ENERGY MAPPING OF INDUSTRIAL FERROALLOY PLANTS

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ABSTRACT

ERAMET Comilog Manganèse is currently the world's 2nd-largest producer of manganese alloys for steelmaking, and the company has adopted very strict policy for environmental impact. This includes drastic control on polluting emission but also constant energy consumption reduction. A systematic investigation of the energy flow through the production plants has been performed. Particular attention was paid the furnaces as they the largest energy consumer on the site. The analysis showed that the large amount of energy is available as chemical energy in the CO rich exhaust gas. Recovering this energy is relatively easy as the technology is mature and is already being done at one of the Norwegian plants. Some plants, situated in the neighborhood of other industry, also sell this CO rich gas. For the plants with no industry nearby, the challenge is to find the economy for the investment for electric energy production plant. The major part of the rest of the energy sources available on the sites are thermal energy in solid materials like metal and slag, or low temperature fluids. These energy sources are more challenging to recover.

KEYWORDS: Energy, ferroalloy.

1. INTRODUCTION

Manganese is essential in the production of steel. Manganese alloys are used to remove oxygen from steel, to modify the sulfur compounds in steel, and contributing to proper hardness and resistance for the steel. On average about 10 kg manganese is used per ton of steel. The most used manganese alloys are ferro-manganese (FeMn) and silico-manganese (SiMn). As all high temperature metal production processes, the production of a manganese alloys, FeMn and SiMn from ore are energy intensive processes. Typical specific energy consumption is around 2700 kWh/kg alloy and 3900 kWh/kg alloy produced for FeMn and SiMn respectively.

ERAMET Comilog Manganèse is currently the world's 2nd-largest producer of manganese alloys for steelmaking, with the most extensive product range on the market. They have plants in Europe, North America and China. The company has adopted very strict policy for environmental impact. This includes control of chemical emission but also a continuous reduction in energy consumption and a continuously investigating the possibilities of energy recovery. In 2007 the total ferrroalloy industry in Norway used 6.9 TWh, which is both used in the production of manganese and silicon alloys [1]. It is estimated that the total reduction potential is as high as 63%. However, this can not necessary be utilized due to infrastructure limitations. To be able to reduce the energy consumption and increase the energy recovery, detailed studies of the types and quantity of energy used and available at each plants are necessary. This report presents energy mapping of the production plants at Eramet Sauda and Eramet Porsgrunn in southern Norway, and investigates energy recovery opportunities.

Manganese alloys are produced in closed electrical furnaces. Manganese ore, coke and fluxes (used to control the viscosity of the products) are added at the top of the furnaces. They descend slowly down to the heart of the furnace, where electrodes provide the necessary thermal energy to start the carbothermic reduction of the ore. Products are a metallic alloy, a slag and exhaust gas exiting the furnace on the top. Gas is removed continuously from the process, while the tapping of metal and slag is typically batch process. Each time the metal and slag are tapped from the bottom of the furnace, some gas also escapes through the tap-holes. This gas is called tapping gas. The exhaust gas is mainly composed of CO_2 and CO. CO is a valuable gas which can be recovered and used in other chemical process. The CO gas can also be used for combustion in power plants.

This work focuses on two production plants, Eramet Sauda which has two FeMn furnaces (ENS11 and ENS12) and Eramet Porsgrunn which has one FeMn (ENP11) and one SiMn (ENP10) furnace. It is the electrical furnaces who use most of the energy consumed at the plants. The refining process is also interesting but was kept outside this study.

2. METHODOLOGY

The total energy consumption used at the reduction furnaces was found. At first the energy consumption was investigated for each furnace, then, an overall overview was established at production site level. The different energy streams on the furnaces were ranked in two categories. First, the energy consumption used in the process. The second group consists of the energy flows out of the furnace. The differentiation can also be based on their recovery potential. The first group is the energy that can not be recovered, but be minimized. The second group is the energy that can be recovered.

As mentioned, the first category corresponds to energy losses that have to be minimized. In this category we placed electricity losses and the energy cost of the reduction process.

Electricity losses

Electricity losses in the transformer and the electrodes is monitored and estimated by Eramet to 4 % of the supplied power. This energy is lost as heat before reaching the furnace.

Reduction process

For FeMn furnace the energy cost of the reduction is estimated to 2145 kWh/ton produced metal [3], and for the SiMn furnace the energy cost of the reduction is estimated to 2740 kWh/ton produced metal [5]. This is the electric energy that is needed to heat the raw materials into the desired temperature, which is between 1400 to 1600°C, and for the reduction work used transforming the raw materials into liquid metal, liquid slag and gas at high temperatures.

The second category corresponds to energy streams that may be recovered. In this category we placed: thermal energy in the exhaust gas, tapping gas, slag and metal. Energy collected in the cooling water, used for furnace cooling, as well as chemical energy of the CO rich exhaust gas are in this category. It must, however, be emphasized that the chemical energy in the raw materials is not included in the first group, and hence, the sum of group one and two will not be equalized.

Thermal energy in the metal and slag

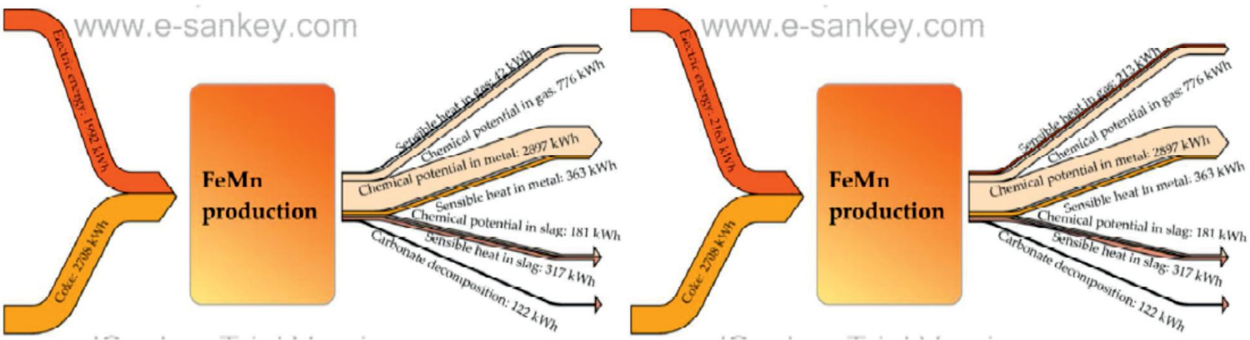
Metal and slag are removed from the furnace in liquid form at high temperature. As the reference is ton metal produced, both the heat in the slag and in the metal is calculated per ton of metal. The slag/metal ratio in the two processes is about 700-800 kg and 1000-1300 kg slag per ton of metal for the FeMn and SiMn production respectively. The heat available when solidified and cooled down to 25°C is estimated to:

- 469 kWh/ton metal produced for the metal and 405 kWh/ton metal produced [3] for the slag in the FeMn production.

- 497 kWh/ton metal produced [5] for the metal and 549 kWh/ton metal produced [5] for slag in the SiMn production.

Thermal energy the exhaust gas

Thermal energy of the exhaust gas is estimated to be 62 kWh/ton metal produced for FeMn furnace, and 79 kWh/ton metal produced for SiMn furnace when cooled from 200 to 25°C. However, the gas temperatures vary from day to day. Typically the exhaust temperature may vary between 100 and 600°C, dependent on the process and the stability of the operation. In figure 1, one can see that the latent heat in the exhaust gas is reduced from 213 kWh to 42, by reducing the temperature from 600 to 150°C [2]. In the following calculations, the actual average gas temperature for each furnace is used for the total energy content in the gases.



(a) 150 °C (b) 600 °C

Figure 1: Comparison of energy flows per ton of metal in a FeMn furnace when the exhaust gas temperature changes from 150 to 600°C [2]

Thermal energy in tapping gas

Gas is produced during tapping, this gas has to be effectively ventilated and directed to a filter for cleaning. The gas exiting the furnace is mixed with air. The flow rate of this mixed gas is used in the calculations. From experience the temperature is typically equal to 40°C. Tapping is a batch process and it is estimated that the furnace is tapped 50 % of the time.

It must be pointed out that the gas is probably heated by the slag and metal during tapping. A large fraction of the heat transported by the tapping gas should then be subtracted from the available heat in the slag and metal (otherwise it should be counted two times in the energy balance).

Heating value of the exhaust gas

Carbonic reduction of Mn oxides produces a CO rich exhaust gas. This gas as a substantial heating value as seen in figure 1. This value will change with the CO/CO_2 ratio in the exhaust gas. The combustion value for burning the CO with O_2 to CO_2 at 25°C is 2800 kWh/ton CO, and this value is the energy content used in these processes. Exhaust gas mass flow rate is estimate to 1.102 kg/ kg produced metal [3] for FeMn and 0.846 kg/kg produced metal [5] for SiMn furnace. CO weight concentration in the exhaust gas is estimated to 40% for FeMn furnace [3] and 78.5% for SiMn furnace [5].

3. RESULTS

Energy profile for the three FeMn and one SiMn furnaces are presented in figure 2 and figure 3. Two categories of energy flows are distinguished:

- losses (negative values) that have to be minimized
- energy streams that can potentially be recovered (positive values)

The energy balance was checked comparing input energy (electricity minus electricity losses and heating value in the coke) to output energy (reduction energy and all thermal energy). An unbalance of 11 to 17 % for FeMn and 12 % for SiMn are found which is reasonable considering all the assumptions the calculation relies on.

Figure 2 presents the energy profile for the three FeMn furnaces. The profiles are very similar. As expected the reduction process stands for the main energy cost. The other observation is that the heating value of the CO rich gas is very important which is in accordance with previous models [2].

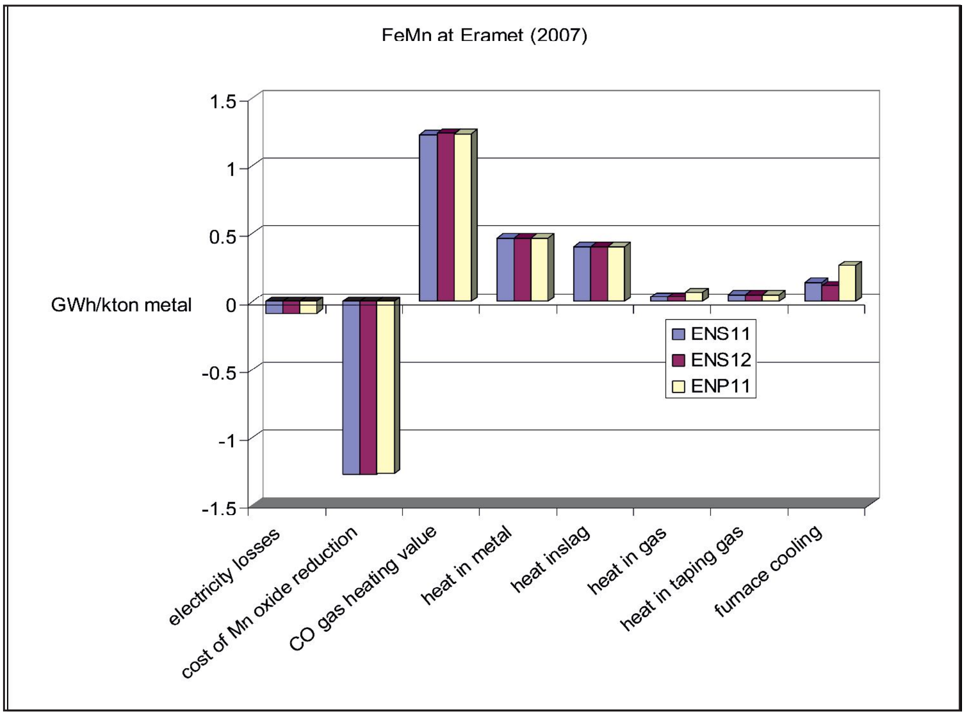


Figure 2: Energy profile for the three FeMn Eramet plants

Figure 3 presents the energy profile for the SiMn furnaces. The profiles are very similar to SiMn furnaces. Heating value is relatively more important as the CO concentration is higher.

If the energy map is to be investigated at production plant level, additional energy streams are help power (electricity to fan, pumps etc) and heating value of LNG used on the site. The result from this mapping is shown in figure 4. The two plants are not directly comparable as only FeMn is produced at Sauda when FeMn and SiMn are produced in Porsgrunn.

Metal production is a very energy intense industry. It is hence a continuous effort to minimize the specific energy consumption (kWh/ton product). Low hanging fruits like limiting help power have been extensively investigated both intern at Eramet and by Vattenfall for the site of Porsgrunn.

Realizing the energy saving with these relatively simple actions is very important. Unfortunately this energy flow analysis shows clearly that the large potential requires important investment, and some energy recovery possibilities would even require more technological development.

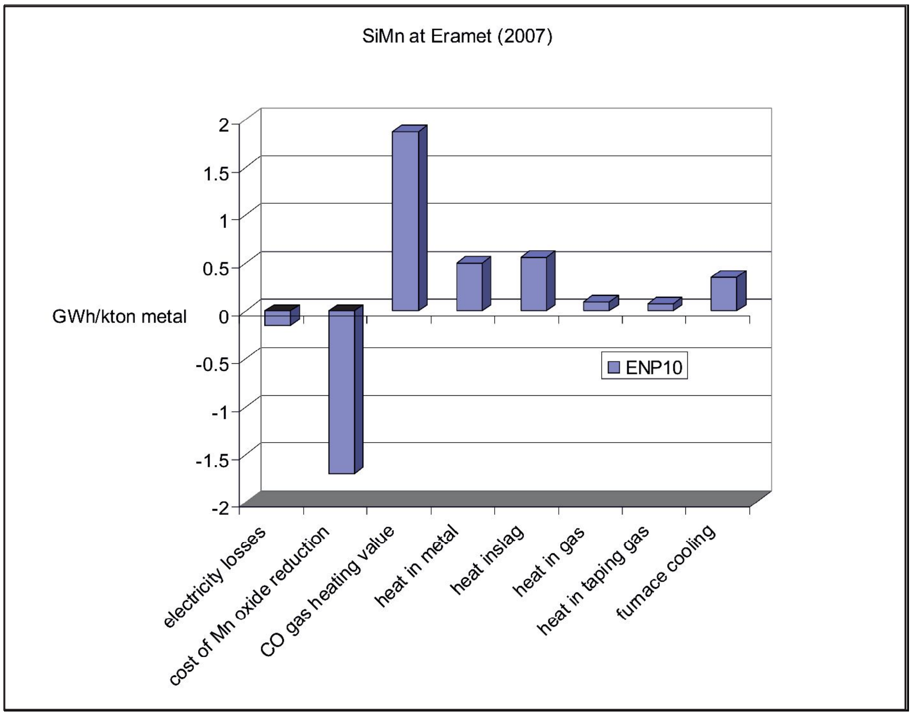


Figure 3: Energy profile for the SiMn furnace at Porsgrunn (ENP10)

The most obvious source of energy coming out of the plants is the CO rich gas. Substantial energy saving is possible using this gas. There are however some issues regarding the usage of the thermal and chemical energy in the exhaust gas. Both the temperature and CO content of the exhaust gas is varying from day to day, dependent on the operation and type of raw materials. The temperature can change from 100 to 800°C, and hence a recovery unit must this into account. Also the CO gas may vary from 50 to 95 % in closed furnaces. The lowest possible CO content and temperature is obtained when the operation is good, which also means that the usage of energy is the lowest. Hence, the best energy situation is when the energy consumptions are low, even though this correlates to the lowest energy recovery potential. But even at the best operation practice, there will be a lot of CO in the exhaust gas, and this may be used for energy recovery. Technology for power production from CO rich gas is well established and practical solution for power production at the Sauda site is being investigated.

Energy recovery from the heat sources, like metal and slag at temperatures above 1200°C, available at the plants is challenging. Also the solidifications of these materials at a higher temperature evolve heat.

- The temperature level can be high but the process is not continuous as the metal and slag are tapped discontinuously. It has to be pointed out that despite technical challenges some energy recovery from slag cooling is performed by the Eramet group on the site of Kvinesdal where district heating is provided.
- For stationary process like furnace cooling, the temperature is too low, and high temperature heat pump like hybrid heat pumps developed at IFE would be mandatory to use this heat for district heating.

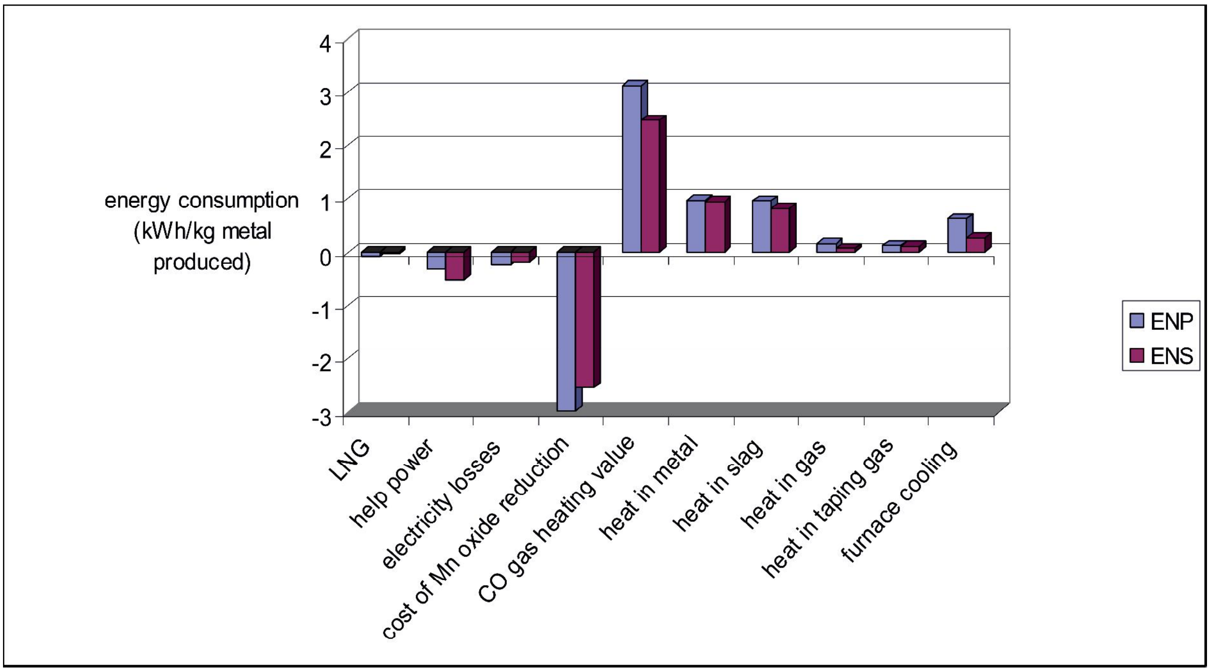


Figure 4: Energy profile for the two production sites, Porsgrunn (ENP) and Sauda (ENS)

4. CONCLUSION

Today manganese plants recover the easy accessable energy. Low temperature water, used for cooling, is used at all the plants to provide energy to low-temperature heating. From the manganese plants in Norway, this used to heat streets in the wintertime, heat swimming pools, and provide heat to fish-farms. However, as the usage of energy is one of the major environmental issues, a continuous effort is made to decrease the total energy consumption. To provide a basis, a systematic investigation of the energy flows at two Norwegian production plants has been performed. Particular attention was paid at the furnaces as they are the largest energy consumer on the site. The analysis showed that the largest recoverable energy is the chemical energy in the CO rich exhaust gas. Recovering this energy is relatively easy as the technology is mature. The challenge is the investment costs. Today, 3 of 4 manganese plants in Norway take advantage of this gas. They either sell the gas to other industries and one plant is also transforming this energy to electric energy.

Other energy sources available on the site are mostly thermal energy. The major part is in the high temperature metal and slag which is cooled to room temperature. Today, some energy is already recovered by Eramet Kvinesdal, but this type of energy is more challenging to recover.

5. REFERENCES

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