# 1 Introduction

## 1.1 Motivation

Boiler tube failures are a major cause of forced outages world-wide. These failures are also the cause of forced outages of the Babcock boilers at Sasol in Secunda. In addition, many boiler tubes have to be replaced at each major scheduled boiler shutdown due to surface degradation. It is believed that erosion due to fly-ash impingement is the main cause of boiler tube surface degradation. Tube failures have occurred more frequently during the last few years. This problem has led to Sasol's sponsorship of this research project to investigate boiler tube surface degradation and boiler tube failures.

Tube surface degradation occurs at locations throughout the whole boiler. The first location of tube degradation due to fly-ash erosion is at the sidewalls at the edge of the bullnose. The superheater tubes at the top of the boiler also suffer from surface degradation. The biggest problem, however, is tube surface degradation that occurs in the tube bank. Surface degradation occurs adjacent to sections with larger than usual tube spacing. Finally, tubes fail at the inlet of the airheater in the boiler back pass.

## 1.2 Objectives of this Dissertation

The two main objectives of this dissertation are:

- To study the phenomenon of erosion in detail as well as to investigate remedial measures proposed by other researchers for boiler tube failures due to erosion. The following sub-objectives are identified:
    - Computational Fluid Dynamics (CFD) boiler models used by other researchers are investigated to become familiar with boiler flows. The assumptions on which their models are based on are investigated and how these models compare to experimental observations.
    - The simplification of boiler CFD models is investigated due to the complexity of boiler environments. These simplifications include neglecting heat transfer, simplified inlet geometry, and the usage of 2D boiler models for comparative studies.

- Investigation of the unique boiler tube failures in the Babcock boilers at Sasol using CFD, and the proposal of remedial measures to combat these failures. To achieve this objective the following sub-objectives must be met:
    - Erosion must be reduced at the superheater tubes and tube bank tubes in the top of the boiler.
    - Erosion that occurs in the tube bank adjacent to the larger than usual gaps in the tube bank must be reduced.
    - Airheater erosion in the boiler back pass must also be reduced.

Research has been performed on boiler tube failures due to fly-ash erosion and flows in tube banks. No research was found that deals specifically with flows in tube banks with irregular gaps. It is believed that the effect of the larger than usual gaps in the tube banks is the main contributor to fly-ash erosion. The effect of gaps in tube banks on flow and fly-ash erosion will therefore be investigated in this study. The purpose of this study therefore is to make suggestions as to why erosion occurs in all the regions discussed above, and to suggest methods as to how to minimise and hopefully prevent boiler tube erosion.

## 1.3 Layout of this Dissertation

CFD is used in this study to model the boiler and to investigate ways to minimise boiler tube erosion. The commercially available CFD solver, STAR-CD, is used. A brief background on CFD is given in Chapter 2, after which a literature survey on boiler tube failures follows in Chapter 3. Boiler tube failures due to erosion are investigated in detail. Remedial measures proposed by other researchers for fly-ash erosion in boilers are also discussed. Literature pertaining to the CFD modelling of boilers is discussed in Chapter 4. This chapter also describes a parametric study performed by the author using CFD. In this parametric study, factors like inlet configuration and fly-ash particle size and distribution are investigated. Porosity coefficients are also obtained for the boiler bank tubes and airheaters using a CFD hydraulic model. In Chapter 5 ways to combat boiler tube erosion are investigated. The remedial measures used are methods described in the literature as well as other new methods suggested by the author. Chapter 6 contains conclusions drawn from this study and suggestions for future work.