Some Approaches to the Integrated Steel-Making Processes Performance Improvement of an Existing Steelmaking Processes

Imre Kiss, Vasile Alexa

Department of Engineering & Management, Faculty of Engineering Hunedoara, University Politehnica Timisoara, Revolutiei 5, 331128 Hunedoara, Romania, imre.kiss@fih.upt.ro, alexa.vasile@fih.upt.ro

Abstract: In modern production workflow optimization is very important because of the direct influence on production expenses. Also the continuous pressure of competitive companies forces the production of cheaper products but maintaining high level of quality and flexibility of the workflow in the same time. To achieve this goal it is necessary to apply new methodology, empirical data and theoretical models to solve practical problems and achieve optimal results. Organizing is the process of arranging resources (people, materials, technology etc.) together to achieve the organization's strategies and goals. The way in which the various parts of an organization are formally arranged is referred to as the organization structure. It is a system involving the interaction of inputs and outputs. It is characterized by task assignments, workflow, reporting relationships, and communication channels that link together the work of diverse individuals and groups. Any structure must allocate tasks through a division of labor and facilitate the coordination of the performance results. Nevertheless, we have to admit that there is not a best structure that meets the needs of all circumstances. Organization structures should be viewed as dynamic entities that continuously evolve to respond to changes in technology, processes and environment.

Keywords: performance improving, steel-making processes, plant management, workflows

1. Making a Steel Casting - Overview

The making of a steel casting is a long and complex process. A large investment in capitol equipment is required for the melting of steel, manufacturing of cores and molds and the cleaning and heat treating of castings. Additional major investments for support equipment and facilities are required for sand reclamation systems, dust collection devices and bulk material handling systems.

A typical casting begins when an order is entered into the Steel Production Control program. This entry adds it to the production schedule which in turn creates a demand for raw materials (i.e. sand, binder, scrap steel etc.) and manufactured items such as cores.

Typically, the core room reacts first, getting the necessary cores ready for setting as the molds are being made. Next, molds halves (upper and lower) are made and sent to the assembly area. At the assembly area, molds are flow coated and cores are set in place. The mold is then closed up for pouring.

As the assembled molds are being staged on the pour-off lines, a heat is melted in the arc furnace. Molten steel from the arc furnace is brought to the molds on the pouring lines in a refractory lined pouring ladle. Once poured, the molds are allowed to cool before being sent to the shakeout. At the shakeout, the castings are separated from the sand mold. The sand is sent to a reclamation system so that it can be reused in the molding process.

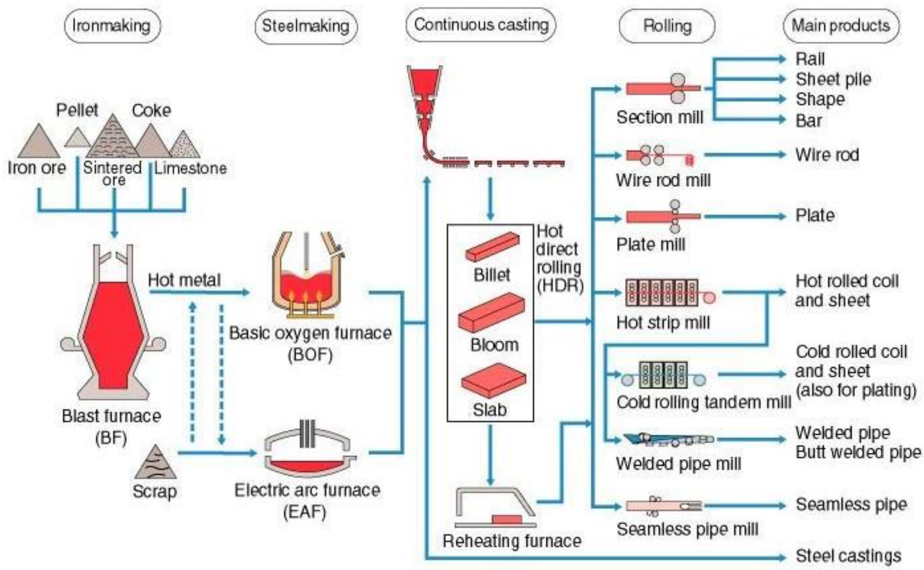

Figure 1. The making of a steel casting

As castings are removed from the shakeout they are sent to the cleaning room where they are ‘finished’ to the customer’s specifications. Processing in the cleaning room includes shot blasting, cut-off, welding, heat treating and inspection.

2. Integrated Steel-Making Processes

An integrated steel mill has all the functions for primary steel production:

- iron making (conversion of ore to liquid iron),
- steelmaking (conversion of pig iron to liquid steel),
- casting (solidification of the liquid steel),
- roughing rolling/billet rolling (reducing size of blocks)
- product rolling (finished shapes).

The principal raw materials for an integrated mill are iron ore, limestone, and coal (or coke). These materials are charged in batches into a blast furnace where the iron compounds in the ore give up excess oxygen and become liquid iron.

2.1. Integrated Process for Iron-making

An integrated steel mill starts with iron-bearing materials, principally iron oxides, which are reduced to molten iron in blast furnaces using the carbon of coke as the reducing agent. The coke is produced on site from coal or is purchased. In coke making, coal is heated at 900-1200C in an oxygen-deficient atmosphere to remove volatile components. The remaining residue is coke. About 1.23 metric tons of coals are needed to produce 1.0 metric ton of coke. This process is carried out in refractory bricklined ovens, with coal introduced in a pulverized state through ports in the top of the ovens. The ovens are heated by coke-oven gas, which burns in flues located in the oven sidewalls. After conversion is complete, the oven doors are removed, and the coke is pushed out of the oven and transported to water quenching towers. The cooled coke is crushed and screened in preparation for the blast furnace. Volatiles removed from coal during conversion to coke are further processed to recover useful by-products. A single mill may operate as many as 500 coke-producing ovens. An overview of the integrated process for making steel is shown in Figure 2.

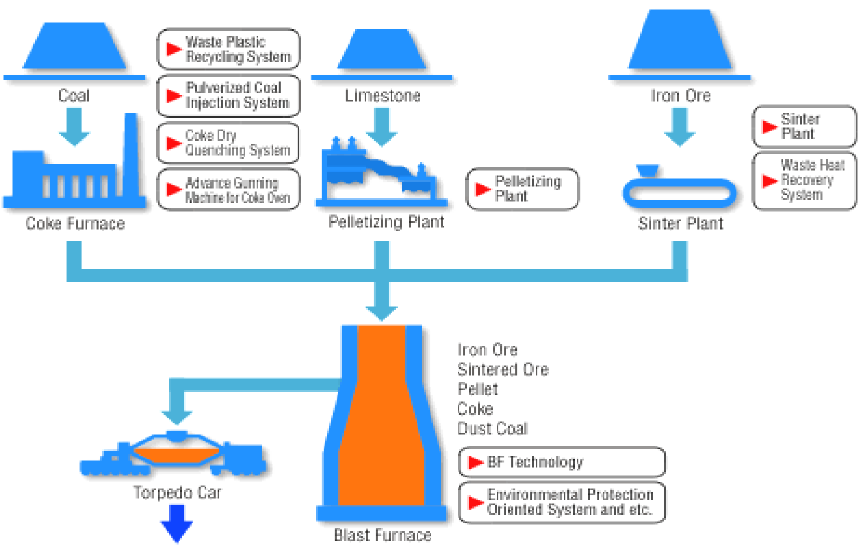

Figure 2. The Integrated Process for Steel Making. Ironmaking Division

Two primary processes are used to prepare the charge for the blast furnace, pelletizing and sintering. In pelletizing, unbaked balls are formed from iron ore combined with a binder. These balls are heat treated in an oxidizing furnace at the mine and shipped to the mill where they are fed into the blast furnace along with coke, fluxes, and often sinter. In producing sinter, iron ore fines, coke fines, water waste sludge, limestone, and air pollution control dust are agglomerated and heated. Heat for producing sinter comes from ignition of the coke fines. The heated mass is fused, cooled, and sized before being sent to the blast furnace. The sintering process aids recycling of iron-rich waste products, but few installations remain because of difficulties in meeting regulatory compliance.

2.2. Integrated Process for Steel-making

The liquid steel, which is produced in large quantities, has to undergo downstream processing. For this purpose it is given certain shapes, dimensions and weights by means of casting. In an integrated iron and steel mill, the capacious casting shop lies, in terms of material flow, downstream of the steel plant and upstream of the rolling mills. Steel is cast according to the ingot or continuous casting method. Ingot casting, which involves pouring the steel portion by portion into permanent (ingot) moulds, is gradually decreasing in importance and used only for high-weight pieces that are to be processed further by forging.

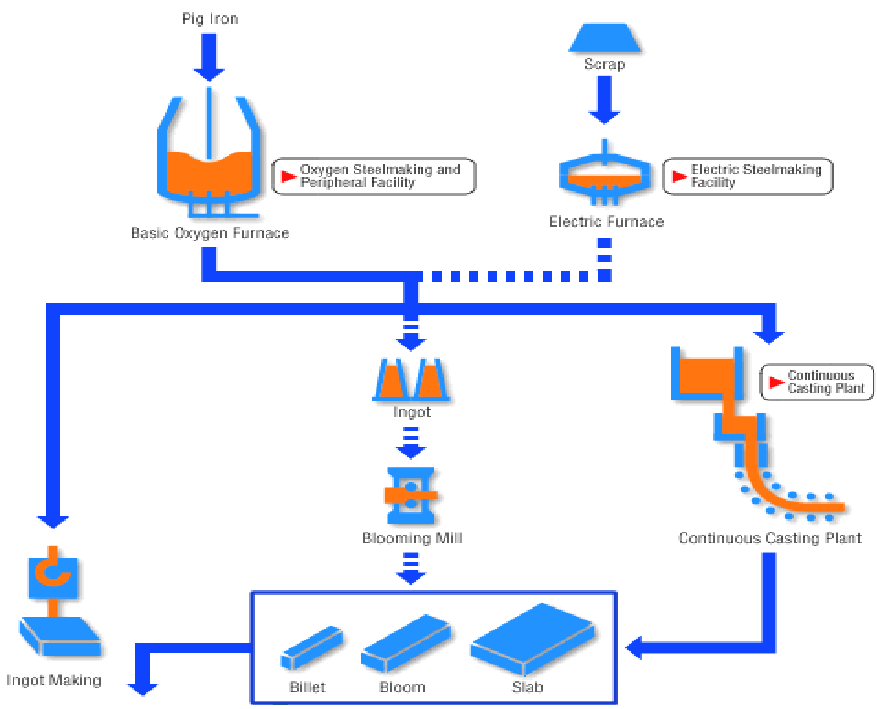

Figure 3. The Integrated Process for Steel Making. Steelmaking Division

Increasing importance is being attached to scrap recycling for reasons of optimum raw materials utilisation and environmental protection. Steel offers everything needed in this respect, making it a particularly eco-friendly material.

2.3. Integrated Process for Continuous Casting Processes

In the continuous casting process, the liquid steel passes from the casting ladle via a tundish, in closed-stream mode, into a short, water-cooled copper mould. The shape of the mould determines the shape of the strand. Before the start of casting, the bottom of the mould is closed-off by means of a link-type chain or so-called dummy bar. As soon as the required metal level has been reached, the mould is subjected to vertical oscillations so that the strand does not adhere to the mould wall. The incandescent strand, once solidified in its surface zone, is withdrawn from the mould, firstly with the aid of the dummy bar, and then by pinch rolls, while the mould is continuously replenished with liquid steel from the top.

Because of its liquid core, the strand has to be carefully sprayed and cooled with water and supported on all sides by rollers until it has solidified completely, thereby avoiding any breakout through the still thin surface zone.

The main components of a casting machine are shown in Figure 4. Essentially, a casting machine consists of a liquid metal reservoir and distribution system (a tundish), a watercooled mold, secondary cooling zones in association with a containment section, bending rolls, a straightener, cutting equipment and a runout table to cooling beds or directly to a product transfer area.

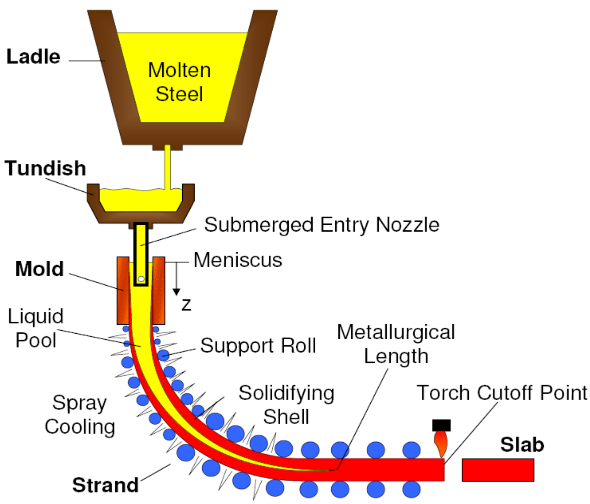

Figure 4. Cross section of a Slab Caster

A casting machine can have a number of casting strands each of which is associated with an independent mold, secondary spray water cooling zone, containment section, etc. The number of strands depends principally on the shape being cast (slab, bloom, billet etc.) and the heat size.

Solidification of the liquid steel starts in the water-cooled mold and continues progressively as the strand moves through the casting machine. Freezing begins at the liquid steel meniscus level in the mold forming a shell in contact with the walls of the mold. The distance from the meniscus level to the point of complete solidification within the machine is called the metallurgical length.

After straightening, the cast section is cut to the desired length either by torches or shears. The hot cut lengths are then either conveyed by a run-out roller table to cooling beds or grouped and transferred directly to subsequent hot and cold-rolling operations.

2.4. Integrated Process for Rolling

Rolling is the most widely used deformation process and for the reason that there are so many versions the process has its own classification.

Continuous rolling mills can be classified according to the arrangement of stands or passes. These are in line in a continuous mill and line abreast in a looping or cross-country mill. Looping and cross-country mills require the workpiece to be bent or turned between stands and are used therefore for rolling rods, rails or sections. Continuous mills are used for plates, strip or sheets. They all require a large capital outlay and are only justified when a large demand for the product is guaranteed.

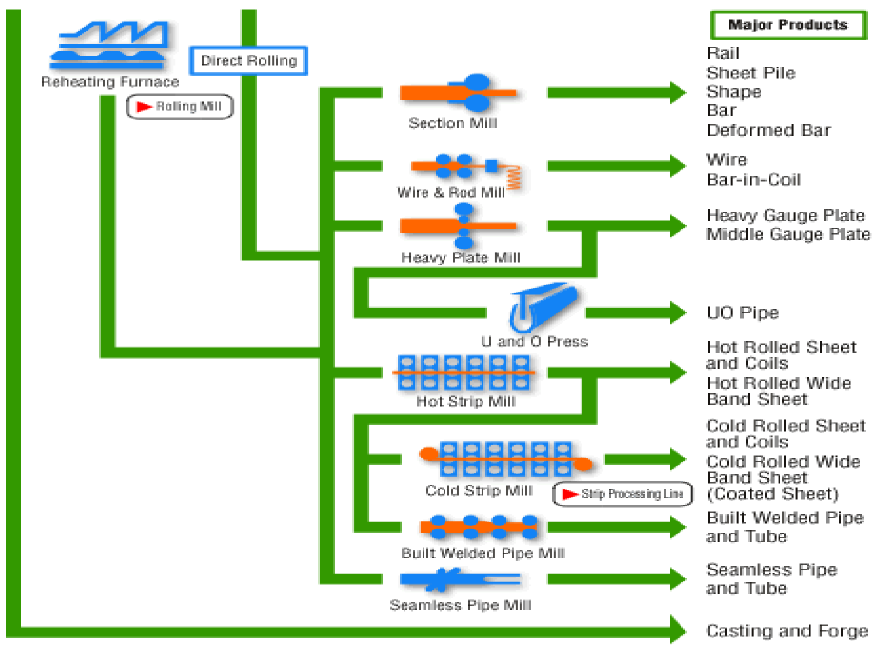

Figure 4. The Integrated Process for Steel Making. Rolling Division

Hot rolling is one of the shaping processes that follow primary forming (ingot/continuous casting). Hot strip and plate are hot-rolled flat products. In conventional (wide) hot strip mills the feedstock (slabs) is heated in reheat furnaces and then transferred to the roughing train. Shortly after leaving the furnace, the slab passes through a descaler to remove the so-called primary scale. Directly downstream of the finishing train are the runout roller table including cooling section and coiler. Precise control of the finishing temperature in the last stand and of the coiling temperature is required so as to impart the appropriate mechanical properties to the hot strip. The strip is cooled with water, the water rate being controlled as a function of strip speed and temperature requirements.

3. Laboratory for Process Metallurgy

The main activities are basic and applied research in the field of melting of steels for the steel and casting industry, continuous casting of steel and hot working of steel. The research activities are performed in close cooperation with other laboratories and departments of the Faculty Engineering Hunedoara and with the steelworks within the Arcelor Mittal – Hunedoara branch.

- study and introduction of new technologies in steel melting process in electric arc furnaces and induction furnaces, optimizing of decarburization, refining and deoxidation in vacuum devices and ladle furnaces, optimization of alloying for the targeted analysis and advanced deoxidation.
- verification of the technological specification of steelmaking processes on the basis of modern steelworks technology of automatic inspection of processes with computer assisted systems.
- evaluation of existing technology from the economy and market point of view.
- technical support at introduction and optimal use of measurements-control systems for steelmaking processes (introduction of direct measurement of oxygen and automatic sampling of melt and slag, control of vacuum process in VOD and VAD devices by means of the PAT measuring technique).
- development of models for complexes steelmaking processes, such as oxidation of carbon. development of algorithms to deoxidation of melts, selection and choice of technology for modification of non metallic inclusions, selection of non metallic additives for formation of slag and their economical use.
- optimization of casting parameters dependent on chemical composition and behaviour of steel during casting and solidification. Study of the influence of solidification mode, concentration of phosphorus, sulphur and other impurities, overheating of the melt on solidification, study of primary and secondary cooling for prevention of crack formation during solidification.

Also, the modern production plant would no longer be imaginable without automated manufacturing processes. In the steel industry, computers are used for production data capture, materials flow tracking and control, process optimisation, and many other tasks. The plants and facilities in the steel industry are varyingly well-suited to automation.

Mechanical, chemical and thermal processes are in need of automation in this respect, with drive-related and logistical problem solutions also requiring consideration. A high degree of automation is achieved for fast processes, such as in rolling mills, where performance is predominantly linear. Installations with differing degrees of automation therefore exist one beside the other. Initially solitary solutions involving lines or process automation systems have, on the whole though, evolved into complex and, in some instances, fully integrated system landscapes.

The increasing "communication" of the production stages and rapid advances of the metallurgical and shaping process technologies necessitate the new and further development of suitable plant and equipment components. It is essential to ensure that the experience gained not only in production but also in maintenance can be channelled back into the fields of design and construction. Cooperation with manufacturers is a particular challenge in that respect.

4. Conclusions

The classic approach to steel production organises iron and steel mills into the production stages of ore preparation, coke, iron and steel making, shaping (rolling, forging, pressing), and steel finishing (coating) or downstream processing. In spite of these individual processes, steel production is a self-contained manufacturing complex, i.e. a system of individual units that are interlinked in terms of logistics and communication. To control such systems with regard to their technical characteristics as well as metallurgical and mechanical equipment, and to preserve the high fixed asset value, it is necessary to have organisational and tactical units in place which, at enterprises of the steel industry, are concentrated under the heading of "plant engineering". An accompanying element of this is plant management, which encompasses the activities in connection with new construction, modernisation, media supply, automation and communication engineering, and maintenance. It involves planning and organising the production plant and equipment, maintaining the availability and functional reliability that is economically necessary, keeping the production units state-of-the-art, and adapting them to the infrastructure of the constantly changing steel production environment.

The routes for producing iron and steel, as well as the product developments and fields of use for the steel grades have reached a very advanced state, yet still offer diverse potentials. The steel industry continues to face challenges with regard to innovations in plant and process engineering, product development, and product application, particularly in the use of steel as a resource-conserving lightweight material.

The trend of development in near-net-shape cast steel products, which began with thin slab casting-rolling plants, has been pursued consistently further and has led to new technical solutions and technologies.

The aim of plant management is not only to measure the performance of existing or future iron and steel mill installations against achievable output and yield but, additionally, to use the current state of the art in such a way that plant and equipment with a higher level of operational readiness and safety are realised, along with improved product quality and reduced costs.

In our efforts to characterize and improve the performance of an existing steelmaking process or in our quest to generate useful knowledge as a basis for the development of new manufacturing routes, measurements and models should be considered as two interdependent requirements. Without measurements, our models are incomplete and unsatisfactory. In addition, as engineers and applied scientists, we have an obligation and a responsibility to facilitate the transfer of new knowledge into the realm of operating practice. In this context, the preeminent aim of collaborative activities between our educational institutions, industrial organizations, government funding agencies, and professional societies it is so necessary.

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