

Chapter 1: Introduction

Several authors have studied the roasting of ilmenite concentrates for beneficiation purposes (Westcott and Parry 1968, Bergeron and Prest 1974, Nell and Den Hoed 1997 and many more). Furthermore oxidative roasting is applied on an industrial scale to beneficiate ilmenite concentrates from South African East Coast heavy minerals deposits (McPherson 1982). Why then another study on the impact of oxidative roasting on the magnetic properties of ilmenite? In this chapter I discuss the reasoning behind the study as well as the major hypothesis and the research program that followed. The outline of Chapters two to five of the thesis concludes this chapter. The order of discussion is:

- 1.1 Idea of the thesis and motivation for the study
- 1.2 The research topic and hypothesis
- 1.3 Research design and methodology in general
- 1.4 Outline of chapters two to five of thesis

1.1 *Idea of the thesis and motivation for the study*

The Heavy minerals industry provides feed material for the production of TiO_2 pigment. TiO_2 pigment is used as an opacifier in paints, paper and fibres and has a variety of other end uses. Considered a 'quality of life' product, the overall level of economic activity on a national and international level governs the consumption of TiO_2 pigment. As the consumption of TiO_2 pigment rises the demand for TiO_2 feed materials for the pigment production plants increases. High TiO_2 slag is one of the raw materials supplied by the heavy minerals industry to TiO_2 pigment production plants (Fisher 1997). High TiO_2 slag is produced in smelting furnaces by reducing ilmenite with a carbonaceous reductant (Pistorius, 1999). Ilmenite (nominally $FeTiO_3$) is a natural occurring heavy mineral associated with the heavy minerals sands deposits. In heavy minerals sands operation, producing high TiO_2 slag from the mining to the smelting stage, different mineral properties are exploited by means of different types of equipment to produce specific types of mineral concentrates. Ilmenite is separated from other minerals in the heavy mineral concentrate, based on magnetic susceptibility properties (Balderson 1999). In high chrome heavy mineral deposits the magnetic susceptibility properties of the ilmenite and chromite in their natural states are very similar. A crude ilmenite concentrate produced from a Southern African East Coast deposit, contains typically 90 per cent ilmenite, 5 per cent Ti-hematite, 3 per cent spinel (including chromite, magnetite etc) and 2 per cent silicates by weight. The Cr_2O_3 content can be as much as 0.3 per cent (Nell and Den Hoed 1997). Only when the per cent Cr_2O_3 in ilmenite concentrate is less than 0.1 per cent is the ilmenite suitable for the production of high TiO_2 slag (Beukes and Van Niekerk 1999).

Several authors found that when roasting an ilmenite concentrate it is possible to increase the bulk magnetic susceptibility of ilmenite. Different roasting atmospheres were described ranging from oxidative (Westcott and Parry 1968; Bergeron and Prest 1974; Nell and Den Hoed 1997; and Nell 1999) to neutral (Grey and Li 2001) to reductive (Walpole 1991; Guzman et al. 1992; Merrit and Cranswick 1994; and Reaveley and Scanlon 2001). Nell and Den Hoed (1997) stated that when roasting crude ilmenite concentrates under oxidising conditions the magnetic susceptibility of the ilmenite increases, but the bulk magnetic susceptibility of the chromite does not increase. This induced difference in magnetic susceptibility properties is used to remove the Cr_2O_3 -containing spinel from the ilmenite concentrate during secondary beneficiation by magnetic separation (Beukes and Van Niekerk 1999).

In their paper Beukes and Van Niekerk (1999) compared three secondary beneficiation processes for crude ilmenite produced from a Southern African East Coast deposit. Their aim was to produce ilmenite with Cr_2O_3 -levels less than 0.1 per cent from an ilmenite concentrate with Cr_2O_3 -levels in the order of 0.3 per cent. They claimed that the third process described by them has a lower operational cost than the conventional process patented by Bergeron and Prest (1974).

Bergeron and Prest patented the first process described by Beukes and Van Niekerk (1999) in 1974. The process consists of three steps:

- Step 1: Wet magnetic separation of the crude ilmenite concentrate at 2000-3000 Gauss. In this step chromite with a high magnetic susceptibility reports to the magnetic reject fraction.
- Step 2: Roasting the non-magnetic fraction in an oxidizing atmosphere.

- Step 3: Dry magnetic separation of the roasted material at 1000-2000 Gauss. Beukes and Van Niekerk (1999) claimed that this process resulted in 80 per cent yield of smelter grade ilmenite with less than 0.1 per cent Cr_2O_3 .

The second process described by Beukes and Van Niekerk (1999) consists of three steps as well but does not include roasting:

- Step 1: Drying of the crude ilmenite concentrate.
- Step 2: Dry magnetic separation of the dried crude ilmenite concentrate at 2350 Gauss.
- Step 3: Dry magnetic separation of the non-magnetic fraction at 6500 Gauss.

Beukes and Van Niekerk (1999) claimed that this process resulted in 70 per cent yield of smelter grade ilmenite with less than 0.1 per cent Cr_2O_3 .

The third process described by Beukes and Van Niekerk (1999) consists of five steps:

- Step 1: Drying of the crude ilmenite concentrate.
- Step 2: Dry magnetic separation of the dried crude ilmenite concentrate at 2350 Gauss.
- Step 3: Dry magnetic separation of the non-magnetic fraction at 6500 Gauss – the non-magnetic fraction is called the low susceptible rejects (LSR).
- Step 4: Roasting of the non-magnetic fraction (LSR) in an oxidizing atmosphere.
- Step 5: Dry magnetic separation of the roasted material at 1000-2000 Gauss.

Beukes and Van Niekerk (1999) claimed that this step resulted in 80 per cent yield of ilmenite with less than 0.1 per cent Cr_2O_3 . This recovery figure is similar to that obtained in Process #1 but with less material requiring roasting.

To remain competitive in industry one of the strategies a company can follow is to continuously investigate new methods to produce the same product at a lower cost (Porter 1988). Beukes and Van Niekerk did investigate alternative production routes but did not recommend process conditions for the roasting step in Process #3, which they claimed to be more cost effective.

Other authors, especially in mineralogy, studied the mechanism of magnetic susceptibility in ilmenite. Authors in this category include Ishikawa and Akimoto (1957a), Ishikawa Y and Akimoto S (1957b), O'Reilly W and Banerjee SK (1966 and 1967), Nord GL et al (1989), Banerjee SK (1991) and Nell and Den Hoed (1997).

1.2 The research topic & hypothesis

Based on the statement made by Beukes and Van Niekerk (1999) that their 3rd process would result in lower production costs but without roasting conditions recommended for the stream to be roasted to support their statement, I decided to test the following hypothesis:

"It is possible to produce an ilmenite product suitable for ilmenite smelting by subjecting low susceptibility rejects (LSR) to roasting and subsequent magnetic separation, using the roasting conditions recommended for crude ilmenite by Nell and Den Hoed (1997) or Bergeron and Prest (1974)"

Based on the statement made by Nell and Den Hoed (1997) that oxidising roasting does not increase the magnetic susceptibility of chromite, I decided to test the following hypothesis:

"The magnetic susceptibility of chromite remains constant during magnetizing roasting of an ilmenite concentrate under the oxidizing conditions reported by Nell and Den Hoed (1997)."

1.3 Research design and methodology in general

From the preliminary reading I decided to:

- Source or prepare samples of crude ilmenite, the waste stream (LSR) described by Beukes and Van Niekerk (1999) and chromite in this waste stream (LSR);
- Characterise all three samples prior to roasting and magnetic separation;
- To conduct laboratory scale batch roast tests on all three types of material at the temperatures reported by Nell and Den Hoed (1997);

- To measure the magnetic susceptibility of each roasted sample. The optimum roasting condition is defined as the condition at which the magnetic susceptibility of the roasted sample has the highest value relative to all other samples;
- To roast larger samples of all three types of material at the optimum roasting conditions determined by the small scale tests;
- To fractionate the larger sample at various intervals of magnetic susceptibility, subject each ilmenite containing sample to XRF analysis and determine the Cr_2O_3 and TiO_2 distributions thereof. This would be done to:
 - Confirm that an ilmenite product with less than 0.1 per cent Cr_2O_3 can be produced from the LSR or crude ilmenite at the ideal conditions;
 - To determine the yield of this product; and
 - To evaluate the distribution of chromite vs. ilmenite before and after roasting.

1.4 Outline of chapters two to five of thesis

In chapter 2 the key concepts available in literature are reviewed and discussed. In chapter 3 the research design and methodology are discussed. Chapter 4 presents the results and the discussion of the results. Chapter 5 concludes the study with a summary of the important points, linking the results to literature and theory, and recommending further test work.

In short: the aim of chapter one was to clarify why another study on ilmenite roasting was required and what it entailed. An overview of the major hypothesis of the study, how the hypothesis was investigated and how the study would be reported on in the remainder of the thesis, was included. In chapter two I review the literature available on ilmenite roasting in more detail.