DEVELOPMENT OF A CFD 3D MODEL TO DETERMINE THE EFFECT OF THE MIXING QUALITY ON THE CNG-DIESEL ENGINE PERFORMANCE

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ABSTRACT

In a CNG-DIESEL DUAL FEED ENGINE, the CNG-AIR MIXER plays a vital role. The CNG-AIR MIXER is an important part of the fuel system of CNG-DIESEL DUAL FEED ENGINE. The basic operation of CNG-AIR MIXER mainly depends on restriction barrel known as venturi. When air flows through venturi, its speed increases and pressure decreases.

CFD approach is applied to investigate the flow behavior of methane and air in a CNG-AIR MIXER to be used for CNG-DIESEL DUAL FEED ENGINE.CFD analysis is done on 8 hole cng-air mixer and results of simulations showed that 8-hole cng-air mixer gives superior performance. Also mixing quality at outlet in terms of spread parameter of CNG-MASS fraction will be calculated.

INTRODUCTION

Now a day's many efforts are being done to reduce the emissions from conventional diesel engine. One of the techniques that can be used to reduce emission without too many modifications to conventional diesel engine is "CNG-

DIESEL DUAL FUEL SYSTEM".CNG contains mostly methane which is well known for its low NOX emissions. However the efficiency of CNG is almost same as compared to efficiency of petrol and diesel.

The CNG-AIR mixer was developed based on some assumptions with engine air flow requirements for a single cylinder, 4-stroke, 1.4 liters engine has been considered with a given volumetric efficiency of 0.85 operating at different engine speeds. Accordingly flow rate at the air-inlet will be determined as prescribed by the standard practices followed in engine calculations.

Some modifications need to be done in dual-fuel system. The main modification is to reduce compression ratio. Since the compression ratio of diesel engine is very high this is necessary because CNG has low ignition temperature and will easily ignite at high temperature.

The main challenge focuses on designing a mixing device which mixes the Air and CNG at an optimum ratio. This is important because the combustion efficiency is directly proportional to the degree of homogeneous mixing, and also for proper mixing of air and prior to the combustion chamber. CNG-AIR mixer is also needed in metering the correct proportion of Air and CNG.

CONSTRUCTION AND WORKING PRINCIPLE.

The main challenge focuses on construction of a mixing device which mixes the supplied gas with the incoming air at an optimum ratio. The mixer used in the present work is of a Venturi type. Air enters the mixer through the main inlet, whereas, fuel enters through small holes located at the throat at 90^0 angle to the main flow. The holes, each with diameter of 4 mm, were distributed evenly at the throat. Figure 2 shows the schematic diagram of the mixer. The throat diameter is 37.66 mm while the diameter at the inlet and outlet of the mixer is 50 mm. The mixer has a uniform cross-section for the first 45 mm from its inlet which later converges to the throat over a length of 35 mm. The throat length is 30 mm with the holes placed exactly at the mid-plane normal to the axis of the mixer. The diameter varies uniformly from the end of the throat to the outlet over a length of 88.26mm.

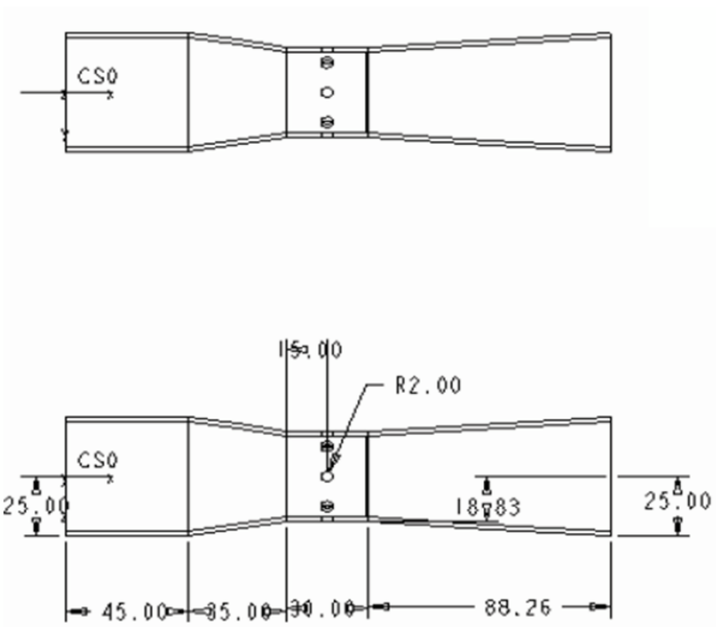


Fig 1: CNG-AIR MIXER

The geometry considered in the present analysis, is with 8 holes for the CNG injection. In this case, the holes are uniformly distributed on the mid-plane of the throat section as shown in the figure above.

Air enters the domain at a low speed and for a static pressure specified at the holes, causes an induction of the CNG (primarily methane gas) due to the low static pressure at the throat owing to high dynamic pressure. The air-CNG mixture then flows downstream along the diverging section and encounters an opening type outlet boundary at a fixed static pressure.

The challenge in this problem has been the determination of the inlet velocity which is based on engine flow rate calculations. In the present case, a single cylinder 4-stroke 1.4 liters engine (typical displacement volume for Tata Indica) has been considered with a volume efficiency of 0.85 operating at different engine speeds. Accordingly, the flow rate at the air-inlet will be determined as prescribed by standard practices followed in engine calculations.

MODELING AND MESHING

The geometry of CNG-AIR MIXER is modeled and meshed in ICEM CFD. And the flow equations solved in ANSYS CFX.

DOMAIN CONDITIONS

The continuity and 3-dimensional momentum equations will be solved for the isothermal flow modeling. Turbulence will be modeled by Turbulence will be modeled by *Shear Stress Transport* turbulence model (a blend of k-ε and k-ω) appropriate to account for high velocities and strong streamline curvature in the flow domain especially for flows involving low Reynolds number. . In addition, another transport equation for the mass fraction of CNG will be also solved. The reference pressure will be set at 1 tam and all pressure inputs and outputs will be obtained as gauge values with respect to this. The low velocities would mean an incompressible flow regime for both gases.

MATERIAL

Air and CNG gas will be the working fluid. The material properties under these conditions are:

Property	Air	CNG (primarily methane, CH4)
Density (kg/m^3)	1.185	0.717
Viscosity (Pa.s)	1.789 x 10-5	1.11 x 10-5

BOUNDARY CONDITIONS

The engine selected for this study is a In the present case, a single cylinder 4-stroke, 1.4 liters engine (typical displacement volume for Tata Indica) has been considered with a volume efficiency of 0.85 operating at different engine speeds.

Air enters from the main inlet with a medium turbulent intensity of 5%. The air inlet velocity will be determined from the engine speeds according to the following formula:

Engine flow rate = Number of engine cycles per second * Total engine displacement volume * volume efficiency

Where,

Number of engine cycles per second = 0.5 * Engine speed (rotations per second)

Total engine displacement volume = Number of cylinders * Displacement volume efficiency = a value between 0.8 to 0.9 the corresponding air inlet velocities through an area of 19.65 cm^2 have been tabulated below:

Case	Engine speed (rpm)	Flow rate (cc/s)	Air inlet speed (m/s)
1	1000	9952.08	5.07

The holes will be considered as static pressure inlets at -10 Pa having only input of CNG. A medium turbulent intensity of 5% will be assumed.

METHODOLOGY

A single phase multi-species incompressible flow simulation with Air and CNG as the working fluid will be carried out at a specific engine speed (1000 rpm) for single geometry for 8holes at the throat section:

i) 8holes

RESULTS AND DISCUSSION

Fig 2 CNG-concentration at 1000 rpm for 8-holes

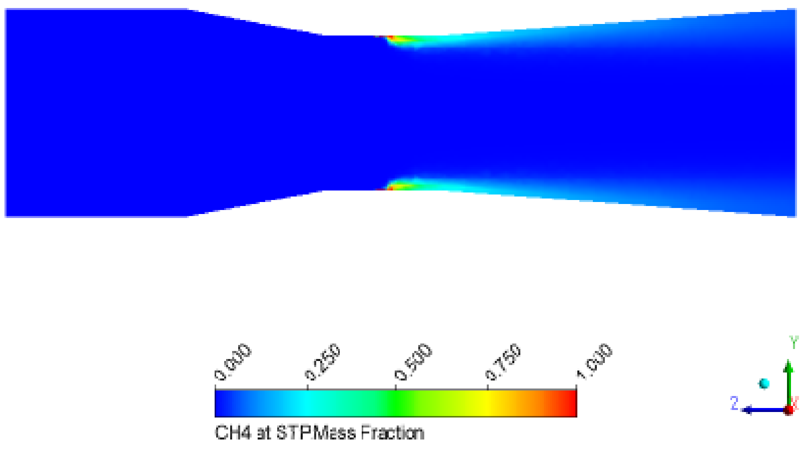


Fig 3 Pressure variation at 1000 rpm for 8-holes

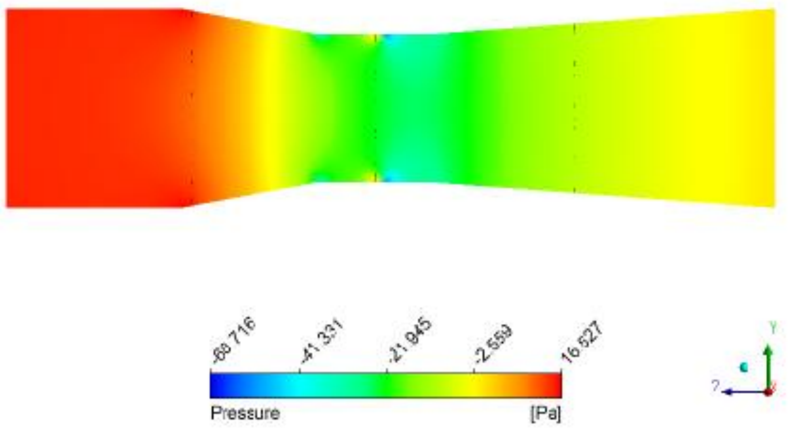
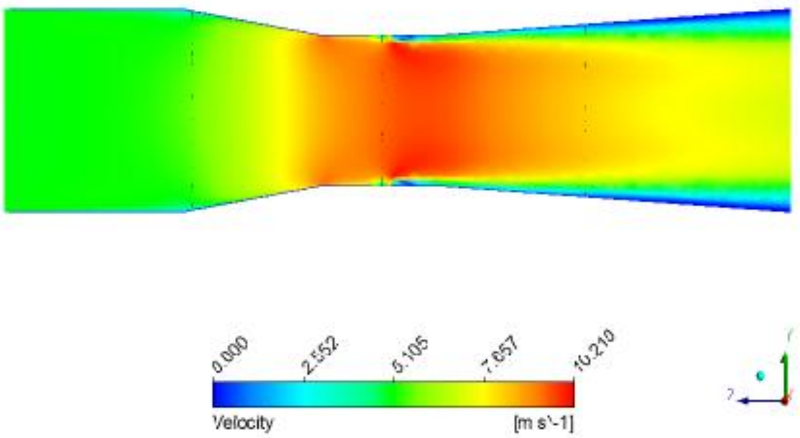


Fig 4 Velocity variation at 1000 rpm for 8-holes



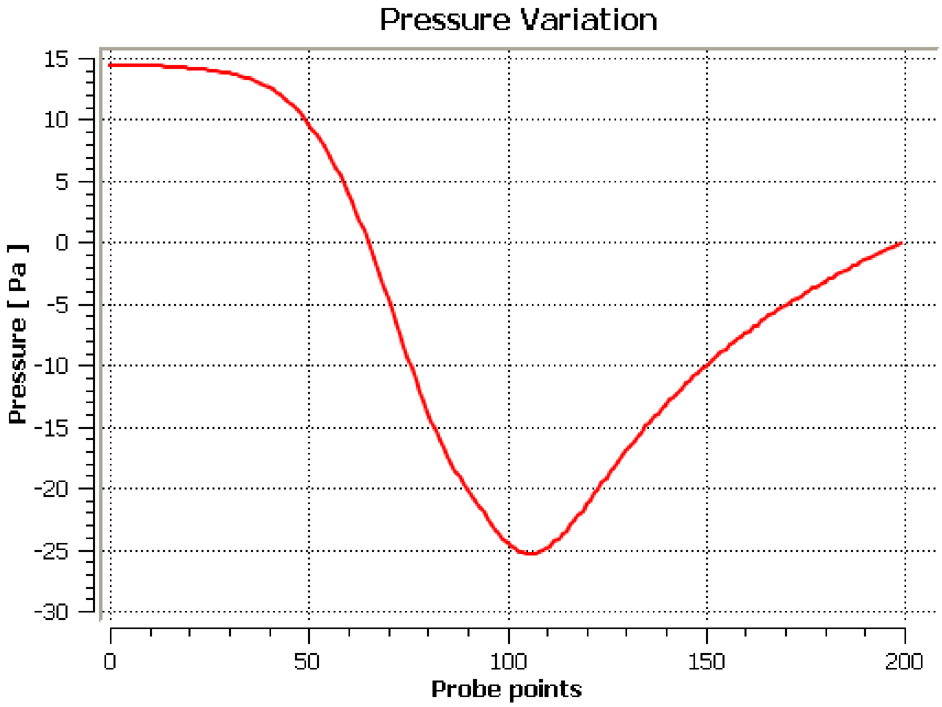


Chart 1. Variation of Pressure along the Axis

Average Mass fraction at the outlet	0.02782550
CNG Mass flow rate at outlet	6.053e-05 [kg s^-1]
Mass flow rate at outlet	3.003e-03 [kg s^-1]
Mass Fraction Spread	0.00150502

TABLE 1 **Quantitative Report for 8-hole at 1000 rpm**

CONCLUSIONS

- A CNG-air venturi mixer for CNG-diesel dual-fuel stationary engine has been designed using CFD analysis. Venturi with eight holes has been simulated. The effect of engine speed is to increase the proportion of mass of fuel inducted into the mixer and hence increasing λ.
- This study shows that the conversion of an existing small single-cylinder stationary diesel engine to a dual fuel system can be done with minimum modification.
- The mass fraction spread of CNG for 8- hole venturi mixer at 1000 rpm is calculated.

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