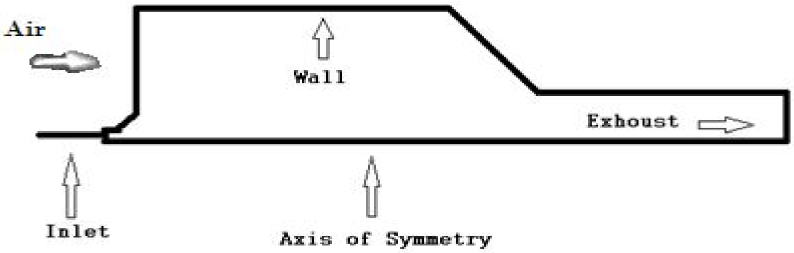

Figure 4.1 CAD MODEL

### *B. Step II Mesh Generation*

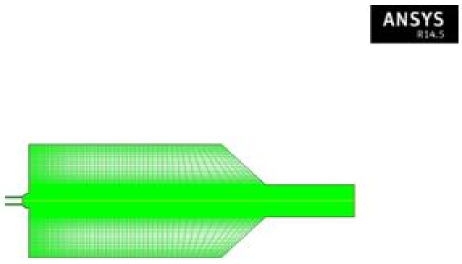

Figure 4.2 MESH MODEL

*C. Step 3 Check The Mesh:* Various checks on the mesh and reports the progress in the console. Also check the minimum volume reported and make sure this is a positive number select mesh to mm.

*1) Methods*
*a)* Pressure based
*b)* 2D Axissymmetry Model is used.
*c)* Gravity is enabling
*d)* Select 2d CAD Model Space list.
2) MODEL
*a)* Energy equation is enabled.
*b)* K-Epsilon turbulence model used.
*c)* Non-Premixed condition is used.
*d)* P-1 radiation model is used, since it is quicker to run. However DO radiation model can be used for more accurate results in typical models.
*e)* Finite rate / eddy dissipation in turbulence chemistry. Interactions are used for species model.

### *D. Step 4 Simulation Set Up*

*1) Boundary conditions*
*a)* Mass Flow Air inlet: - Mass flow rate is 1.32 kg/s,
*b)* Mass flow premixed Fuel inlet – 0.05 kg/ s of Mixture
*c)* Outlet – pressure based.
*2) Material:* Diesel+ Hydrogen
*a)* Five blends has been taken for combustion as per ASME Standard with varying load and speed condition
*b)* Mixture: - Species I $H_20$, II-O2, III-Fuel -EG, IV-$CO_2$, V-N2

| *A. Reactants* | *B. Stoichmetric Coefficient* | *C. Rate exponent* | *D. Products* | *E. Stoichmetric Coefficient* | *F. Rate exponent* |
|---|---|---|---|---|---|
| *G. Fuel* | *H. 1* | *I. 1* | *J. CO2* | *K. 1.087* | *L. 0* |
| *M. O2* | *N. 16.23* | *O. 1* | *P. H2O* | *Q. 30.28* | *R. 0* |

*c)* Mixing law is used.
*d)* Thermal conductivity: - Define two polynomial coefficients
(a) 0.0065234 (b) $8.72369*10^{-6}$
*e)* Polynomial coefficient for viscosity
(a) 5.2348e-07 (b) 5.12365e-9
*f)* For absorption coefficient take stable domain.
*g)* Scattering coefficient is 1.2e-8.

### *E. Step 5 Solutions*

*1) Method*
*a)* Coupled
*b)* Presto model is used:-

Presto model is often used for buoyant flows where velocity vector near walls may not align with the wall due to assumption of uniform pressure in the boundary layer so presto can only be used with quadrilateral .

*i) Note:* Higher time scale size is used for the energy and species equation to converge the solution in less number of iterations.
*ii) Solution Initialisation:* The solution is initialized
*iii) Run Calculation:* Start the calculation for 10000 iterations.

*iv) Calculation Parameters:* Entire calculation is done for following blend percentages at 1000, 2000, and 3000 RPM at given engine condition and load.

| S.NO. | Materials | Blend % sample (I) | Blend % sample (II) | Blend % sample (III) | Blend % sample (IV) | Blend % sample (V) |
|---|---|---|---|---|---|---|
| 1 | H2 (Hydrogen) | 05 | 10 | 15 | 20 | 25 |
| 2 | Diesel | 95 | 90 | 85 | 80 | 75 |

## V. RESULTS

### A. *For blend 1 :* Diesel 95% and Hydrogen 5%

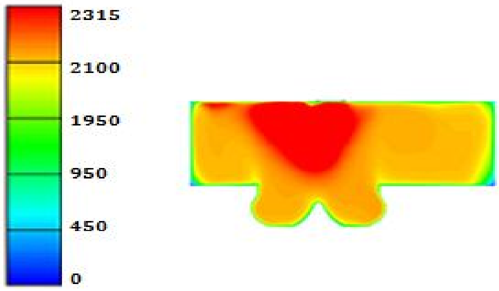

Figure No. 5.1 Temperature (˚K) in D95H5 @3000 RPM

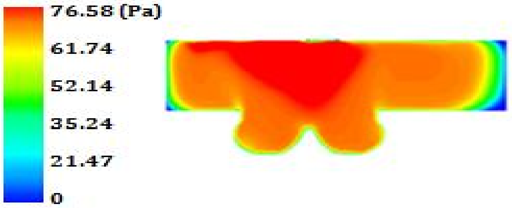

Figure No. 5.2 Pressure in D95H5 @3000 RPM

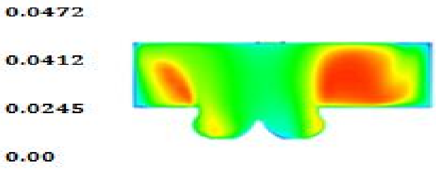

Figure No. 5.3 Mass fraction of CO2 in D95H5 @3000 RPM

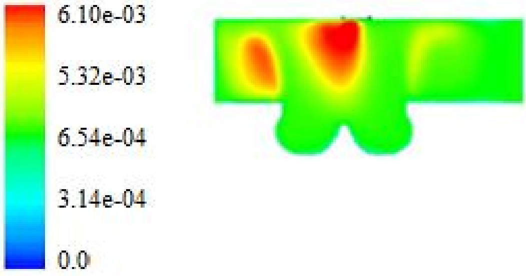

Figure No. 5.4 Mass fraction of NO2 in D95H5 @3000 RPM

### *B. For blend 2:* Diesel 90% and Hydrogen 10%

Figure no. 5.5 Temperature (˚K) in D90H10 @3000 RPM

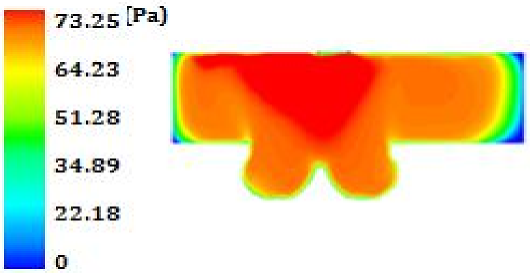

Figure No. 5.6 Pressure in D90H10 @3000 RPM

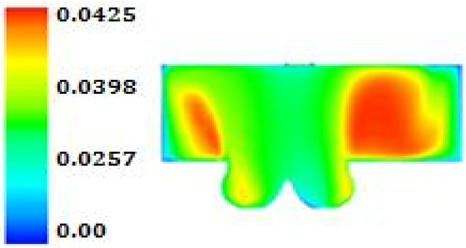

Figure No. 5.7 Mass fraction of CO2 in D90H10 @3000 RPM

Figure No. 5.8 Mass fraction of NO2 in D90H10 @3000 RPM

### *C. For blend 3:* Diesel 85% and Hydrogen 15%

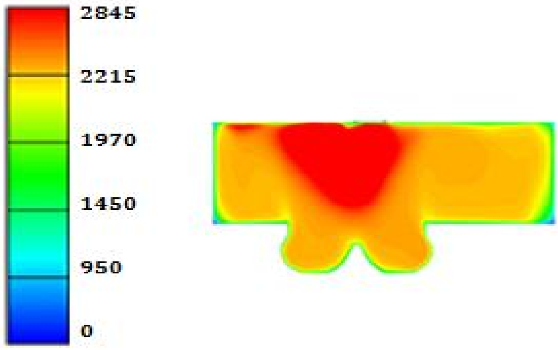

Figure n No. 5.9 Temperature (˚K) in D85H15 @3000 RPM

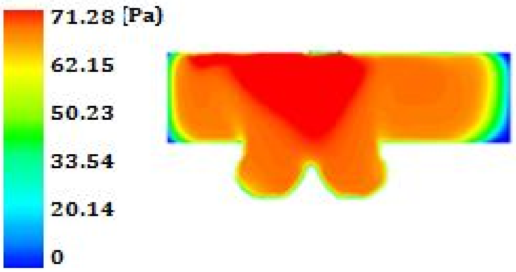

Figure no No. 5.10. Pressure in D85H15 @3000 RPM

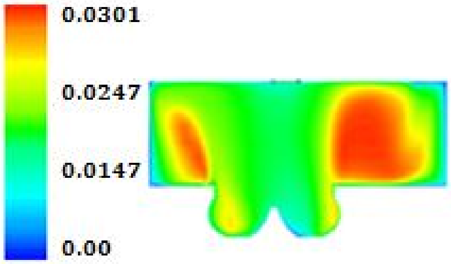

Figure No. 5.11 Mass fraction of CO2 in D85H15 @3000 RPM

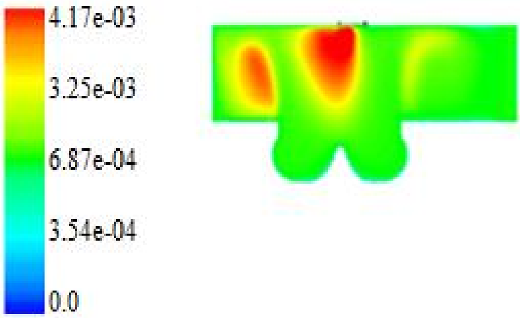

Figure No. 5.12 Mass fraction of NO2 in D85H15 @3000 RPM

### *D. For blend 4:* Diesel 80% and Hydrogen 20%

Figure No. 5.13 Temperature (˚K) in D80H20 @3000 RPM

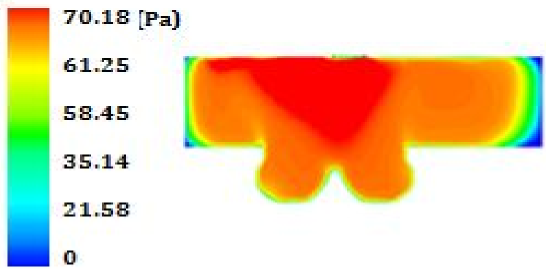

Figure No. 5.14 Pressure in D80H20 @3000 RPM

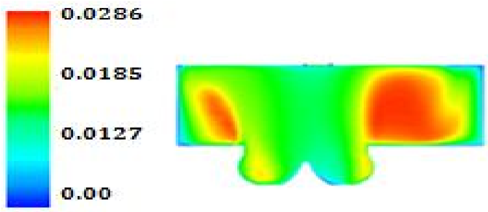

Figure No. 5.15 Mass fraction of CO2 in D80H20 @3000 RPM

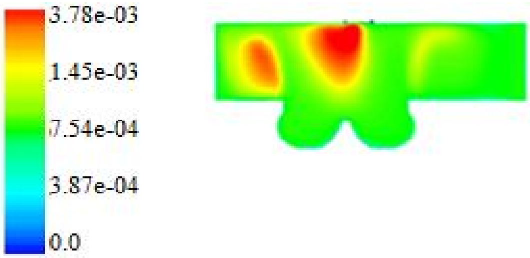

Figure No. 5.16 Mass fraction of NO2 in D80H20 @3000 RPM

### *E. For blend 5:* Diesel 75% and Hydrogen 25%

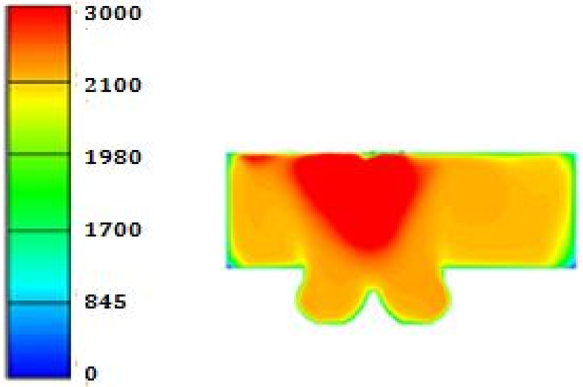

Figure No. 5.17 Temperature(˚K) in D75H25@3000 RPM

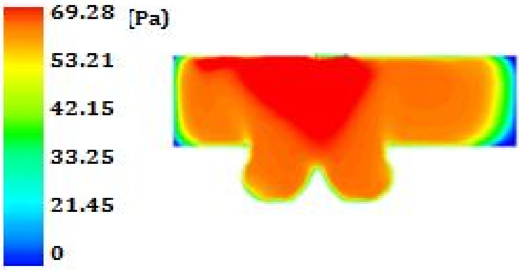

Figure No. 5.18 Pressure in D75H25 @3000 RPM

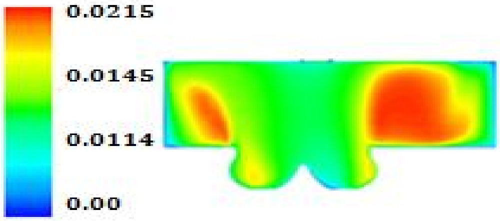

Figure No. 5.19 Mass fraction of CO2 in D75H25 @3000 RPM

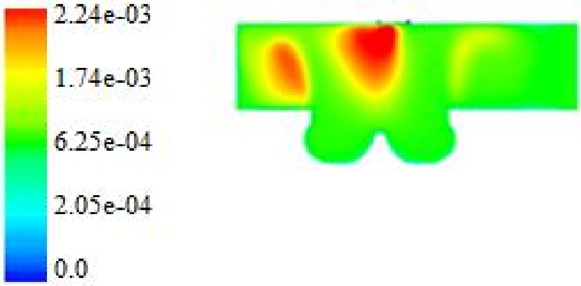

Figure no. 5.20 Mass fraction of NO2 in D75H25@3000 RPM

Results Table

| BLENDS % | Engine speed (RPM) | Temperature (K) | Pressure (Pa) | Mass fraction of $C0_2$ | Mass fraction of $N0_2$ |
|---|---|---|---|---|---|
| D95H5 | 1000 | 2100 | 80.12 | 0.0587 | 0.00689 |
| | 2000 | 2250 | 79.23 | 0.0478 | 0.00642 |
| | 3000 | 2315 | 76.58 | 0.0472 | 0.0061 |
| D90H10 | 1000 | 2415 | 79.25 | 0.0498 | 0.00589 |
| | 2000 | 2586 | 73.15 | 0.0452 | 0.00546 |
| | 3000 | 2687 | 73.25 | 0.0425 | 0.00534 |
| D85H15 | 1000 | 2589 | 75.28 | 0.0358 | 0.00487 |
| | 2000 | 2670 | 72.18 | 0.0315 | 0.00425 |
| | 3000 | 2845 | 71.28 | 0.0301 | 0.00417 |
| D80H20 | 1000 | 2715 | 73.29 | 0.03 | 0.00396 |
| | 2000 | 2790 | 72.23 | 0.0298 | 0.00385 |
| | 3000 | 2870 | 70.18 | 0.0286 | 0.00378 |
| D75H25 | 1000 | 2860 | 74.15 | 0.0275 | 0.00286 |
| | 2000 | 2945 | 72.85 | 0.0267 | 0.00258 |
| | 3000 | 3000 | 69.28 | 0.0215 | 0.00224 |

## VI. CONCLUSION

To overcome the heterogeneity problem for the gaseous fuel (CNG and HCNG) with air inside the diesel engine under different tri-fuel engine and dual-fuel engine modes, using ANSYS Workbench (CFD). The simulation results obtained under the maximum engine speed (3000 rpm) and full-open valve conditions. In present study we conclude that among the five blends that we analyzed by CFD Simulation, D75H25 shows a good results at maximum speed and its emission characteristics is also low as compare to other blends percentages. Hydrogen fuel have great characteristics for better mixing and that will help to complete combustion but it also highly inflammable and not to easy for handling due to this stability is a big concern in the use of hydrogen fuel.

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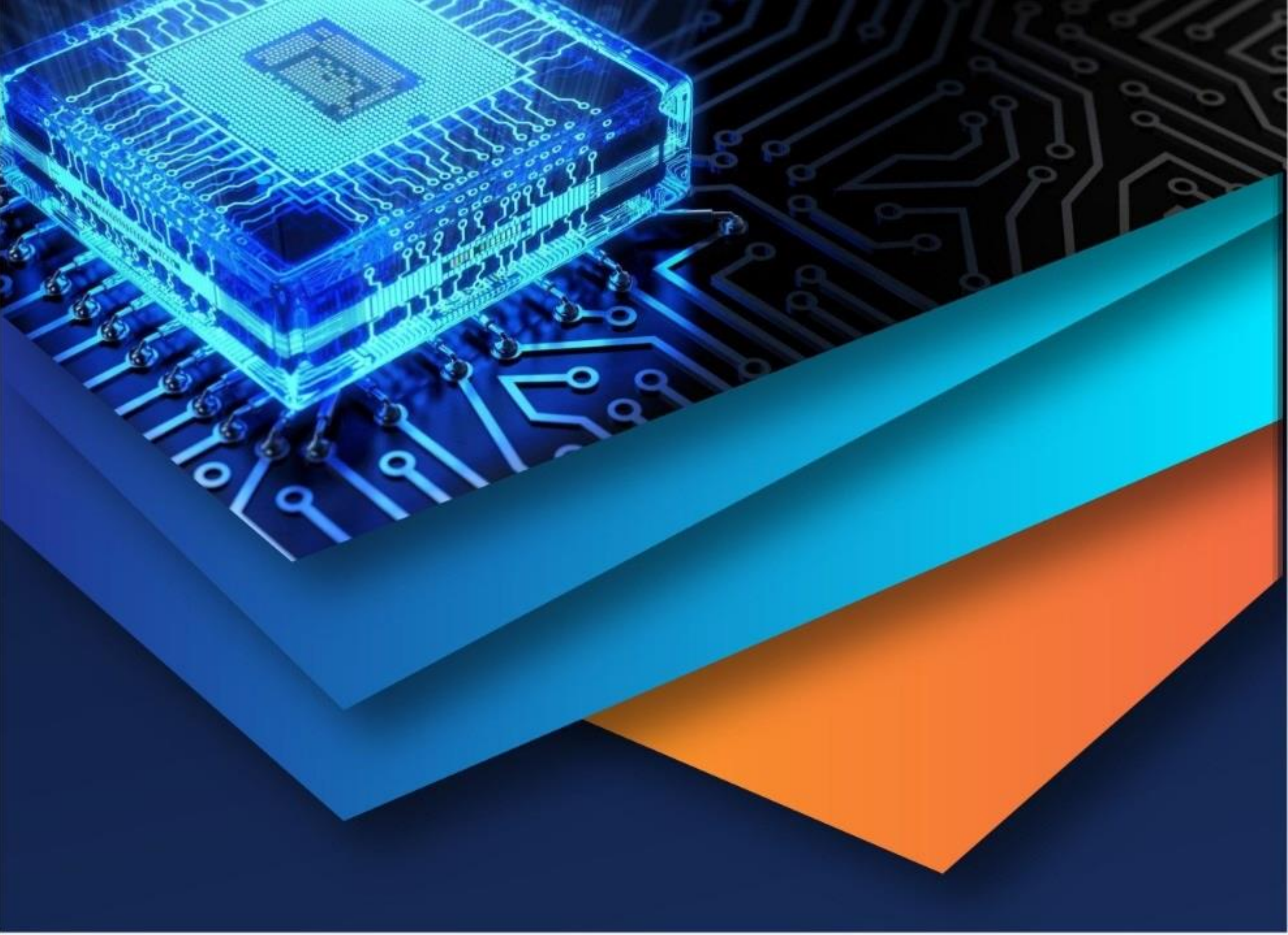

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