Solar Thermal Treatment of Manganese Ores

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Manganese ore processing – current landscape

Figure 1. Manganese ore processing

Mining
18.5 Mt/a ore (2015)

Sizing and classification

Dense medium separation

Sinter plant

Lumpy product

Sintered product

Smelters
2.8 MWh/t HCFeMn
3.9 MWh/t SiMn

Ferromanganese alloys, 4.9 Mt/a alloy

Slag

Fluxes

Reductant and/or fuel

Air

Fuel

Carbon

Figure 1. Manganese ore processing
Manganese ore processing – future landscape?

Figure 2. Manganese ore processing tomorrow

Mining

Sizing and classification

Upgrading of marginal ores

Sinter plant

Dense medium separation

Carbon

Air

Fuel

Lumpy product

Pelletising
Sintering
Briquetting

Sintered product

Ferromanganese alloys

Preheating and pre-reduction

Smelters that accept fines

Alternative reductants

Fluxes

Slag
Experiments

Figure 3. STERG solar concentrator

Figure 4. Untreated ore, -6 mm

Figure 5. Pellets, -13 mm + 6 mm
Experimental Set-up – Sample container

Figure 6. Positions of central thermocouples

Figure 7. Empty sample container

Figure 8. Full sample container

x = 50 mm
x = 25 mm
x = 0 mm
Figure 9. Temperatures recorded, Pellets B +
The assumptions made for the present model include:

- Approximation of the bed as a continuum slab of material with constant and uniform thermal conductivity, effective density, and heat capacity.
- Approximation of the heat transfer mechanism in the bed as one-dimensional (perpendicular to hot face) and transient.
- A single “concentration factor”, $\eta$, expressing the concentration ratio between the measured instantaneous direct normal insolation (DNI) and the energy flux experienced at the bed hot face.
- A boundary condition at the hot face expressed in terms of a convective heat transfer coefficient and a surface emissivity, both pre-specified constants.

<table>
<thead>
<tr>
<th>TABLE 1. Fixed parameters used for all model fitting runs</th>
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<tbody>
<tr>
<td>Parameter</td>
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<td>$\delta$</td>
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Figure 10. Experimental temperatures and model predicted temperatures
Effective Thermal Conductivity

Figure 11. Effective thermal conductivities

- $k_{\text{manganese ores}} = 0.5 - 4 \text{ W/(m·K)}$
- $k_{\text{air}} = 0.02 - 0.06 \text{ W/(m·K)}$
- $k_{\text{graphite}} = 25 - 470 \text{ W/(m·K)}$

$k_{\text{manganese ores}} = 0.5 - 4 \text{ W/(m·K)}$
Ksiazek, 2012

$k_{\text{air}} = 0.02 - 0.06 \text{ W/(m·K)}$

$k_{\text{graphite}} = 25 - 470 \text{ W/(m·K)}$
Figure 12. Effective concentration factors
Figure 13. Thermodynamic equilibrium model - A
Figure 13. Thermodynamic equilibrium model - A
Figure 14. Thermodynamic equilibrium model - B
Figure 14. Thermodynamic equilibrium model - B
Figure 15. Thermodynamic equilibrium model - C
**Thermodynamic Modelling**

**Figure 15.** Thermodynamic equilibrium model - C

![Graph showing mass loss vs. temperature for different carbon contents and ore types.](image-url)
Future studies

• Modify set-up to investigate forced convection

• Take measures to improve concentrator efficiency

• Expand heat transfer model to include chemical reactions and variable convection

• Review implications of results on economic model

Figure 16. How to avoid sunburn
Conclusions

• Heating and thermal decomposition of manganese ores has been demonstrated
• Effective thermal conductivities has been determined for test materials in air
• The effective concentration ratio has been determined for the concentrator
• Empirical results when compared to thermodynamic equilibrium models indicate that kinetics factors are limiting decomposition
• Organic content in ore C facilitated higher mass loss by acting as a reductant
Acknowledgements

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Figure 17. SAURAN station on adjacent rooftop

Thank You

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