Experimental and numerical studies of an inverted cyclone gasifier- isothermal analysis

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The isothermal aerodynamic characteristics of a novel inverted gasifier are described via the use of LDA and Fluent predictions. The inverted gasifier allows material such as coarse sawdust to be gasified by centrifugal suspension, giving sufficient residence time for good fuel burnout and char conversion. The addition of an external Vortex Collector Pocket (VCP) on the top of the device allows significant quantities of ash to be collected here as well as in a drop out pot at the base of the unit (which also incorporates a VCP), thus giving a reasonably clean gas that can be used to directly fired small gas turbines. Only one inlet is used on the system as this enables the fuel and gasifying air to be simply premixed upstream of the inlet. The use of only one inlet has been found not to seriously affect the system performance. This study was directed at investigating the isothermal properties of the unit both to optimize the swirl number and maximize the centrifugal force field used to suspend the gasifying particles as well as maximizing the amount of material collected by both sets of collector pockets. LDA was used to experimentally characterize a full size model of the system with access being provided via quartz windows. Three different swirl numbers were covered as well as a range of flow rates and Reynolds Numbers. These results showed that there was an optimal level of swirl number whereby the inlet flow most effectively coupled with the flow in the cyclone chamber and this has been subsequently used for all the gasification studies. Complimentary CFD studies have been used on the optimized configuration to explore the flows in and around the VCP, the outlet and the effects of three-dimensionality. It was shown that good match between the experimental studies and the CFD was only obtained when hexahedral meshes were used, with more cells being concentrated in the central vortex core region and in the various boundary layer regions. Similarly second order discretisation schemes were needed to accurately reproduce the measured flow patterns in the central vortex core region of the device.

1. CFD Modeling

The computational CFD code Fluent was used in the work and especial attention was paid to developing meshes which could represent known areas of high velocity gradient where experience with other related work had indicated such needs. Several different three dimensional grids were investigated involving the initial use of tetrahedral grids, but finally converging to the use of hexahedral grids, despite the difficulty of adapting such a grid to the highly complex configuration of the inverted gasifier and VCP system. Similarly grid cells had to be concentrated in the central region of the device to most accurately represent flow in the central vortex core regions, similar comments apply to the boundary layer region. Care was taken to ensure that good quality meshes were obtained. Finally second order discretisation methods needed to be used coupled with the RSM model of turbulence. A typical hexahedral three dimensional grid is shown below in figure 1. A modeled collection pot is shown attached to the VCP, being representative of practice on the gasification rig.

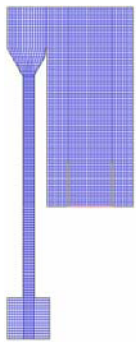
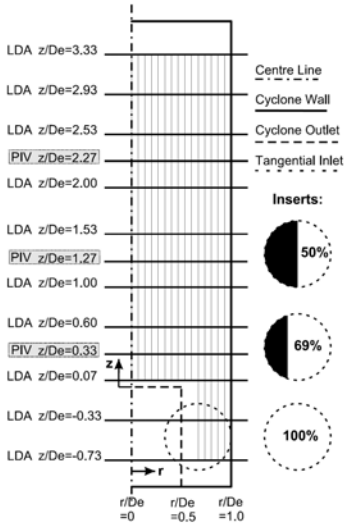


Fig. 1 Hexahedral Grid on section through VCP and cyclone Chamber 115883 elements

2. Experimental Measurements

Experimental velocity profiles have been obtained via the use of a Dantec two component LDA system using Burst Spectrum analyzers for data reduction. Titanium dioxide was used for seeding purposes and typically up to 10,000 doppler busts were recorded for at each measurement point. The measurement grid used for the LDA is shown in figure 2. Measurements were taken at 13 radial sections in the gasifier with the circular tangential inlet being modified by the addition of 'D' shaped inserts at the inner section to alter the inlet area, hence swirl number. By this technique geometric swirl numbers between 3 and 7.5 could be achieved. In terms of gas turbines pressure drop is crucial and thus the lowest level of swirl is sort commensurate with best particle retention and also separation in the VCP.



Dimensions:
Outer Cyclone Diameter, Do= 300 mm
Exit diameter of Cyclone, De=150 mm
Total height of cyclone chamber = 700mm
Height of Vortex Finder = 160 mm

Fig. 2 Experimental Measurement Sections