

Metallothermic production of cement extender from manganese waste slags

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INTRODUCTION

Southern Africa has a rich history in the pyrometallurgical processing of ores. The products from the manganese ferroalloy industry include an alloy and slag. Some of the alloys produced in the manganese ferroalloy industry are silicomanganese (SiMn), medium-carbon ferromanganese, and high-carbon ferromanganese (HCFeMn). These have monetary value, whereas the slag is classified as a hazardous waste product due to its MnO content (25-30 wt.%). 20 Mt of HCFeMn and SiMn slag has accumulated over the years on dumps in South Africa, and an average of 0.5 Mt is added each year (Steenkamp and Basson, 2013). Reducing and reusing waste products will play an important role in the future of the mining and minerals industry in the quest for zero waste.

A techno-economic assessment study was done on manganese waste slags for possible use as a cement extender. The slag was treated by a metallothermic reduction in a bench-scale DC electric furnace, using silicon, ferrosilicon, and/or aluminium as reductants for the reduction of MnO to produce a commercial silicomanganese alloy. Small amounts of slag modifiers were added during the smelting and the slag was granulated upon tapping from the furnace. The SiMn alloy produced met the ASTM specifications and the modified granulated slag met the Ground Granulated Blast Furnace Slag specifications (EN-197).

Table I contains the mass and energy balance for the six conceptual process flow sheets. The slag from the mine dump is first crushed, then fed to the DC furnace; otherwise, if feeding hot molten slag then it is transferred by a ladle to the furnace, where it is reacted with calcined lime and reductants. The product metal is cooled, crushed, and taken to the metal stockpile. The product slag is granulated and the entrained metal recovered in spirals. The spiral tails are dried and milled.

Table I. Mass and energy balance data for six conceptual process flow sheets

Scenario/option	1	2	3	4	5	6
Slag type	FeMn	FeMn	FeMn	FeMn	SiMn	SiMn
Dump or molten	Molten	Dump	Dump	Molten	Molten	Molten
Product	Cement	Cement	Cement	Slag	Cement	Cement
Reductant	Si/FeSi/Al	Si/FeSi/Al	Si/FeSi	Si/FeSi/Al	Al	Si/FeSi
Furnace/ladle size, MW	2	16	25	2	2	2
Cement/slag rate, t/h	55	55	65	55	71	80
Alloy rate, t/h	16	16	15	16	4	5

METHODOLOGY

The capital expenditure (CAPEX) was estimated for each of the major components using the literature and quotations from equipment suppliers. The major components included a conditioning furnace, granulator, dewatering unit, and a milling and grinding circuit, together with associated building and civil works. The ongoing CAPEX was estimated at 2.5% of total operating costs and it would cease three years from the end of the project.

Only the main categories of the operating expenditure (OPEX) were considered, namely the reagents, labour, and utility costs.

The revenue for the project in the model came from selling the alloy and granulated slag or slag cement, and also a saving on disposal costs of waste slag, which was estimated at about R64 per ton.

The main financial assumptions for the 20-year discounted cash flow model included borrowing rate at 8%, inflation at 8%, and risk rate at 7%. The capital allowance and tax rates were 12% and 29% respectively. The model was constructed to cater for different scenarios and to provide comparative characteristics such as net present value (NPV), internal rate of return (IRR), and simple payback period (Lagendijk, Auchterlonie, and Ramsay, 2016).

RESULTS AND DISCUSSION

The high-level evaluation indicated different possible outcomes. Using the NPV, IRR, and the payback period for comparison purposes, it can be seen from Figure 1 that option 1 is the best option, with a short payback period and higher IRR and NPV values. Option 5 is the worst option as it fails to make positive returns, even under the most favourable conditions. Options 2, 3, 4, and 6 make reasonable returns, but are more susceptible to risk and sensitive to changes in raw material and product prices.

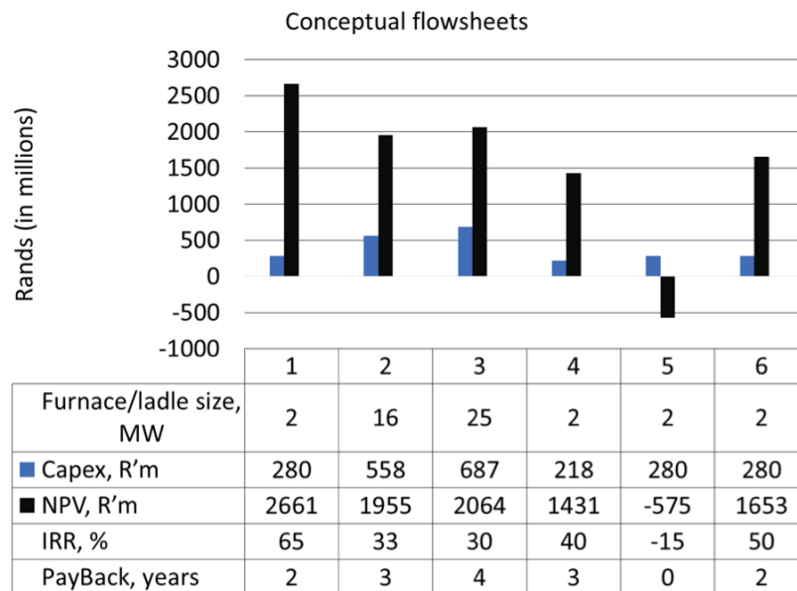


Figure 1. Economic evaluation summary of the six conceptual flow sheets.

CONCLUSION

A high-level techno-economic evaluation was conducted on six conceptual flow sheets for a plant treating 355 kt/a of waste FeMn or SiMn slag. Because of different MnO levels in the waste slag feed, it was found that dumped HCFeMn slag could be processed profitably by re-melting and slag treatment in an electric arc furnace. SiMn slag would need to be modified in the molten state after it has been tapped from the submerged-arc furnace, using a ladle/ladle furnace, for the waste slag processing to become economically viable. In addition, it is more profitable to use silicon and FeSi rather than aluminium as the reductant, and modify the alumina levels in the slag as required through the addition of bauxite.

The evaluation indicated that the process is economically viable. The two saleable products, an alloy and a cement extender, will allow the mining industry to exploit more value from the minerals, hence contributing to Vision 2040.

REFERENCES

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