6 Conclusion

6.1 Boiler CFD Model Simplification

It is evident from Chapter 4 that great simplifications can be made to CFD boiler models. It was observed from CFD analyses that different inlet geometries did not significantly influence the flow patterns in the upper boiler and boiler back pass. Both a uniform inlet geometry below the bullnose and the inlet through the actual location of the burners were considered. The location of high peak velocities, recirculation zones, and particle concentration were approximately the same for the different cases. Because combustion in boiler environments is very complex and expensive to simulate in CFD, great simplifications can be made regarding inlet geometry and grid size because the flow pattern in the upper boiler is approximately the same for the different cases due to channelled flow forced by the bullnose when excluding the burner region and including it.

Another great simplification that can be made to CFD boiler models is the fact that 2D boiler models can be used to great effect to determine the flow field through the boiler. This is especially true for quantitative results to obtain regions of high peak velocity and particle concentration. The flow field will only differ near the boiler side walls as determined by other researchers. 2D models can therefore be used near the centre section of the boiler with symmetrical boundaries on both sides. Boiler CFD models can therefore be greatly simplified for erosion studies in the centre of the boiler through the use of 2D models.

Because of the fine-scale grid needed to model boiler internals such as the airheater and tube bank, it is necessary to 'replace' the boiler internals with porous cells with the same pressure drop versus velocity characteristics. After constructing a detailed hydraulic model of the tube bank, the pressure drop versus velocity characteristics of the tube bank were determined. These results did not exhibit good correlation with experimental results published by another author. The numerical results from this study under-predict the pressure drop with respect to the experimental correlations by a factor of five. The CFD model was also very unstable and the velocity field was not realistic at the inlet of the tube bank due to the directional properties of the porous cells. It was therefore decided to omit the effect of the tube bank in the overall CFD boiler models. However, the effect of the boiler bank was included in some CFD analyses for reasons of comparison. This was only done on a quantitative basis for the identification of global trends, such as the influence of the tube bank on particle trajectories through the boiler. The scope for future work in this field is the determination of more reliable porosity coefficients for boiler internals. As CFD gives only guidelines, experimental research is necessary for the validation of the results in actual boilers. This can be done through cold flow boiler studies to determine flow parameters at certain pre-selected locations throughout the boiler.

6.2 Remedial Measures for Boiler Tube Failures

6.2.1 Erosion in the Centre of the Tube Bank

Tube fins can be used to cover larger than usual tube spacing in tube banks in order to eliminate the channelling of the flow in these larger than usual gaps. It is important that the flow-modifying devices do not shift the erosion to other areas. It was therefore necessary to install multiple tube fins across the whole tube bank in the larger than usual gap to prevent the flow from being deflected by fins onto adjacent tubes. Multiple fins were used because if only a few fins are used, channelling of the flow still occurs in the larger gaps and the flow is then deflected onto adjacent tubes by the fins. With multiple fins installed in the tube bank, the particles are distributed more evenly across the tube bank with lower local peak velocities. As flow velocity and particle concentration are major factors influencing particle erosion, erosion in the tube bank will therefore be decreased. For future work, the optimum number and size of tube fins can be determined through mathematical optimisation. Experimental verification of this work should also be conducted to check the inherent assumptions of the CFD model.

6.2.2 Erosion of Superheaters and Tube Bank at the Top of the Boiler

Tube erosion of the superheater and tube bank occur at the top of the boiler. This is due to channelling of the flow in the top of the boiler because of the influence the bullnose has of the flow field. The channelling is exacerbated even further due to the 180° turn the flow must follow through the boiler. Larger particles are also flung outwards towards the top of the boiler due to centrifugal forces. One effective remedial measure that can be used is to remove the bullnose completely from the boiler. As this will alleviate tube erosion in the top of the boiler due to the uniform flow across the tube bank after the removal of the bullnose. However, this method will be very expensive to implement because extensive boiler modifications will be necessary. As the bullnose shields the superheaters from furnace radiation other materials should probably be used for the superheater tubes which has further cost implications. The savings due to the reduced erosion will probably not justify the cost of boiler modification.

A much more cost-effective remedial measure is to install baffles in the boiler that will have the desired effect on the flow pattern through the boiler, i.e. a uniform flow across the superheaters and tube bank. A baffle that achieves this goal is a permeable baffle located just upstream of the superheaters at the top of the boiler. If a solid baffle is used, the flow is shifted downwards towards the middle of the superheaters and the tube bank with high flow velocities and a high particle concentration. This can lead to severe erosion in that area. A large permeable baffle, that covers the entire flow area from above the bullnose to the top of the boiler, was implemented in the CFD model. There are no major differences in the flow field when the small permeable or large baffle is used. The small baffle therefore represents the best solution because it would prove more cost effective. For future work, the optimum size, permeability, and location of the baffle can be determined through mathematical optimisation.

6.2.3 Airheater Erosion

As airheater tube failures do not influence boiler availability to a great extent, it is therefore not critical if such a tube fails. It was, nevertheless, decided to investigate different concepts to obtain remedial measures for airheater tube erosion. All the different concepts involve the usage of flow-modification devices such as solid or permeable baffles. The aim here is to again have uniform flow across the airheater. Some concepts proved to be ineffective, while others showed some promise, of which two stood out from the rest. The one successful concept entailed only the usage of one permeable baffle, which is installed at an angle of approximately 45° from the vertical datum. The other concept uses four large baffles with a relatively complex geometry. As both concepts of flow-modifying approaches have essentially the same effect on the flow field, the concept with only one baffle is more cost-effective due to its simplicity compared to the multiple baffle concept. For future work, the optimum location, size, permeability and, angle of the baffle can be obtained through mathematical optimisation, and verified by experimental comparison.

6.3 Future Work

- Some suggestions for future work were already made in this chapter. These suggestions include the determination of more reliable methods to determine porosity coefficients for hydraulic CFD models of tube banks and the implementation of these porosity coefficients in stable CFD models of boilers. Because reliable results could not be found during this research, future work is necessary. Other suggestions of the future work mentioned previously in this chapter concern remedial measures through the usage of baffles. Mathematical optimisation can be used to great effect in this regard to obtain optimum solutions, as the current method relied on trial-and–error CFD runs.

- A large relatively untouched field in this study is Lagrangian two-phase flow. As the presence of particles in fluids can alter the properties of the fluid, the vortices, for example, can behave differently in tube banks. As only quantitative results are appropriate in this study, it was not important to investigate the influence of particles on fluid behaviour, but there is definitely scope for further investigation into this field.

- Heat transfer was omitted in the CFD models in this study. As cold flow studies in actual boilers was used very successfully by other researchers to determine regions of high velocity in tube banks, it was deemed unnecessary to include heat transfer in the CFD model. As heat transfer is an integral part of boiler operation it can be included in future CFD models to investigate the effect of heat transfer in boiler flows.