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ENERGY ANALYSIS OF THE STEEL MAKING INDUSTRY

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SUMMARY

Steel making is an energy intensive industry. This work presents and identifies heat losses of the main components of this industry in Jordan. The heat losses are considerable and range from 17 to 36% of the total energy input. Some heat losses are considered to be recoverable, especially in the furnace and the crucible and mould. Specific energy consumption was found to be 6·0 MJ per ton of steel for the Jordanian steel industry. © 1998 John Wiley & Sons, Ltd.

KEY WORDS energy in steel industry; electric arc furnace; SEC

INTRODUCTION

Steel making involves different cycles such as heating, cooling, melting and solidification. It is a highly energy intensive industry. The reduction of energy consumption in this kind of industry is of a special concern. The specific energy consumption (SEC) of steel plants for different countries was reported in literature (Bhaktavatsalam and Choudhury, 1995, Choudhury and Bhaktavatsalam, 1997). In general, energy savings can be achieved by cutting down direct energy consumption, increasing energy recovery, and adopting the policy of replacing oil products and natural gas in primary steel making with coal and coal-by-products. According to Perlov (1987), increasing the energy efficiency of the most consuming facilities is achieved by improving the use of secondary energy sources such as minimizing the heat lost in hot waste gases, minimizing the heat radiated through refractory linings of metallurgical furnaces, and cooling the highly thermally stressed components.

ALTERNATIVE TECHNOLOGIES AND ENERGY CONSERVATION

In a recent study it was reported that the developments in iron and steel making took two separate lines (Zervas *et al*., 1996). The first line was concerned with the blast furnace as the principal process for production, and the second was based on the direct reduction and smelting in which iron oxide feedstocks were reduced by gases to metallic iron. The different technologies are summarized in Figure 1.

Energy consumption in the different stages of steel production is about 70% for iron and steel production, 20% for rolling, and 10% for miscellaneous (Eketorp, 1987). Therefore, the primary step is the main energy consumer in steel making, and most efforts have been directed towards the blast furnace. Energy efficiency in the blast furnace can be improved by improving iron-ore benefaction, removing raw fluxes from the blast furnace burden, reducing the ash content of coke, reducing the sulphur content of coke and iron-ore materials, reducing the output fraction of cast iron and ferroalloys, using larger fractions of partly reduced

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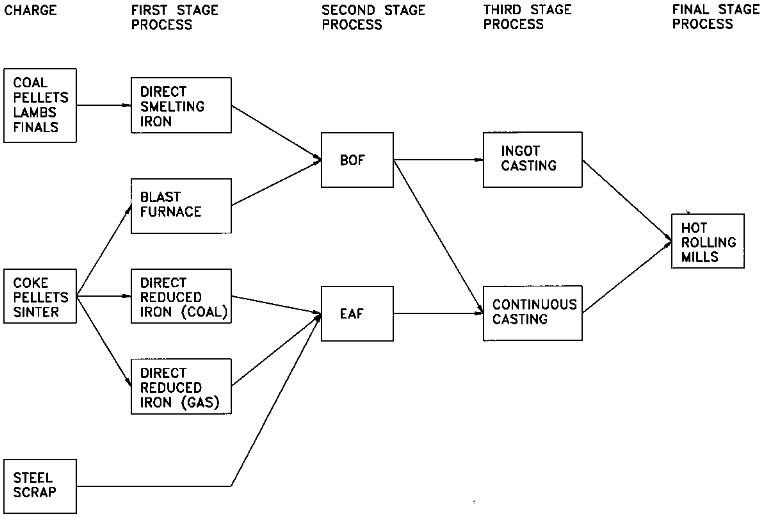

Figure 1. Summary of different technologies

metallized raw materials, improving the blending, classification and mechanical strength of iron-ore raw material, increasing the internal pressure in the blast furnace, increasing the blast temperature, and introducing external desulphurization. The scrap charging electric arc furnace (EAF) route of steel making requires considerably less energy than the integrated route. It has been reported, that EAF route is seen to be 40% less energy intensive than the open hearth furnace (OHF) route and less than 50% as energy intensive as the basic oxygen furnace (BOF) route (Lyakishev and Perlov, 1987). It has been shown that as the percentage of scrap in the charge increases, the energy efficiency of the BOF and OHF will increase, since about 90% of the total energy use is associated with the smelting of pig iron.

World-wide steel plants switched over to BOF route from OHF route of steel making due to energy conservation considerations. Also, the ingot casting route was replaced by the continuous casting technology (Bhaktavatsalam and Choudhury, 1995).

THE SCRAP CHARGE EAF ROUTE

The EAF is widely used in many countries for refining the quality of steel for industry. The technologies used in steel making in different countries are summarized in Figure 2 (Bhaktavatsalam and Choudhury, 1995). The scrap-based EAF route of steel production required less energy than the integrated route. Ross (1987) reported that melting involves the transfer of 1·1 MBtu to each ton of scrap (1·16 GJ ton^{-1}), and in average practice about 2·4 MBtu is consumed per ton of liquid steel (2·53 GJ ton^{-1}). For example, the scrap remelting is playing an important role of reducing energy consumption in steel making industry in Italy, it was reported that the production of new steel requires about 18 GJ ton^{-1} of liquid steel, while the production of remelted steel from scrap requires 6·5 GJ ton^{-1} of liquid steel (Bisio, 1993). The theoretical quantity of heat necessary to melt the scrap and to bring the steel to the tapping temperature is about 345 kW h ton^{-1} (Scotti, 1990). Although, in practice, the amount needed is higher due to non-homogeneity of the scrap, heat is lost during charging phase of the scrap. Heat is also lost through the fettlings, the walls and the water-cooling crown, the outlet of hot gases from the clefts of the crown, and reactance of the electric furnace and consequent lower exploitation of the active energy and increase of electric losses.

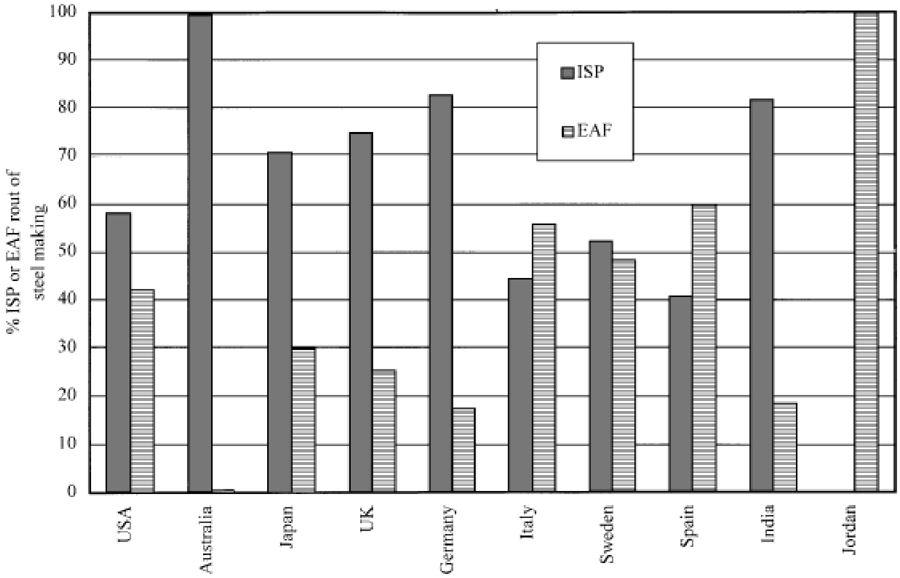

Figure 2. Routes used in steel making in different countries

The main measures for saving energy in the EAF steel making are: recovery of heat from off gases with its use to preheat scrap, using oxygen, increasing the voltage of the transformer, installing electrodes with protective coatings, reducing furnace downtimes, automatic controls for the voltage and power factor, and for the position of the electrodes, water cooling of the sides and insulation, and increasing the volume of metal treated in the ladle.

The production of liquid steel in the electric furnace absorbs the highest proportion of the total energy consumption in the scrap charge EAF route. A proportion of 67% has been reported (Poggi, 1990). A mathematical model which integrates the electrical model with the thermal model has been developed for the performance of an electric arc furnace (Chirattananon and Gao, 1996). The influence of operational parameters on the overall energy performance and productivity of an arc furnace operation has been demonstrated.

The most prominent change in shaping technology is the continuous casting since it offers important benefits in product quality for most products because of its uniformity and reduction of defects during solidification. Continuous castings has large immediate energy benefits. It was reported that the direct savings are about 1688 MJ ton^{-1} of rough shaped steel (Ross 1987). About 0·17 ton more liquid steel per ton of shaped steel is required with the ingot casting than for continuos casting. The savings due to this requirement are about 3060 MJ ton^{-1} of rough shaped steel.

Energy can be saved in the hot rolling stage, in current practice, almost 4220 MJ ton^{-1} of hot rolled product is used for reheating (Ross, 1987). Improvements in the reheat furnace through automatic control based on sensing the surface temperatures of the slab and separately controlling different zones of the furnace heat recovery including waste heat boilers, improved insulated water-cooled skids, and improvements in the envelope will reduce energy consumption.

STEEL INDUSTRY IN JORDAN

The steel making industry in Jordan is based on recycling of iron and steel. It involves melting of scrap in the electric furnace. This type of process takes place as a result of the electric arc which is generated between the electrode and the scrap. As an example, the Jordanian Iron & Steel Industry Co. facility plant has been investigated and analysed. The 120 ton-per-day capacity production line consists mainly of the smelting by EAF and the shaping part. Block diagrams of the production line are shown in Figures 3 and 4. Electricity is primarily used to operate the rolling mill and electric arc furnace. The electric arc furnace uses 700 kW h ton^{-1} to melt the scrap, which consists of about 62% of the total energy consumption. The energy content of each stream entering and leaving the unit in the smelting section, was calculated from the appropriate site of measurement. Magnitudes of all heat losses were calculated and presented in Figures 5–7. Based on energy balance of each unit, it is found that 914 MJ ton^{-1} (36% of total heat input) are lost in the furnace. Heat losses in the crucible and mould add up to 439 MJ ton^{-1} (17% of total heat input). On the other hand, 651 MJ ton^{-1} is lost in the cooler (26% of total heat input). Recovery of the heat content of the cooling water can be accomplished by steam generation and preheating the scrap. From heat content difference in the cooler, the initial temperature of the scrap can be raised approximately to about 800°C.

The shaping involves casting the liquid steel into rough shapes, then these rough shapes are reheated and rolled into reinforcement steel bars. The casting, reheating furnace and rolling mills for steel rods absorb approximately 65% of the total energy consumption of the production line as shown in Table 1. The energy consumption of this stage is 70 kW h ton^{-1} (0·25 GJ ton^{-1}) of electricity and 70·5 kg of fuel oil per each ton of steel (3·00 GJ ton^{-1}).

SEC of the Jordanian steel making industry is thus obtained by the procedure described by Choudhury and Bhaktavatsalam (1997). It is found to be equal to 6.0 GJ ton^{-1} of steel. It is presented in Figure 8 as compared to SEC of other countries. It is lower than those values of other countries, since steel industry in Jordan is based on remelting or recycling of scrap. However, steel making in other countries presented in Table 1 is based from manufacturing of steel from raw materials. Therefore, energy consumption and thus, SEC is lower for Jordanian steel making industry.

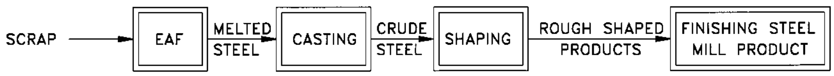

Figure 3. Block diagram of scrap-based EAF route.

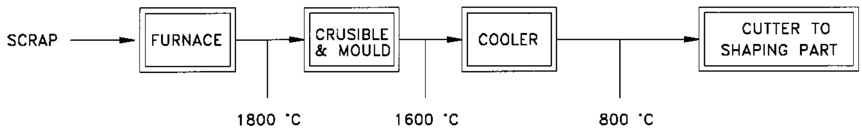

Figure 4. Block diagram of temperature distribution of EAF route

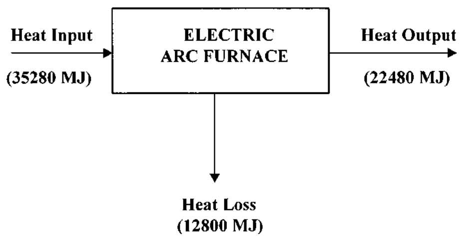

Figure 5. Energy balance in EAF

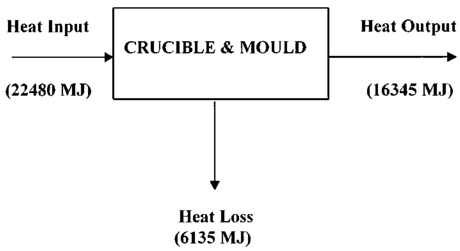

Figure 6. Energy balance in crucible and mould

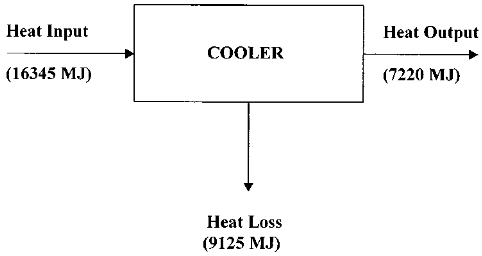

Figure 7. Energy balance in cooler

Table 1. Energy consumption (GJ ton steel^{-1})

	Electricity	Fuel oil	Gas oil	Total
EAF	2·52	—	—	2·52
Casting, reheating furnace and rolling mill	0·25	3·00	0·05	3·25
Others	0·18	—	—	0·18
Total	2·95	3·00	0·05	6·00

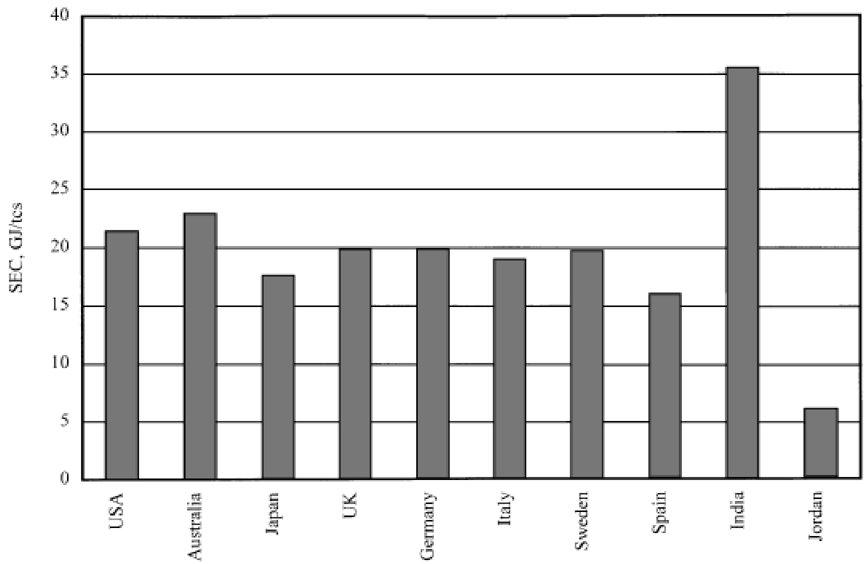

Figure 8. Specific energy consumption

CONCLUSION

Heat losses occur along the line of production of the steel making industry. About 36% of total heat input is lost in the furnace. This is a recoverable heat which should not be wasted. 17% of total heat input is lost in the crucible and mould. Some of it can be recovered or used in processing of steam. Over 26% of heat is rejected in the cooler. The recovery of heat of last process could be difficult to achieve, except for space heating or reheating of scrap to higher initial temperature. Due to the nature of steel making in Jordan is based on remelting of pellets or scrap, SEC is found to be equal to 6·0 GJ ton^{-1}. It is lower than SEC of other industrialized countries.

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