CHAPTER EIGHT

CONCLUSIONS

The following conclusions have been drawn from the literature review, thermodynamic analysis and experimental invertigations:

1. Characterisation of Smorgon Steel Works dust by SEM-EDS analysis, diagnostic leaching and XRD analysis showed that the dust particles are generally less than five microns in size and present as spherical particles. Iron and zinc are the most abundant elements in EAF dust. In addition, the Smorgon Steel Works dust contains significant quantities of alkaline elements, such as sodium and potassium, and halide, such as chlorine. Hazardous elements, such as lead, cadmium and chromium also occurred. The dominant phases are present as a spinel zinc ferrite and magnetite. Another form of zinc is present as zinc oxide. The halide group are present as sodium and potassium chloride. Lime is also present.

2. From the thermodynamic prediction and the experimental studies, it was confirmed that the iron-reduction distillation process consisted of two reduction stages could be applied to extract metallic zinc from EAF dust.

In the first reduction stage, it was found that the reaction of magnetite and zinc ferrite in the EAF dust with carbon monoxide and carbon dioxide gas mixture were promoted by increasing temperature from 600 to 800 °C and by increasing CO/CO_2 gas ratio from 3 to 9 . It was found that the sintering process retarded the reduction rate in the first two and a half hours but after that the rates were quite similar for both sintered and non-sintered briquette. Zinc ferrite was also reduced in this stage to zinc oxide and metallic iron.

3. In the second reduction stage, it was found that the reduction rates of zinc oxide and metallic iron in the EAF dust obtained from the first reduction stage was promoted by increasing reduction temperatures from 900 to 1200 °C in a nitrogen atmosphere and from 800 to 1000 °C under vacuum of $2.0*10^{-3}$ atm. The increased rates of transfer of zinc vapour under vacuum promotes a faster reduction rates.

4. The reaction of zinc oxide with metallic iron has no well interface. A grain model was proposed. A possible reduction mechanism of zinc oxide and metallic iron in both nitrogen atmosphere and under vacuum was proposed as follows :

1) The chemical reaction at the zinc oxide and metallic iron particle interface.
2) The zinc vapour diffuses through the pore between the particles to the surface and is transfered from the briquette surface to the nitrogen atmosphere or vacuum.

In a nitrogen atmosphere, the experiment data were fitted to a chemical or mixed controlled model with an activation energy of 141.65±8.20 kJ/mol. For the experiments under vacuum, the activation energy was 69.83±8.20 kJ/mol. This result may indicate a diffusion controlled process. The reduction rates under vacuum are significantly faster than in a nitrogen atmosphere because the rate of transfer of zinc vapour from the briquette to vacuum ($2.0*10^{-3}$ atm) is faster compared with that in a nitrogen atmosphere such as, at 1000 °C, all of the zinc oxide was completely reduced within 40 minutes under vacuum but required 4 hours in a nitrogen atmosphere.

5. The study of the behavior of minor elements during both reduction stages shows that cadmium evaporated almost completely during the first reduction stage. In the second reduction stage, the percentage of lead, sodium, potassium and chlorine apparently decreased during reduction. The lead percentage after reduction under vacuum is lower than in a nitrogen atmosphere because lead has a relatively high vapour pressure compared with the other volatile elements. Lead vaporised at pressures below $1.8*10^{-3}$ atm at 1000 °C. This mean that in order to treatment lead, a vacuum system is essential for the second reduction stage. Chromium cannot be removed by this process.

6. Using the iron-reduction distillation process, zinc in the EAF dust was recovered in metallic zinc form and iron could be recycled to an ironmaking or steelmaking process.

The residues obtained from the iron-reduction distillation process are contained relatively high level of iron. The iron percentage increased from 37.2 percent (in unreacted EAF dust) to 61.5 percent after zinc recovering process with decreasing of the hazardous element percentage.

The percent zinc recovery from this process was found to be about 95 percent. The zinc product is contaminated by 5.5-7.6 percent lead but this zinc product can be used in the galvanised process without the problem of the lead contamination.

7. The following design were established for the iron-reduction distillation process from these investigation :

1) For the first reduction stage, the operating temperature range is between 700 to 800 °C with a CO/CO_2 gas ratio of 9 and two and a half hours reduction time.
2) For the second reduction stage, the operating temperature is higher than the first reduction stage. The operating temperature range is between 900 to 1000 °C with 4 hours reduction time in nitrogen atmosphere and 40-80 minutes reduction time under vacuum.
3) A vacuum of $2*10^{-3}$ atm applied to transfer zinc vapour gives the faster reduction rate than in nitrogen atmosphere.
4) The molar ratio of Fe/ZnO should be equal to or greater than one. In case of a low iron percentage in other EAF dusts, the addition of iron oxide would be required.