Chapter 1

Introduction

1.1 Background

Worldwide, major sources of energy and chemicals are derived from coal, petroleum, biomass and natural gas. Coal is the main feed material to a wide range of conversion processes. The major constituents found in coal include carbon (C), hydrogen (H), nitrogen (N), oxygen (O), sulphur (S) and mineral matter. Conversion processes that can be used to convert coal into different products include gasification, destructive distillation, and hydrogenation. Each of these processes yield different set of products, and therefore it is important to analyse all the products that are produced from these processes.

The carbonisation of coal takes place in coking ovens that are operated in the absence of air, giving yield to coke as the main product. During the process of coking, volatile organic matter will evolve and the gases emitted comprise ammonia, coal tar vapours and many other products that can be recovered through a number of processes [Fuchs and Sandhoff, 1942; Codd, et al., 1971]. The coal tar (CT) obtained from the destructive distillation can be converted through distillation to coal tar pitch (CTP). CTP is a solid material at room temperature that softens on heating. The chemical and physical compositions of CT, CTP and other related products all depend on the type and rank of coal used.

Many techniques have been developed to characterise various coal conversion products such as CT and CTP. Some of these techniques include chromatographic analyses, such as Gas Chromatography/Gas Chromatography-Mass Spectroscopy (GC/GC-MS) and High Performance Liquid Chromatography (HPLC), as well as spectroscopic methods, which include: Fourier Transform Infra-Red spectroscopy (FT-IR) and Nuclear Magnetic Resonance spectroscopy (NMR). Thermal analysis techniques that can be used include:

Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Thermomechanical Analysis (TMA) and Differential Scanning Calorimetry (DSC) [de Castro, 2006]. It is unlikely that one technique alone will give a complete and accurate picture of the structure of coal conversion products and their transformations occurring during the processes. Therefore, research studies usually include a combination of these analytical methods to characterise different coal conversion products [Cebolla et al., 1996; Tiwari et al., 1998; Casal et al., 2005; Takashi et al., 2008]. Carbon-related products obtained from coal have a wide range of industrial applications. The application considered in this study is self-baking or Söderberg electrodes. In the manufacture of Söderberg electrode paste, coke and calcined anthracite are used as fillers, while CTP is used as a binder.

1.2 Motivation of the study

Söderberg electrodes are widely used in different ferroalloy smelting processes. This electrode system is characterised by an important temperature known as the baking isotherm temperature. At this temperature, the liquid electrode paste (mixture of CTP and calcined anthracite or coke) is transformed into a solid carbonaceous material. During the thermal treatment of the electrode paste in the operation of the Söderberg electrode system, structural, as well as dimensional changes are bound to occur. The changes that occur are thought to be related to the physical and chemical properties of the CTP used. This study is aimed at establishing the relationship(s) between the chemical compositions of CTPs and the dimensional, as well as structural changes that occur when CTP is subjected to a high temperature thermal treatment.

1.3 Objectives of the study

In order to achieve the general objective, i.e. establishing the relationship(s) between the chemical compositions of CTPs and the dimensional, as well as structural changes that occur when CTP is subjected to high temperature thermal treatment, the following specific objectives were set for this study:

i) Obtaining CTP samples from several different producers that produce CTP specifically for Söderberg electrode paste production. Having a range of CTP samples, with different composition and properties, will aid in testing the hypothesis put forward on a broad spectrum of CTPs.

ii) Establish the fundamental chemical and physical properties of the CTP samples obtained. Proximate and ultimate analyses, as well as the determination of the softening point (SP), coking value (CV), and quinoline (QI) and toluene insoluble (TI) contents will be done.

iii) Use multi-linear regression of relatively commonly determined characteristics of CTP (e.g. proximate and ultimate analyses, as well as SP) to compile mathematical equations that can be used to calculate less commonly determined characteristics (e.g. CV, TI and QI).

iv) Determine the Söderberg electrode baking isotherm temperature of the above-mentioned CTP samples. Thermal pre-treatment under an inert atmosphere, followed by TMA analysis, will be used to determine this transitional temperatures more accurately than what has previously been indicated in literature.

v) Relating the observed baking isotherm temperature to fundamental properties and changes of the CTPs taking place during thermal treatment. For this purpose, FT-IR analysis will be conducted on CTP samples to determine how the functional group composition of the CTP samples changes during thermal treatment.

v) Use XRD analysis to study the graphitisation/structural ordering of the CTPs that result from the thermal treatment.

1.4 Chapter layout

The thesis is divided into 7 chapters. Chapter 1 focuses on background, motivation for the study, objectives and thesis outline. Chapter 2 focuses on the literature of CT, CTP, graphite and the Söderberg electrode system. Chapter 3 provides the experimental procedures, as well as materials used in this project. The results and discussion chapters were divided into three chapters, i.e. Chapters 4, 5 and 6. Chapter 4 provides the results on the characterisation of CTP using various analytical techniques. Multi-linear regression was also used to predict the fundamental properties of CTP. Chapter 5 provides the results and a discussion on the determination of the Söderberg electrode baking isotherm temperature, as well as FT-IR analysis of CTP samples thermally treated. Chapter 6 reports on the TMA analysis beyond the baking isotherm temperature as well as determining the degree of ordering in heat-treated samples using XRD. Chapter 7 provides the project conclusions and recommendations. References and appendices, with present journal papers that have already been published in peer-reviewed international journals, are attached as separate sections. An overall mind map of the whole PhD thesis, which also indicates some of the main sub-sections, is presented in Figure 1.1.

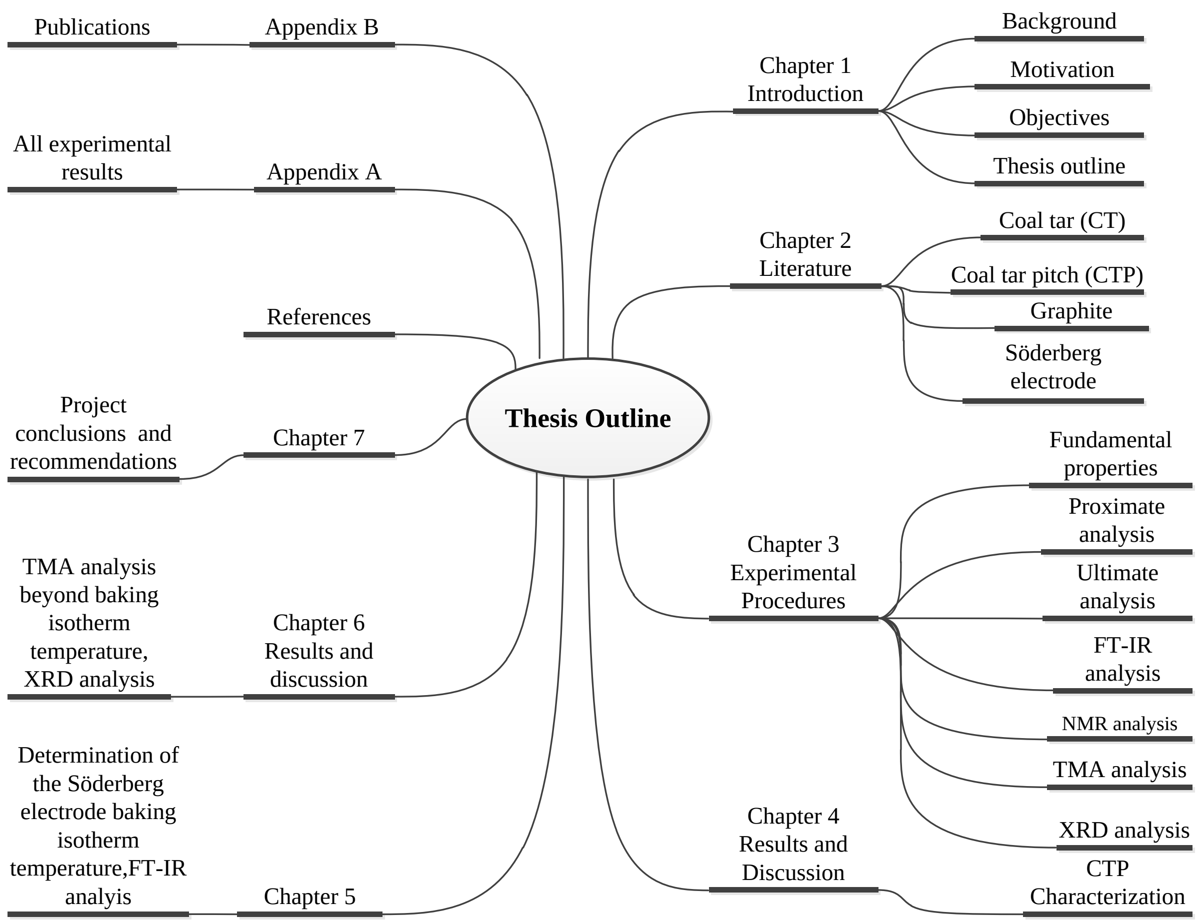

Figure 1.1 Thesis outline