COLD FLOW ANALYSIS OF TANGENTIAL INFLOW OF AIR-PRODUCER GAS CARBURETOR

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Abstract— Currently there has been no Producer gas carburetors sold commercially. Some of theconcepts evolved have not been optimized and are not standardized as well. In this view, development of an optimized carburetor for producer gas application addressing the low energy density of the delivered mixture is need of the time. Design of a carburetor for producer gas application with special reference for reduced loss of pressure is taken up to generate the optimal fuel–air mixture to meet different load conditions of the engine as well as for varying operating conditions of producer gas reactor. A specially designed producer gas carburetor is comprehensively analyzed for its mixing performance and response with a CFD modeling. The model is made up of a mixing chamber that has the essential orifices for air and fuel (producer gas) inlets to generate stable stoichiometric mixture nearer to ambient conditions. The CFD simulations are carried out followed with experimental studies under engine simulation conditions using pressure controlling system to validate the analysis. The results show a consistency in the experimental data and the modeling has provided a good insight into the flow details and has paved way in optimization of geometrical design to get a good mixing efficiency.

Keywords— Computational Fluid Dynamics, Producer Gas, Carburetor, Air/Fuel Ratio, Turbulence.

I. INTRODUCTION

In the current state of technological advances, it is recognized that Biomass is one of the viable and sustainable renewable resources and new technologies emerging out of biomass based gasification systems find a significant role in bridging the energy crisis. The advanced biomass gasification systems are known to generate producer gas as the combustible fuel that is clean enough to be used in Direct Injection gas engines. However in order to adapt standard gas engines few of its components need modifications before they are used in the biomass power plants. Since this area is an emerging one and the technology has not been disseminated to the scale of driving market, it is essential that specialized components that require modification need be studied. Carburetor is one of the important components in such Category and it is identified that additional research work is to be carried out in establishing a design procedure for this application. The work presented here is an effort in this regard. Air/fuel ratio characteristic exert a large influence on exhaust emission and fuel economy in Internal Combustion engine. With increasing demand for high fuel efficiency and low emission, the need to supply the engine cylinders with a well-defined mixture under all circumstances has become more essential for better engine performance. Carburetors are in general defined as devices where a flow induced pressure drop forces a fuel flow into the air stream. An ideal carburetor would provide a mixture of appropriate air-fuel (A/F) ratio to the engine over its entire range of operation from no load to full load condition. To ensure proper performance, Carburetors should be reproducible and have unequivocal adjustment procedures. CFD software used for cold flow analysis is ANSYS FLUENT. The k-ε turbulence model is most commonly used and is considered to be the best model between computational time and precision. The geometric model is built using Solid Works.

II. PRODUCER GAS CARBURETOR

Mixing devices for gases used in gas engines generally referred to as carburetor, for mixing air and gaseous fuels are commonly attached to the intake manifold of an internal combustion engine. In gas carburetor the mixing of air and gaseous fuels needs to be in a proper ratio for a particular engine load and speed. In designing the producer gas carburetor, simplicity and ruggedness have always been considered as a basic requirement to achieve easy adjustment and reproducible performance. The effective area reduction of gas and air entry holes is considered bytaking a suitable coefficient of discharge. The air and fuel flow is through orifices into the mixing chamber of the carburetor which has baffle plates that enables proper mixing of air and fuel. The producer gas carburetor is being designed to have air and fuel flow at ambient conditions to be stoichiometry. The producer gas carburetor is as shown in the Figure 1 has orifices placed at air and gas inlets such that the A/F ratio at ambient flow condition should be stoichiometry for an engine suction pressure of a 25 KWe engine. The amount fuel flow inside the carburetor is controlled by a butterfly valve which is located prior to the fuel inlet orifice. The pressure balancing electronic controller drives suitably the butterfly valve with the help of a motor that brings the valve for a null pressure differential across the manifolds for the fuel and air attached upstream to the main engine manifold and works in suction pressures. If the differential pressure at both the carburetor manifolds are maintained at zero, with the manifolds tuned for their effective flow areas to match the ideal mixture condition, then the mixture flow what we get at engine intake manifold will be stoichiometry. The Figure 1 shown below is the geometric model of the producer gas carburetor designed and analyzed for optimal pressure drop with good mixing ability.

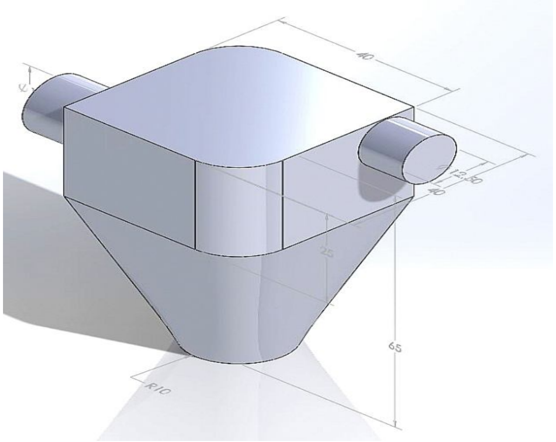

Figure 1: Isometric view of the model

III. GRID GENERATION

The Mesh geometry shown in Figure 2 is a Cut sectional model used to simulate the flow analysis in a carburetor with nodes of around 192570 computational nodes is considered. The grid is an unstructured mesh with a maximum mesh grid size of 18mm.

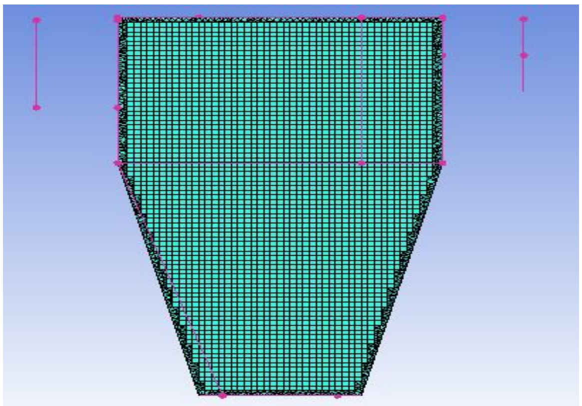

Figure 2: Meshing of Mid Plane

IV. BOUNDARY AND INITIAL CONDITIONS

The flow domain considered for simulation the carburetor mixing chamber with steady state flow. Here for simplicity of analysis a single gas entity is considered having air ideal gas and Argon. The relative pressure of the carburetor domain is 1 atmosphere with non-buoyancy condition. For air inlet boundary condition mass and momentum, static pressure equivalent to domain reference pressure is set with flow condition being subsonic. The initial condition of flow through the air inlet with air ideal mass fraction as 1 is considered. The initial boundary condition for fuel inlet is same as the air inlet except for the flow of producer gas mass fraction being 1 at the inlet, The boundary condition for carburetor outlet is of different mass flow rate which is to be simulated is considered.

A 3 Dimensional RANS code having unwinding implicit scheme and k–ε approach for turbulence is used for obtaining numerical solution. The Equations are solved for steady incompressible flow. The boundary conditions and initial conditions used include (a) no slip and adiabatic walls; (b) At inlet and outlet ports, pressure and mass flow rate respectively.

1. Inlet Conditions: For air side and Gas side velocity input has been given.
2. Mixing flow without reaction: In this simulation, it is assumed that there is no reaction occurs between air and natural gas.
3. Outlet: Fixed Pressure outlet boundary condition was considered.

V. CFD RESULTS

Case I: The velocity at the inlet of air and gas side 2.0 m/s and 2.5 m/s respectively. Figure 3 shows proper mixing of air and gas. From the analysis it is found that, air mass fraction is 0.56, and gas mass fraction is 0.43 maximum velocity of 3.55 m/s has been achieved at the outlet.

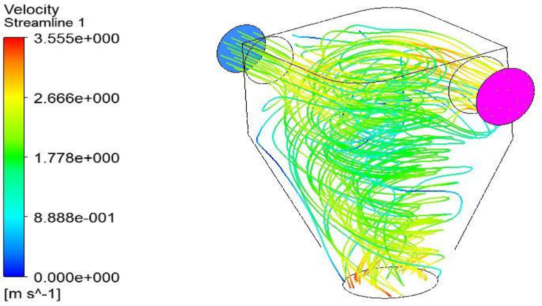

Figure 3: Stream line (Case I)

Case II: The velocity at the inlet of air and gas side 2.5 m/s and 3 m/s. Figure 4 shows proper mixing of air and gas. From the analysis it is found that, air mass fraction is 0.55, and gas mass fraction is 0.44 maximum velocity of 4.48 m/s has been achieved at the outlet.

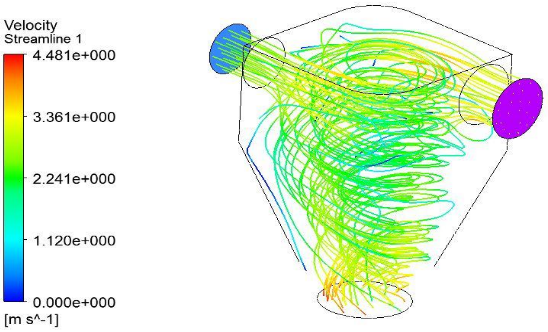

Figure 4: Stream line (Case II)

Case III: The velocity at the inlet of air and gas side 3 m/s and 3.5 m/s. Figure 5 shows proper mixing of air and gas. From the analysis it is found that, air mass fraction is 0.53, and gas mass fraction is 0.46 maximum velocity of 7.46 m/s has been achieved at the outlet.

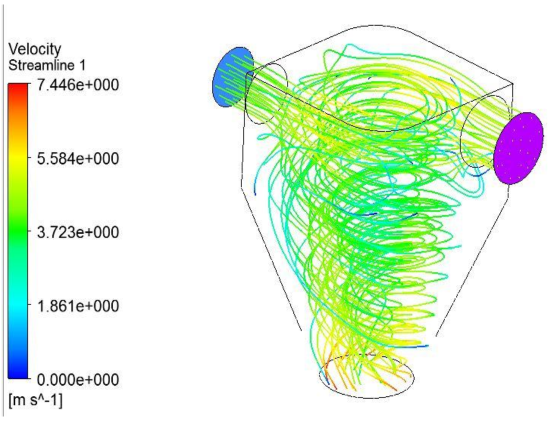

Figure 5: Stream line (Case III)

CONCLUSIONS

1. From the above three cases it is found that, a proper mixing of air and gas has been achieved.
2. Tangential inflow geometry of air and gas will provide better mixing.
3. 3.Air Mass fraction of 0.565 has been obtained in case I
4. Air Mass fraction of 0.555 has been obtained in case II
5. Air mass fraction of 0.539 has been achieved in case III
6. Mass fraction of nearly 0.5 has been achieved with the current geometry, which indicates 50% of air and gas in the outlet.

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