Abstract

The application of the pressurised circulating fluidized bed technology to the coal-based combined cycle power generation may fulfil both the environmental compatibility and high energy conversion efficiency. In this cycle, high pressure and high temperature flue gas from the PCFB combustor is supplied to the gas turbine after necessary 'hot gas cleaning' to generate power. The cyclone separator is an integral part of the circulating fluidized bed to separate the solid particles from the exiting flue gas. The exit gas from the gas turbine is utilised in the bottoming part through the heat recovery steam generator. Rankine cycle is usually used as the bottoming cycle in which boiling essentially takes place at constant temperature. The thermal irreversibilities are more due to the large temperature difference between the hot flue gas and the working substance. These irreversibilities are reduced by using aqua-ammonia as the working substance.

Though sufficient literature is available on performance, there is hardly any information available on heat transfer studies in the cyclone separator of a CFB. Also, not much literature exists on bed hydrodynamics and heat transfer at elevated pressures. Some literature is available on thermodynamic analysis of Kalina cycle, still more detailed study is necessary to optimize the concentration of ammonia in water and also to integrate the cycle into the actual plant.

Present investigation is aimed to make some heat transfer and thermodynamic studies related to combined cycle power generation. In the first part, an experimental investigation has been carried out in a cold bed set-up to study the effect of fins and other relevant operating parameters on heat transfer coefficient in the cyclone separator of a CFB at atmospheric conditions. Local sand of mean particle size $259\mu m$ is used as the bed material. The experiments are conducted for different velocities ranging from 4.0m/s to 7.0m/s, three different heat fluxes of $1505.98 W/m^2$, $1969.22 W/m^2$ and $2469.27 W/m^2$, three different bed inventories of 15kg, 19kg and 23kg. All these experiments are repeated with the incorporation of fins in the heat transfer probe to see its effect. An empirical model has been proposed to predict

the heat transfer coefficient in the cyclone separator based on dimensional analysis. The heat transfer coefficient is found to be somewhat less with the incorporation of fins. However, the total heat transfer rate is more with the finned surface than the unfinned surface. The model results are compared with the experimental data and good agreement has been observed.

In the next part of the investigation, experiments are conducted in a pressurised circulating fluidized bed bench scale unit to study the effect of pressure and other relevant parameters on bed hydrodynamics and heat transfer in the riser column. The pressure drop measured without sand particles is assumed as the pressure drop due to gas density for evaluating the bed voidage and the suspension density. The bed voidage profile along the riser column shows two distinct zones i.e., dense phase bottom zone and dilute phase top zone. The bed voidage is found to be increasing in the bottom zone and decreasing in the top zone with increase in operating pressure. The heat transfer coefficient is observed to be monotonically increasing with the operating pressure as well as average suspension density. A mechanistic model has been developed similar to the cluster renewal model to predict the heat transfer in the riser column of a PCFB. The experimental results are compared with the model results and also with the published literature.

In the last part, thermodynamic analyses (energy and exergy) of the Kalina cycle have been made to optimise the ammonia concentration at turbine inlet. Peng-Robinson's equation of state is considered for studying the phase behaviour of binary mixture. Using Gibbs free energy equations, a generalised computer code has been developed for evaluating the thermodynamic property data of $NH_3 - H_2O$ mixture. The important parameters which affect the cycle performance have been identified as the turbine inlet condition i.e., ammonia concentration and temperature, and separator temperature. The second law efficiency of the cycle is found to be increasing with increase in ammonia concentration first and thereafter decreasing. The ammonia concentration has an optimum value for a set of other operating parameters where the exergy loss of the cycle is minimum. The effects of all the key parameters on fractional exergy loss of each component have also been studied.