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TALLINN UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING
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Analysis and improvement of production flow in ASG Metals Limited.

M.SC. IN INDUSTRIAL ENGINEERING AND MANAGEMENT

MASTER'S THESIS

TALLINN 2016

Author's Declaration

I have written the Master's thesis independently.

All works and major viewpoints of the other authors, data from other sources of literature and elsewhere used for writing this paper have been referenced.

Master's thesis is completed under the supervision of

Eduard Ševtšenko (Tallinn University of Technology, Estonia)

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Master's thesis is in accordance with terms and requirements "......."....................201….

Supervisor …... signature.

Accepted for defence

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TUT Faculty of Mechanical Engineering

Master's thesis task

2014 /2015 academic year 5th semester

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Master's thesis topic (Estonian and English languages):

Analysis and improvement of production flow in ASG Metals Limited.

Tasks and timeframe for their completion:

No.	**Task description**	**Completion date**
1	**Topic proposal and structure of thesis**	**15-09-2015**
2	**Literature search and reading**	**03-12-2015**
3	**Case studies**	**20-12-2015**
4	**Comparison and conclusion**	**28-12-2015**
5	**Final reporting**	**05-01-2016**

Engineering and economic problems to be solved:

Comparison of alternatives and their impact to production process (technologically) and production flow improved production process performance and increased the level of production by reducing cost consumption and other factors like time, costs, production volume and efficiency. Improvement in production process flow and provide better quality product with optimal results.

Defence application submitted to deanery not later than …...… Deadline ……..........

Student ……………………. /signature/ ………..…………. date …..........………

Supervisor……………………… /signature/ …………….……. date …..........………

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First of all I would like to say this master thesis has provided me a great opportunity to apply some knowledge that I have been learned during my previous studies of this master program and it was a valuable experience to deal with production flow, impact to production process (technologically).

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INTRODUCTION:

Why Abbas Steel?

These days steel products are of high demand with good quality and performance and all the manufacturers are focusing on high production and high quality goods to avoid product and production loss to serve the customers on time. Abbas Steel Group is a very reputed organization and one of the best manufacturers of Steel parts and components. Abbas Steel Group is the largest provider of long steel products in the country. Founded in 1988 The Group was quick to establish itself as a high quality manufacturer of re-rolled steel products which prompted expansion through acquisition of Al-Abbas Steels (PVT) LTD in 1989 and later, Abbas Engineering Industries Limited in 1996. It was a conscious decision to retain the name “Abbas” for all the companies. At present, Abbas Steel Group comprises of a combination of automatic and manual re-rolling mills which have the combined capacity to produce approx. 200,000MT of steel as well as several sales centres spread out across the country. [8]

Products/Profile

Abbas Steel Group is the largest provider of long steel products in the country. It takes time to know their customers and how they do business. By getting to know their customers' markets and products, they are in a position to better serve their needs. Abbas Steel Group extensive product range enables to cater to different markets within the construction industry. [13]

1. DESCRIPTION OF THE RESEARCH OBJECT

1.1 Purpose of the study

From couple of years they were having problems/issue regarding their products, production process, cost and volume of production resulting loss in production. The author was given the task to figure out reasons of these problems/issues and propose effective solutions so the topic analyses and improving production flow (planning) of Billets & Ingots was selected.

Problems to solve

Abbas steel is a big manufacturer of billets and steel parts. Their daily production is about 300tons of billets. From the start of 2013, they were facing different problems which are as follows.

- ✓ Production Process
- ✓ Cost Issues
- ✓ Refractories
- ✓ Furnace Performance
- ✓ Slag Issues
- ✓ Energy Consumption
- ✓ Impact on Production

Main Objective of the study

The master thesis has the following objectives:

- ✓ To understand Manufacturing process in metal & steel industries.
- ✓ To compare successful practices in production department.
- ✓ To identify challenges that companies face during production phase.
- ✓ To recommend appropriate production flow process, tools and techniques applicable to manufacturing to standardize the work processes
- ✓ To improve case companies' financial position by eliminating waste and focusing on what customers value
- ✓ Comparison of alternatives and their impact to production process (technologically) and production flow (how fast, how secure, what cost…)

- ✓ “Improvement” or the “change” in detail / what is the impact to: costs, time, production volume, quality, efficiency.

Main Tasks/Goals of the work

The main goal of the thesis is to study all manufacturing processes, equipment’s, tools and techniques to control manufacturing processes, equipment efficiency, bring out the better solution for the production improvement. Also to focus on cost effectiveness, better quality results, find out the problem causing reasons and to propose optimum solutions which are not only to enhance/improve the production flow and quality of products but also to increase volume of the production on the bases of real facts and figure to make sure smooth production process to meet the required standards on time. Also Estimating costs and setting the quality standards, monitoring the production processes and adjusting schedules as required.

1.2 Description of solution

After the inspection and analysis of one month by getting the facts and figures and discussion with production teams author come gave solutions and come to the conclusion on the basis of company reality. Author figure out the solutions in to two stages. First was related to the equipment parts and accessories and its impact on the product costs and performance. Author propose that Abbas Steel group was using acidic refractories like High alumina which has more than 45 percent alumina and Silica brick which contains no less than 93 percent SiO_2. After couple of research and experiments about acidic and basic refractories author comes to the conclusion that Abbas Steel Group should try basic refractories instead of acidic as Abbas steel was in great loss by using it. Although basic refractories are expensive then acidic but production team took the risk and try basic refractories in inductions furnace and ladle furnace by changing the composition and ratio of Chrome-magnesite. Couple of attempts was made by using Chrome-magnesite but finally they got the desire results by using the Chrome-magnesite with the ratio of 16-35% Cr_2O_3 and 42-50 % MgO and Magnesite-chromite refractories almost have 62% MgO and 9-20% Cr_2O_3. These are utilized on regions where slags and climate are fundamental, they are steady to basic materials however could respond with acids. These materials can withstand destructive slags and gasses and have high hard-headedness. They are suitable for administration at the most noteworthy temperatures and for contact with the most essential slags utilized as a part of steel softening. Basic refractories are little expensive then acidic but it carries phenomenon properties and characteristics as compare to acidic refractories. It gives more lives than acidic because the environment of steel melting is basic in nature. Whereas Abbas steel was using opposite refractory so due to negative reaction acidic erode fastly and give less lives. Where using acidic refractories Abbas steel got 66% recovery of scrap with a big consumptions of fluxes and energy while using basic refractories their production capacities increases and now their scraps recovery improve to 88 % and now they are in profits position and optimising their production process and plans in a better way and by using basic refractories now Abbas steel gets around 15 heats which also improve the performance of their furnaces with good results and now they have less rejection ratio and improve the quality of billets and ingots. It was a great achievement because by taking those steps we reduced almost 20 to 25% manufacturing cost.

Second problems/Issue was related to the selection of production process. On the proposal of production team, Abbas steel management finally convinced to make changes in their manufacturing process and installed Ladle refining furnace after induction furnace to refine the products and get the desire quality products without the amendments and controlling the undesired elements in the rolling mills, because in ladle refining furnace ladle metallurgy is associated with producing high grades of steel in which the tolerances level of chemistry and consistency are narrow and we control and get homogenization of composition and temperature of liquid steel, deoxidization or killing in other words removal of oxygen, Superheat adjustment for continuous casting, by fluxes addition the chemistry of liquid steel is adjusted, vacuum degassing means removal of hydrogen and nitrogen, decarburization, desulfurization reduction of sulphur concentrations as low as 0.002%, micro cleanliness, Inclusion morphology changing the composition of remaining impurities to make and improve the microstructure of the steel whereas mechanical properties enhance the toughness, transverse and ductile properties and preheat or reheating of liquid steel which is conducted by graphite electrodes homogenization of fluxes and steel temperature and control chemistry by inert gas rinse and protects refractory from arc damage whereas focus and heat transfer to the liquid steel and on other hand trap metal oxides and inclusions, and provides desulphurization in additions of Ferro alloys to give for bulk or tight chemical control and cored wire is used for trimming and morphology control. Whereas by installing the Ladle refining furnace which reduces the consumptions of energy up to 20% and increase production and reduce the cost. It was also phenomenon steps towards optimisation.

Verification of solution

Without the improvement in the production process and refractories Company was getting scrap recovery at the rate of 66 percent and consumed energy almost double in the form of electricity which is far below to meet the company desire level. Whereas after the amendment of production process and change of refractory now company is getting scrap recovery at the rate of 88 percent with good results. Whereas company is in profits around 12%.

1.3 Project/case study

Author completed this project in different steps including Production Improvement, Cost reductions, process analysis, Energy consumption on cost, problem solving related to refractories, Inspection and chemical composition of Low Carbon Steel. The main sections of the project are as follows:

- ✓ **Melting Shop**
- ✓ **Fettling Shop**
- ✓ **Casting Defects: Their Causes and Remedies**
- ✓ **Refractory Section**
- ✓ **Analysis**
- ✓ **Cost Calculation**
- ✓ **Cost Comparison**

"A Billet is a round or square cross-section metals having different lengths and sizes are called billet". Billets can casted by continuous casting and by hot rolling as shown in figure 1. Further billet can be processed through drawing and profile rolling. In other words it is a semi-finished casting product. Centrifugal casting technique can also use to produce billets in the form of short circular tubes to get the precise metallurgical structure. Billets needs speciality to produce it. [14]

Figure 1. Example of billets(Asg metal ltd)

“Ingots are the rough castings designed metals in the form of bar or block for the easy storage and shipment. It shape resembles like a square or rectangle” as shown in figure 2.

Figure 2. Example of Ingots (Asg metal ltd)

Abbas steel production flow

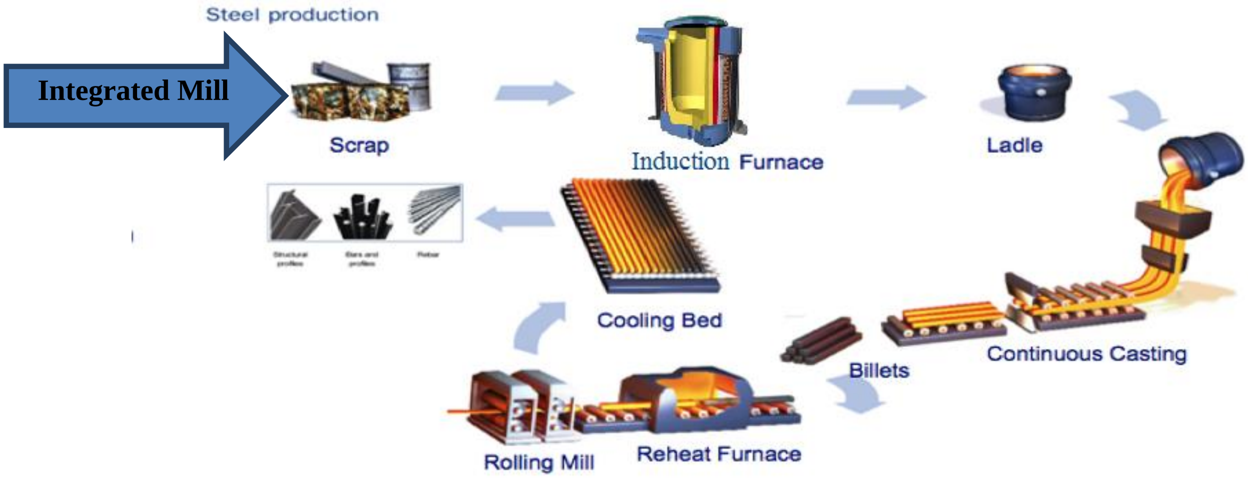


Figure 8: Example of a Abbas Steel Manufacturing Process (**As it**) (Alter Ego 2012)

Casting shop components

Following are the components which are required for casting of billets and bloom.

- ✓ Scrap Yard
- ✓ Induction Furnace
- ✓ Continuous casting machine
- ✓ Ladle furnace
- ✓ Refractory Shop
- ✓ Ladle refining furnace
- ✓ Tundish
- ✓ Crane
- ✓ Scrap Hooper

Crane

Abbas Steel using three cranes of different bearing capacities which are as follows

50 tons

- Maximum Speed 25 mph (40 km/h)
- FRAME consists of high tensile steel all welded.
- Sort - Rear motor, left hand directing, driving pivot 2-route mounted with water driven lockout chambers. Chosen sort by manual switch, 4x2 front drive, 4x4 front and back drive.

- Transmission. - Full power shift with 6 forward and 6 converse rates. Back pivot disengage for 4 x 2 travels.
- Front Axles: Drive/steer with planetary and differential diminishment which focuses unyielding mounted to case
- Rear: Drive/steer with differential and planetary diminishment centre points turn mounted to frame
- Optional: Cross axle differential lock front and rear.

40 tons

- Maximum travel speed: 80 km/h
- Carrier engine: 205 kW
- FRAME - High tensile steel, all welded mono-box construction

Scrap yard

Scrap comprises of recyclable materials left over from item assembling and utilization, for example surplus materials, building supplies and parts of vehicles etc. Not at all like waste, scrap has money related worth; particularly recouped metals and non-metallic materials are additionally recuperated for reusing. Abbas steel has 809273 square meters space for assembling of steels and metals items. Out of 809273 square meters 202350 square meters is comprise of scrap yard in which they have loads of distinctive scraps as substantial metal scraps, light metal scraps ,nigger, Pig Iron, Ferro Alloys, Steel Bundles and so forth. Abbas steel utilizes nearby scraps from distinctive structure and they likewise transported in scrap from China, India, South Africa and Dubai.

Induction furnace

Figure 3. Induction furnace (Weifang Jinhuaxin Electric Furnace Manufacturing)

Abbas steel has three pairs of 10 tons Induction furnace. An induction furnace is an electrical furnace in which the heat is supplied by metals through induction heating. Induction furnace range from kilogram to couple of hundred tonnes capacity. Induction furnace is used to melt iron, steel, aluminium, copper and precious metals as shown in figure 3. The advantage of the induction furnace is a well-controllable melting process compared to most other means of metal melting, easy to use, clean, energy-efficient etc. Now Induction furnace is common to most modern foundries and cupola furnaces are replaces by this furnaces to melt pig iron, cast iron, as the by cupolas emits lot of dust and creates other pollutants. The temperature of the materials is not higher than required temperature to melt the materials and that prevents loss of valuable fluxes and alloying elements. Big disadvantage is that induction furnace use in a foundry is the lacking of refining capacity because charge materials should be clean from oxidation products and of a known composition and some alloying elements lost during oxidation and must be added to the melt later.

Coreless induction furnace

The most important part of the coreless induction furnace is the coil which consists of heavy duty hollow section, high conductivity copper tubing which are wound into a helical coils. Coil shape is contained within a steel shell. The coils are water-cooled, water continuously recirculated and cooled in a cooling tower. The shells are supported on trunnions on which the furnace tils to perform pouring. The crucibles are formed by ramming a granular refractory between the hollow internal former and coils which are melted with the first heat leaving a sintered lining. The power cubicle converts the frequency and voltage of main supply to that required for melting. The higher the operating frequency, the large amount of power which can be applied to a furnace of given capacity and the lower the amount of induced turbulence. At the point when the charge materials are liquid, the cooperation of the electrical streams and attractive fields streaming in the instigation curls create a blending activity inside of the liquid metals. This blending activity drives the liquid metal to rise upwards in the middle take the trademark meniscus on the surface of the metals. The level of blending activity is impacted by the forces and recurrence connected as the size and state of the curl and the thickness and consistency of the liquid metal. The mixing activities inside of the pot is essential which assists with blending of combinations and softening of turnings and in addition keeping up and homogenizing of temperatures all through the heater.

The coreless induction furnace is now largely replacing the crucible furnaces, especially for melting of high melting point alloys and metals. The induction furnaces are commonly used to melt all grades of irons and steels and many of non-ferrous alloys. The furnace is ideal for re melting and alloying because of the high degree of control temperature.

Channel induction furnace

The channel instigation heater comprises of a headstrong lined steel shell which contains the liquid metal. Appended to the steel shell and joined by a throat is an incitement unit which frames the dissolving segment of the heater. The incitement unit comprises of an iron centre as a ring around which an essential actuation curl is wound. This get together structures a straightforward transformer in which the liquid metal circles involve the auxiliary segment. The warmth produced inside of the circle causes the metal to flow into the principle well of the heater. The flow of the liquid metal impacts a valuable blending activity in the melt. Channel prompting heaters are generally utilized for dissolving low liquefying point composites as well as a holding and superheating unit for higher softening point amalgams, for example, cast iron. Channel prompting heaters can be utilized as holders for metal liquefied off top in coreless instigation affectation units along these lines avoiding so as to diminish aggregate softening expenses top interest charges.

Continuous casting machine

Abbas steel has CCM machine having span 4mm and size 100x100, 130x130 and 150x150 and having ability to cast up to 6m billets. Ceaseless throwing, additionally called strand throwing, is the procedure whereby liquid metals change into semi solid form like blooms, billets etc. for ensuing coming in the completing factories. It permits lower-cost generation of metal areas with better quality, because of the naturally lower expenses of nonstop, institutionalized creation of an item, and also giving expanded control over the procedure through mechanization. This procedure is utilized most much of the time to cast steel (as far as tonnage cast).Aluminium and copper are likewise constantly thrown as shown in figure 4. From basic oxygen furnace and electric arc furnace the steel is tapped in ladle furnace and then it is been taken to the continuous casting machine. Ladle furnace is raised to turret that rotates the ladle furnace in casting position over the tundish. [2],[5]

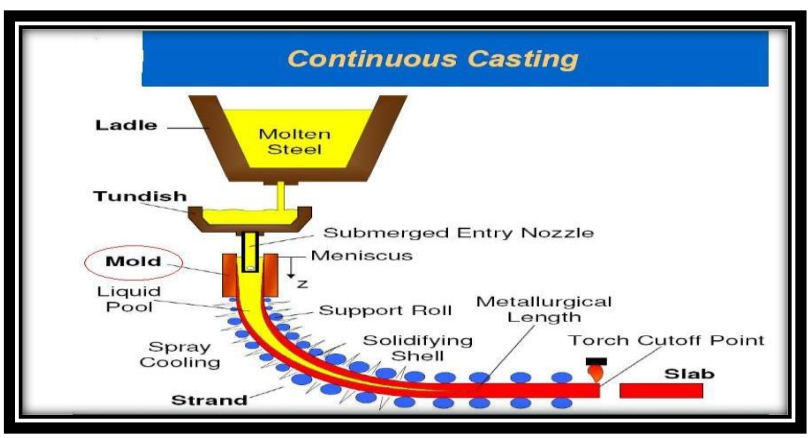


Figure 4. Example of CCM(Jay Market Creator Pvt ltd)

Referring to figure 4, liquid steel go out of bucket into the tundish and after into a mould where solidification starts in the mould, and continues through the different zone and strand. The strand is straightened, torch-cut, and then discharged for different storage and warm charged for finished roll. When the steel is prepared it is ready to go for casting. Ingots are still used for special purposes, but now days the most common plant and process is the 'continuous casting' plant. The steel is 'teemed' by valves in the bottom of the ladle furnace, which can control its flow rate, whereas the steel is casted directly into separate moulds for ingots. However, in continuous casting the steel is put in 'tundish'. This is a like a square box and its function is to transport the liquid steel into the moulds of the CCM. CCM machines may have one and two moulds if billets are being thrown for moving to flat strip. On a few plants, the cast steel can be charged to the re-warming heaters in the moving factory whilst still hot and this spares vitality – this is frequently called 'hot interface'. Most generally, it is chilly when charged in light of the fact that the logistics of hot join present troubles. Persistent throwing offers a few essential advantages in examination with ingot throwing: The fluid steel is empty from the furnace to ladle for the transportation of the steel after optional metallurgy to the "tundish" of the ceaseless throwing machine (CCM). This is a transitional ladle with a controllable outlet. The scoops are preheated preceding tolerating a fluid steel charge with a specific end goal to maintain a strategic distance from temperature stratification in the tundish. When the fluid steel has reached the craved temperature it is filled the tundish. From here, it goes to a short water-cooled copper mould where no air is available and which performs swaying here and there developments to keep the steel from staying. The mould gives the metal they sought shape. Nonstop throwing is a procedure which empowers the throwing of one or a succession of spoons of fluid steel into a ceaseless strand of billet, blossom, piece, bar clear or strip. Mould ointment is included powder structure or vegetable oil. On account of non-self-supporting areas, the scorching strand, with its cemented surface zone, travels through various driven and undriven move sets which bolster its shell against ferro static weight. As the centre is still fluid, it is splashed deliberately with water and cooled until completely set (optional cooling). This procedure forestalls splits in the strand surface zone, which is still genuinely thin, furthermore shields the moves from overheating. The supporting, passing on and driving components are regularly outfitted with idler-roller with inside and outside cooling. In the auxiliary cooling zone, inside move cooling gets to be unnecessary when the temperature is lessened adequately by the water shower. Various orientations are joined with programmed oil greasing up framework. When the strand has completely set, it can be sliced to estimate by cutting lights moving with the strand or by shears. The quick cooling procedure gives the steel a uniform cementing microstructure with positive innovative properties. The hardening microstructure of the strand can be affected by downstream air or water cooling.

The state of the strand is controlled by the mould geometry. Current mould sorts incorporate rectangular, square, round or polygonal segments. For the generation of steel shapes, it is conceivable to utilize moulds taking after the estimated cross-area of the planned item. Run of the mill strand measurements in constant throwing fluctuate between 80 × 80 mm and around 310 × 310 mm, 600 mm (round) in billet and 450 × 650 mm in sprout frameworks, while piece casters produce sizes of up to 350 mm in thickness and up to 2720 mm in width. Billet casters can deal with a few (right now up to eight) strands in the meantime, while the quantity of strands in piece throwing.

Casting overview

To begin a cast, the mould base is fixed by a steel sham bar, which is held set up powerfully by the Straightener Withdrawal Units .This bar keeps fluid steel from streaming out of the mould. The steel filled the mould is incompletely set, creating a steel strand with a strong external shell and a fluid centre. In this essential cooling zone, once the steel shell has an adequate thickness, around 0.4 - 0.8 inches (10 to 20 mm), the Straightener Withdrawal Units are begun, and continue to pull back the somewhat hardened strand out of the mould alongside the fake bar. Fluid steel keeps on filling the mould to renew the pulled back steel at an equivalent rate. The withdrawal rate relies on upon the cross-area, evaluation and nature of steel being delivered, and may differ somewhere around 12 and 300 inches every moment.

After leaving the mould, the strand enters a roller control area and auxiliary cooling chamber in which the cementing strand is showered with water, or a mix of water and air to advance hardening. This range jam cast shape respectability and item quality. When the strand is completely hardened and has gone through the Straightener Withdrawal Units, the spurious bar is disengaged, evacuated and put away. Taking after the straightener, the strand is cut into individual bits of the accompanying as-cast items: sections, billets, adjust, or bar spaces, contingent upon machine plan. Billets have thrown area sizes up to around 7 inches square. Bloom sizes ranges from 7 inches square to about 16 inches by 25 inches. Round castings incorporate widths of roughly 5 to 20 inches, and over 100 inches wide.

To outline, the throwing procedure is contained the accompanying areas:

- ✓ A tundish, situated over the mould to encourage fluid steel to the mould at a managed rate.

- ✓ A essential cooling zone or water-cooled copper mould through which the steel is bolstered from the tundish, to produce a set external shell adequately sufficiently solid to keep up the strand shape as it goes into the auxiliary cooling zone
- ✓ A optional cooling zone in relationship with a control segment situated beneath the mould, through which the still basically fluid strand passes and is splashed with water or water and air to further harden the strand.
- ✓ Except straight Vertical Casters, an Unbending and Straightening segment
- ✓ A separating unit (cutting light or mechanical shears) to cut the cemented strand into pieces for evacuation and further.

Liquid steel transfer

There are two stages included in exchanging fluid steel from the ladle to the moulds. To start with, the steel must be exchanged (or overflowed) from the ladle to tundish. Next, the steel is exchanged from the tundish to the molds. Tundish-to-shape steel stream regulation happens through whole gadgets of different plans: slide entryways, plug bars, or metering spouts, the recent controlled by tundish steel level conformity.

Tundish overview

Abbas steel has five arrangements of tundish having limit of 2.5 tons. The state of the tundish is normally rectangular. Spouts are situated along its base to convey fluid steel to the molds. The tundish likewise serves a few other key capacities: Enhances oxide incorporation detachment Provides a nonstop stream of fluid steel to the mould amid ladle trades to maintains a relentless metal stature over the spouts to the moulds, in this manner keeping steel stream consistent and subsequently giving velocity steady a role as well (for an open-pouring metering framework) which provides steadier stream.

Mould

The primary capacity of the mould is to build up a strong shell adequate in quality to contain its fluid centre upon section into the optional shower cooling zone. Key item components are shape, shell thickness, uniform shell temperature appropriation, deformity free inward and surface quality with insignificant porosity, and little non-metallic incorporation. The mould is essentially an open-finished box structure, containing a water-cooled internal coating created from a high virtue copper amalgam. Mould water exchanges heat from the cementing shell. The working surface of the copper face is regularly plated with chromium or nickel to give a harder working surface, and to stay away from copper pickup on the surface of the cast strand, which can encourage surface splits on the item. Mould warmth exchange is both basic and complex. Scientific and PC displaying are regularly used in building up a more noteworthy comprehension of mould warm conditions, and to help in appropriate outline and working practices. Warmth exchange is by and large considered as a progression of warm resistances as takes after:

- ✓ Heat exchange through the hardening shell.
- ✓ Heat exchange from the steel shell surface to the copper mould external surface.
- ✓ Heat exchange through the copper mould.
- ✓ Heat exchange from the copper mould internal surface to the mould cooling.

Mould oscillation

Mould swaying is important to minimize contact and staying of the cementing shell, and maintain a strategic distance from shell tearing, and fluid steel breakouts, which can wreak ruin on gear and machine downtime because of tidy up and repairs. Grating between the shell and shape is diminished through the utilization of mould ointments, for example, oils or powdered fluxes. Swaying is accomplished either using pressurized water or by means of engine driven cams or levers which bolster and respond (or waver) the mould. Mould wavering cycles change in recurrence, stroke and example. On the other hand, a typical methodology in which the descending stroke of the cycle empowers the mould to move down speedier than the area withdrawal speed. This empowers compressive anxieties to create in the shell that build its quality via fixing surface crevices and porosity.

Secondary cooling

Normally, the auxiliary cooling framework is contained a progression of zones, each in charge of a section of controlled cooling of the hardening strand as it advances through the machine. The showered medium is either water or a blend of air and water.

Ladle furnace

Abbas Steel has six modern ladle furnace having limit of 10 tons in a foundry, a ladle as a vessel used to transport and pour out liquid metals. Ladle range in size from little hand conveyed vessels that look same as kitchen bowl and hold 20 kilograms to big steel plant ladle that can carries up to 300 tons. Numerous non-ferrous foundries likewise utilize ceramic crucibles for transporting and pouring liquid metal as shown in figure 5.

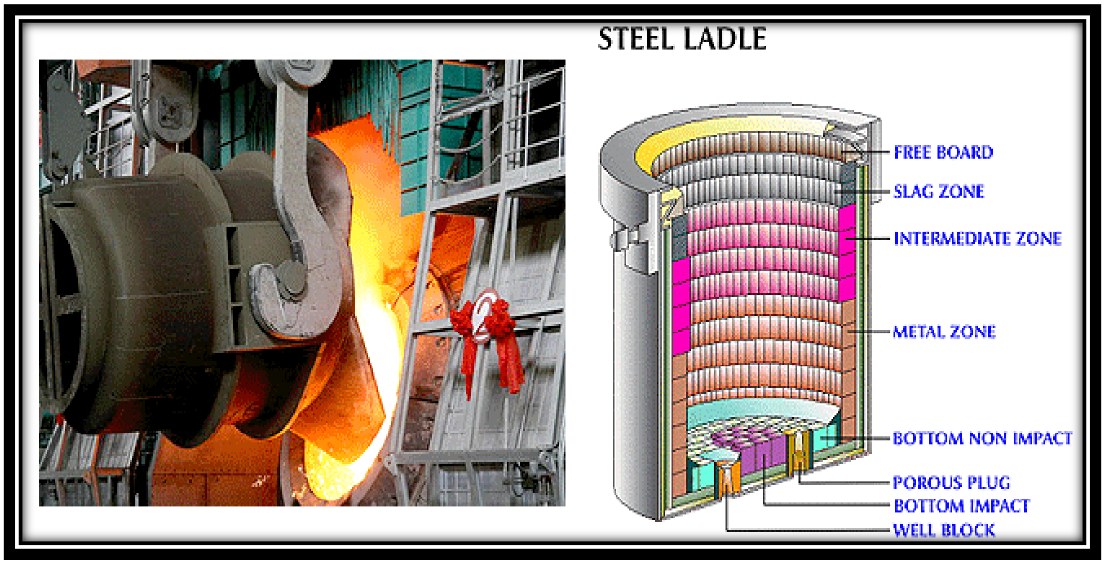


Figure 5. Example of Ladle furnace (kosmokraft Cosmos Power in Refractories**)**

In fact, steel delivered by either the incorporated course or the EAF course is the same separated from minor difference which is imperative just in unique grades.[15] The procedures turn into somewhat diverse at the secondary steelmaking process and called ladle metallurgy. This happens after the "unrefined" steel is tapped from the BOF or EAF into a scoop containing anything up to 350 tons. It is amid this tapping operation that meets the steel grade particular. There is an open compartment used to transport the fluid steel to cast. Contingent upon the evaluations of steel being made, diverse optional steelmaking process is utilized. The determination of these procedures is chosen mostly by the properties required depend upon the economy of companies. The greater part of the procedures treats the steel at a "station" situated between the BOF or EAF and cast of the liquid metal.

Ladle refining furnace

After pouring of steel from an essential steelmaking heater, for example, BOF, EAF or liquid steel for good quality or strength applications is subjected to further refining in various option forms all in all known as ladle metallurgy. Ladle metallurgy is also known as ladle refining or auxiliary steelmaking as shown by figure 6. Ladle metallurgy procedures are regularly performed in ladle. Tight control of metallurgy is connected with creating high evaluations of steel in which the resistances in science and consistency are narrow. The targets of ladle metallurgy are following. A ladle heater is utilized to relieve the essential procedure of steel making of a number of the optional refining operations which as follows. [3]

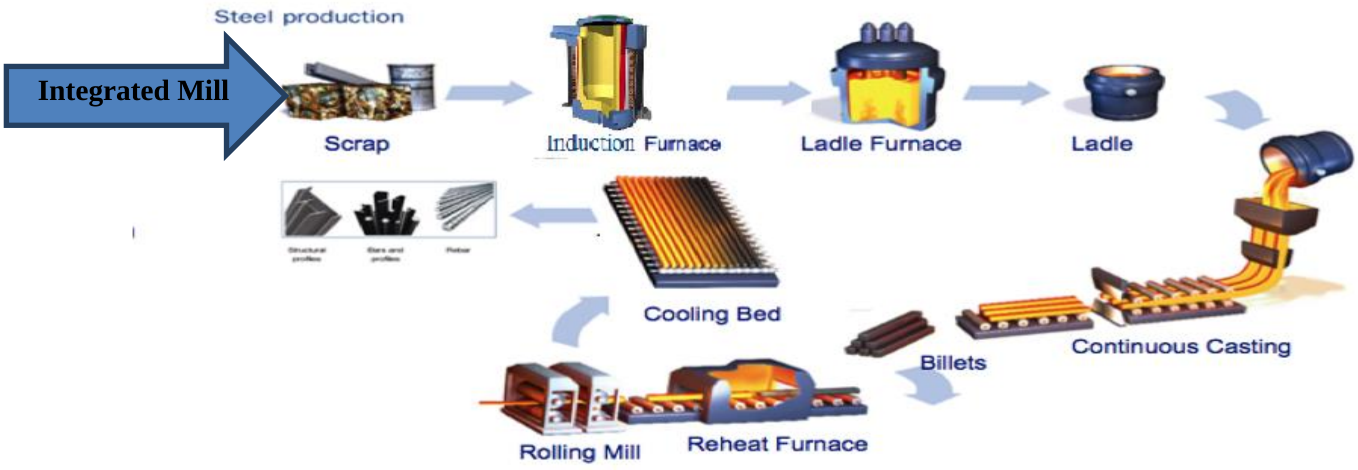


Figure 6: Abbas Steel Manufacturing Process **(to be)** (Alter Ego 2012)

- Homogenization – Homogenization of compound piece and temperature of fluid steel in the ladle.
- Deoxidization or murdering – Removal of oxygen
- Superheat alteration – Heating of the fluid steel to a temperature suitable for ceaseless castings.
- Ferro composites and carbon increases – Making changes in the science of fluid steel.
- Decarburization – Removal of carbon for meeting the prerequisite of specific evaluations of steel.
- Desulfurization – Reduction of sulphur fixations as low as 0.002%
- Micro cleanliness – Removal of undesirable non-metallic components
- Mechanical properties – Improvement in sturdiness, pliability, and transverse properties.
- Reheating of fluid steel by electric force which is led by graphite terminals.

- Homogenization of steel temperature and science through inactive gas washing.
- Formation of slag layer that shields stubborn from circular segment harm, thinks and exchange warmth to the fluid steel, trap incorporations and metal oxides, and gives intends to desulphurization.
- Additions of Ferro compounds to accommodate mass or trim substance control.
- Cored wire expansion for trimming and morphology control.
- Provide a method for profound desulphurization.
- Provide a mean for dephosphorization.

The roof of ladle is water cooled outline with an refractories or delta area and is arranged to facilitate with existing ladles such that the rooftop covers totally cover the top segment of heater when in the working position. The refining of steel in the heater is extensively characterized here as involving the operations, for example, deoxidation, desulphurization, dephosphorization, controlled increases of alloying components and consideration alteration.

The refining steel in heater is normally execute by deoxidation of steel with Ferro-manganese, aluminium, silico-manganese, and aluminium. The steel is initially deoxidized somewhat with silico manganese, ferromanganese, and/or ferrosilicon took after by a last deoxidation with aluminium. Such a practice has a few points of interest including minimization of nitrogen get, minimization of phosphorus inversion and minimization of aluminium misfortunes amid essential steel making. Today utilization of manufactured slags in the ladle has turned into a fundamental piece of the ladle metallurgy. The utilization of manufactured slag comprising of calcium-alumina silicate helps in the disintegration of the deoxidation items which helps in the deoxidation movement. In part deoxidized steel can likewise be further deoxidized with calcium silicide (Ca-Si) which is infused in the scoop as cored wire. Murdered steels deoxidized with aluminium ordinarily have less than 10 ppm of disintegrated oxygen.

Certain steel reviews, a low sulphur substance is determined for example 25 ppm and less. This low sulphur substance must be accomplished by steel desulphurization in the heater in the vicinity of a calcium aluminate slag when the steel is completely murdered. For the required level of desulphurization to take place inside of a pragmatic time compass, great blending of steel and slag is vital. The rate, at which the sulphur can be evacuated, is unequivocally prescribed by the gas stream rate amid washing of steel. Another strategy for accomplishing low sulphur substance is by the infusion of fluxes into the heater. A commonplace flux utilized for desulphurization contains almost 72 % CaO and 28 % CaF_2. Desulphurization accomplished through powder infusion is around 12 % speedier than the desulphurization with a top slag joined with the gas rinsing. Desulphurization of steel in the heater is done by lowering the temperature of the steel shower and thus required reheating.

Dephosphorization in heater is required when the phosphorus substance of input hot metal amid essential steel making is high. This adjustment in consideration structure and shape is usually known as incorporation morphology control or change. Since the breaking point of calcium is 1491 degree C, calcium is a vapour at the steel making temperature. While adding calcium to the fluid steel, exceptional measures are required to be taken to guarantee its legitimate recuperation in the steel bath. Calcium or calcium combinations are added to the fluid steel shower at the best possible depth in order to make utilization of the expanded weight from the ferrostatic head to keep the calcium from vanishing. Further calcium maintenance recurrence diminishes with expanding amount of calcium injected. The amount of calcium to be infused must be balanced as per the level of cleanliness of the steel and its aggregate oxygen content.

Charges for furnace

The charge contains the following:

Pig iron

Pig iron is the primary product of blast furnace. It is the semi-finished metal which is produced from ores in blast furnace which contains 90 % iron and high amounts of carbon up to 3.5 %. Raw materials for the production of pig-iron are iron ore and coke and different fluxes are added like limestone, dolomite etc.

Scrap

Scrap comprises of recyclable materials left over from item assembling and utilization, for example surplus materials, building supplies and parts of vehicles etc. in the form of LMS (light metal scrap), HMS (heavy metal scrap) and steel bundles. Not at all like waste, scrap has money related worth; particularly recouped metals and non-metallic materials are additionally recuperated for reusing.

Fluxes

Limestone is a normally happening mineral. The term limestone is connected to any calcareous sedimentary rock comprising basically of carbonates. The metal is broadly accessible topographically everywhere throughout the world. Earth's covering contains more than 4 % of calcium carbonate. Limestone is fundamentally calcite which is hypothetically made out of solely calcium carbonate ($CaCO_3$). At the point when limestone contains a sure partition of magnesium, it is called dolomite. Dolomite hypothetically contains $CaCO_3$ 54.35 % and $MgCO_3$ 45.65 % or CaO 30.4 %, MgO 21.9 % and CO_2 47.7 %. In any case, in nature, dolomite is not accessible in this precise extent. Subsequently for the most part the stone containing 40-45 % $MgCO_3$ is normally called dolomite. At the point when $MgCO_3$ is under 40 % yet more than 20 % then the limestone is called dolomitic limestone. The substance structure of limestone and dolomite fluctuates enormously from district to locale and also between diverse stores in the same area. In this manner, the finished item from every characteristic store is distinctive. Commonly limestone and dolomite are made out of calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), silica (SiO_2), alumina (Al_2O_3), iron (Fe), sulphur (S) and other follow components. These minerals are appeared in Fig 7. [10]

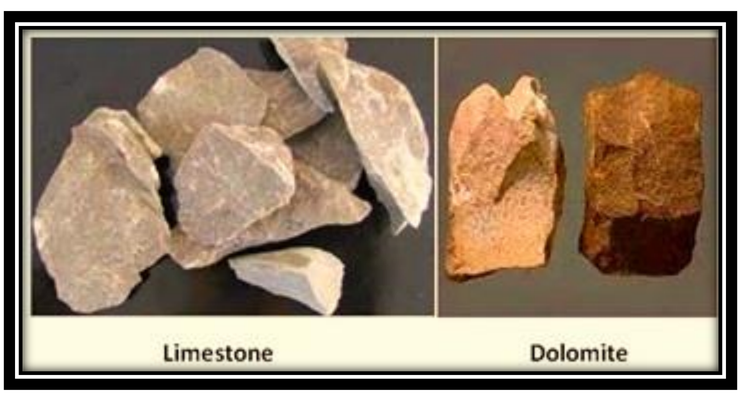


Figure 7. Limestone and dolomite (By SATYENDRA,Ispat Digest 2013)

The limestone from the different stores varies in physical synthetic properties and can be ordered by substance structure, composition and topographical arrangement. Limestones from distinctive sources contrast extensively in synthetic creations and physical structures.

The compound reactivity of different limestone's for the distinction in crystalline form. The changing properties of the limestone affect the preparing technique. Subsequently it is important to know far reaching data of the limestone, for example, physical and concoction properties. Both limestone and dolomite are widely utilized as a part of an iron and steel plant in different procedures and their utilization is clarified underneath. Detail of limestone and dolomite for iron making is less inflexible. In any case, for steel making limestone ought to have low silica (SiO_2) and alumina (Al_2O_3) since these components will require extra flux to kill them which will expand slag volumes, further extra warmth will be required for keeping liquid this measure of extra slag. Likewise essential is the consistency of synthetic organization and size division. Further limestone utilized for calcination ought to have great decrepitating list.

Essentially limestone is utilized as a slag previous. Dolomite is utilized as a slag previous, slag modifier and as an unmanageable material. The procedure of iron making is the lessening of iron mineral to deliver iron. Iron metal regularly contains gangue materials, for example, silica (SiO_2), Alumina (Al_2O_3) alongside sulphur and Phosphorus. Leaving of these pollutions is finished by joining the gangue materials with CaO and/or MgO to shape slag which comprises of low dissolving point complex mixes, for example, calcium silicate, calcium aluminate and so on. CaO and MgO is accused along of other crude materials as lime stone and dolomite or it is charged through sinter where again fines of limestone and dolomite is utilized. This limestone or dolomite is initially deteriorated into CaO or CaO+MgO which then join with gangue to shape slag. Further lime from limestone responds with sulphur present in the crude materials to frame CaS which goes into slag. Amid pre-treatment of hot metal in desulphurization plant lime is a key segment of the desulphurizing compound. Amid steel making high basicity of the steel making slag is being kept up with the assistance of lime. Lime is likewise utilized as a part of optional steel making. In steel dissolving shop, fettling of the coating and in addition fixing is finished with dolomite based mixes. Calcined dolomite is likewise utilized as a part of converters to keep up MgO levels in the steel making slags. It additionally goes about as a slag modifier if there should be an occurrence of slag sprinkling. Blazed dolomite is likewise utilized for making unmanageable blocks with the end goal of covering in steel softening shop. Lime, essentially CaO, and dolo-lime, basically CaO.MgO, are added to steel making vessels (electric curve heaters, fundamental oxygen heater (BOF) and Q-BOP, and so forth.) to frame a mind boggling melt of oxides, normally called "slag," with the end goal of engrossing undesired contaminations from the hot metal shower of liquid iron. Slag in the steel making procedure is a blend of CaO, Al_2O_3, SiO_2, MgO, and other mineral substances in little sums including sulphur, and phosphorous. The silica, SiO_2, sulphur, and phosphorous are the significant debasements of the hot metal shower that the slag is expected to evacuate, or assimilate. The steel making operation involves dissolving scrap metal, and/or utilizing liquid iron and refining the melt to the wanted science to make steel items. The materials added to the steel making vessel are regularly termed as "the charge". Lime and dolo-lime (and in some melt shops, bauxite) are a piece of the charge. As the melt is framed, the warmth is dissolved in, or "shaped up", the fluid metal shower is secured over by a lower thickness melt of mineral substances, the slag. Getting an all-around blended, uniform slag is a critical initial phase in the steel making procedure.

Charging lime and dolo-lime rocks to the vessel has two inborn issues. The perfect oxides of lime, CaO, and dolo-lime, CaO.MgO, are not effectively wetted, and moreover, a layer or shell of calcium silicates shapes on the lime stone which impedes the disintegration of CaO and MgO into the slag. The steel making procedure is not began until the slag is shaped up in light of the fact that it is the CaO that goes about as the essential permeable of the debasements. The MgO is added to adjust the science of the slag with the stubborn covering of the vessel. Without MgO in the slag it will artificially assault the headstrong coating until the slag achieves substance balance with the covering. Including MgO carries the slag into harmony with the stubborn and amplifies unmanageable life. The MgO likewise has its own part in expelling pollutions from the metal. Along these lines, the time required for making up the slag, dissolving the CaO and MgO, is a crucial initial phase in steel making, however it is likewise an irretrievable loss of generation time. Al_2O_3, alongside CaO and MgO, is a fundamental constituent of any melt added substance since these materials are best to remove polluting influences from the hot metal shower. The second significant issue is that lime and dolo-lime are produced using limestone, calcitic and dolomitic, separately, which are removed from the beginning ordinary quarrying and/or mining procedures. Accordingly, the limestone is delivered in a scope of estimated and moulded pieces, from dust to stones. The stones can be separated yet the dust has, until this development, been hard to blend or total.

While the limestone is moderately hard, warming the limestone, yields lime which is delicate and disintegrates effortlessly. Both the quarrying procedure and calcination step join to create an item with an extensive size appropriation. Whenever lime stones are mixed in steel making ladle, the fine part and clean which are promptly air-borne, are lost to the fumes fan arrangement of the vessel. Since the limestone quarrying and lime creation steps are variable, the blend of sizes in the lime charge is an arbitrary variable. The variability of the lime charge is a major issue for the melt shop. A charge of 140 pounds of lime for every ton of hot metal to one warm might really net 135 pounds of lime in the vessel per ton of hot metal. In any case, the following lime charge for the following warmth may be involved a bigger segment of fines and tidy with just a net of 125 pounds of lime in the vessel per ton of hot metal. The expulsion of silica and sulphur from the hot metal is delicate to the segment of lime present, subsequently, the lime clean and fines that are lost are of no utilization and the variability of size dispersion of the lime turns into a donor to variability in the nature of the steel created. In numerous examples the issue is further convoluted by the way that the dolo-lime is fundamentally weaker than the high calcium lime. These outcomes in a bigger bit of the dolo-lime being lost as fines and clean than for the high calcium lime.

2. LITERATURE REVIEW

2.1 Universal process/methods of billet casting

Figure 9: Manufacturing process (LeTourneau University Civil Engineering for Sustainability)

Iron production

Iron production can take place at independent offsite as Primary steel making and secondary steel making. By blast furnace normally iron production done but it can be produced by a direct reduced process which involves the reduction of iron ore to metallic iron in the solid form below 1000 °C. [22]

Metallurgical coke production

Metallurgical coke is firstly used in the blast furnace to make iron. It is also used in other processes like lead and zinc, cast iron, and in kilns to prepare magnesium and lime. Coke is prepared from the carbonisation of coal at high temperature. Coking coal refers to bituminous coal which allows the production of a coke suitable for blast furnace charge. It is a by-product as show in figure 10. [1]

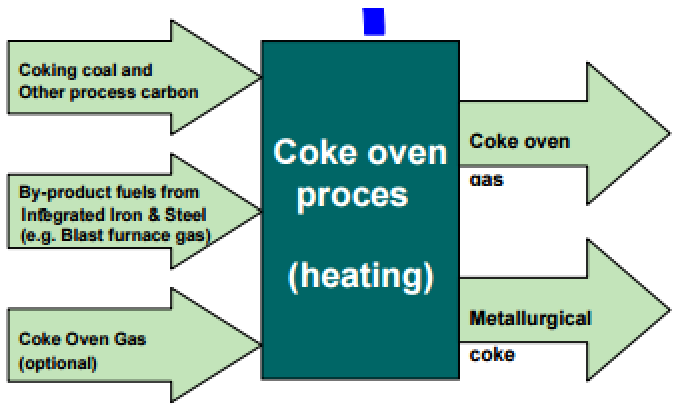


Figure 10. Process scheme of the coke production process.(EMEP/EEA emission inventory guidebook 2009)

Coke oven gas heated for energy recovery with coke plant. Coke oven gas may also be transferred off site like into the natural gas distribution and used as energy source. The coke combustion in blast furnaces during the steel-making produces blast furnace gas which is recovered and transferred from steel mill to the coke plant and heated within the coke ovens.

Sinter and pellet production

This section addresses travelling grate sintering which is the most important technique for iron ore sintering. Iron ore and other iron-containing materials are agglomerated in sinter plants at integrated iron and steel plants. Feedstock to sinter plants may include fine iron ores, additives from downstream steel and iron making processes.

Iron making

Carbon is use to convert iron ore to iron is a major source of carbon monoxide (CO), carbon dioxide (CO_2). Figure shows the iron-making process. Carbon goes to the blast furnace as coke produced from metallurgical coking. Carbon serves a multipurpose for iron making process, initially as a reducing agent and also as an energy source to flow heat whereas carbon and oxygen exothermically react. Blast furnace gas is produced during the combustion of coke in blast furnaces. It is recovered and used as a fuel half within the plant and half in other steel industry processes. Blast furnace gas also recovered and transferred from the iron and steel mill to the coke plant where it burned for energy with the coke ovens. Blast furnace gas may also be transferred offsite where it is used as energy with the furnace and when blast furnace gas is combusted to heat blast air. Oxygen gas is obtained as a by-product as shown in figure 11. All carbon used in blast furnaces should be considered process-related industrial process and produce use (IPPU) emissions.

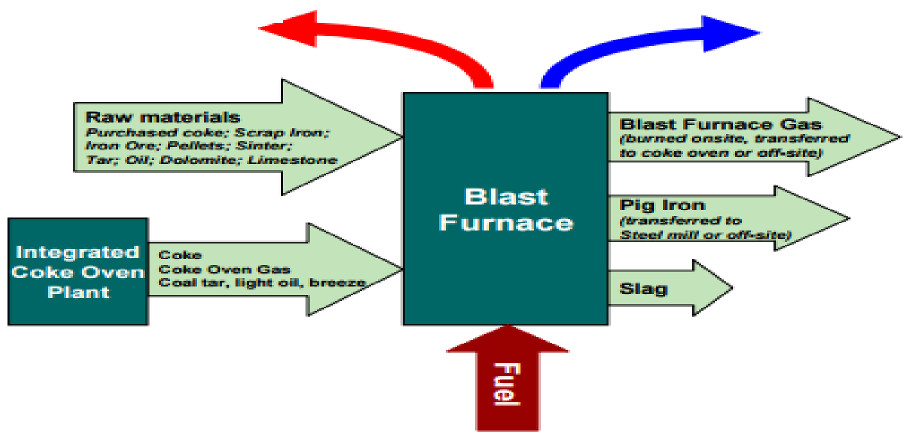


Figure 11. Process scheme of the iron making process.(EMEP/EEA emission inventory guidebook 2009)

As mention above iron can be produced by direct reduction process. DRI involves the reduction of iron ore to metallic iron in the solid state below 1000 °C. It is produced by the direct reduction process. DRI has a carbon content of less than 2 percent. Direct reduction iron is normally used as scrap replacement in the electric arc furnace but may also be used as a feedstock for blast furnace iron making. Direct reduction iron may also be melted into briquettes, referred to as hot briquetted iron (HBI), when the product has to be stored or transported. [1]

Blast furnace for pig iron production

The physical and chemical reactions inside the blast furnace are extremely complex. As a result, the process variables always show a strong deviation from normal distribution and the process demonstrates time-varying characteristics. [21] The main emissions from the blast furnace charging are carbon monoxide, carbon dioxide, hydrogen and hydrogen sulphide. It is rather coarse dust, with a particle size larger than 12 microns. Whereas the dust contains heavy metals from the ore and the cokes like pelletizing and sintering. Emissions can also arise from conveying operations. Dust emissions also arise from the boring of the tap and the filling of the trough, mainly from the contact between the hot metal and slag. This dust has some heavy metals in it. The particle size of the dust during the boring is mainly below 10 microns. The size of the particles from emissions from the roof is usually about 50 % bigger than 10 microns. The heating of the transport trough after coating gives volatile decomposition products, which are also emitted by the heating of the plugging material. Decomposition products from tar are polycyclic aromatic hydrocarbons and benzene containing aromatics. The exact benzene content is not available. In principle the same products are produced by the heating of coal. The amount of coal used is however so small that these emissions can be neglected.

2.2 Techniques

Coke plant

The process of making coke can be divided into several steps (European Commission, 2001):

Coal handling, consisting of:

- ✓ Discharge of coal from ships or trains onto a transportation system
- ✓ Coal storage in large coal stocking areas, where wind may cause coal dust emissions; o coal transport by conveyor, transfer points outside buildings and road transportation
- ✓ Coal preparation, bed blending, leading to dust emissions, bunker blending etc.
- ✓ Charging of the coal tower with possible dust emissions; o charging of the charging car with possible dust emissions.

Coke oven battery operations, which dominate the emissions from a coke oven plant. This process consists of various elements, as follows.

- ✓ Coal charging, where pulverised coal (mainly coking coal) is charged through the charging holes. The flow of coal must be kept under control; the aim is to achieve charging with reduced emissions ("smokeless charging").

- ✓ Heating and firing of the chambers. Heating flues with nozzles for fuel supply are used to fuel the individual coke oven chambers. This process generally uses clean coke oven gas as a fuel but blast furnace gas can be used as well. To improve the process efficiency, regenerators exchange heat from flue gases with combustion air or blast furnace gas. If the heating walls are not completely gas tight, coke oven gas will reach flue gas and be emitted via the stack.
- ✓ Coking. This carbonisation process starts right after the coal charging. The process takes around 14–24 hours to complete. Emissions may occur through holes, wall cracks and via heating gases. Crude coke oven gas (COG) is released as a by-product in this process.
- ✓ Coke pushing and quenching. After the coke is fully carbonised, it is pushed out of the oven and quenched. Generally a quenching car is used to transport the hot coke to a quenching tower.
- ✓ Coke handling and screening. After quenching, the coke is stored in stock piles from which it is transported. Finally, the coke is crushed and screened. Smaller coke less then 20mm is mainly used for the sinter process.

Collection and treatment of coke oven gas. COG is treated before being used as a fuel, because the raw gas contains valuable products. The treatment process consists of five steps:

- ✓ Cooling of the crude oven gas by a primary cooler and an electrostatic precipitator, causing part of the COG and present water vapour to condense;
- ✓ Tar recovery from the condensate by a tar/water separator;
- ✓ Desulphurisation of the coke oven gas, using either wet oxidation or absorption.
- ✓ Recovery of ammonia from the coke oven gas as well as the condensate;
- ✓ Recovery of light oil (mainly benzene, toluene and xylene) from coke oven gas.

Coke oven water flows are generated during the coking process and coke oven gas cleaning. Water vapour originates from various sources: coal moisture, chemical water formed during the coking process and steam or ammonia liquor. Most of the water vapour is condensed by the primary cooler and electrostatic precipitator.

2.3 Steel making

Steel production can occur at integrated plant from iron ore or at secondary facilities as shown in figure 4. Integrated plant typically includes blast furnaces and basic oxygen steel making furnaces or in some cases open hearth furnaces. Raw steel is produced using a basic oxygen furnace from pig iron produced by the blast furnace and then processed into finished products. Pig iron may also be processed directly into iron products. In electric arc furnaces mostly secondary steel making occurs. In 2003, BOFs accounted for approximately 63 % of world steel production and EAF approximately accounted for 33 %; OHF production accounted for the remaining 4 % but is today declining. Steel production in a BOF begins by charging the vessel with 70–90 % molten iron and 10–30 % steel scrap. High purity oxygen then combines with the carbon in the iron to create an exothermic reaction that melts the charge while lowering the carbon content. Iron from the blast furnace usually contains 3–4 % carbon, which must be reduced to less than 1 %, refined and alloyed to produce the desired grade of steel. Steel production in an EAF typically occurs by charging 100 % recycled steel scrap, which is melted using electrical energy through carbon electrodes and then refined and alloyed to produce the desired grade of steel. [1]

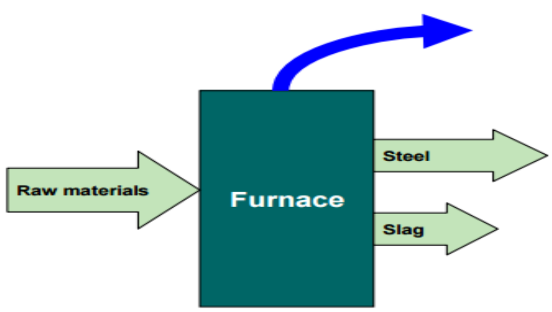


Figure 12. General process scheme for steel making, applicable to the three types of furnaces (EMEP/EEA emission inventory guidebook 2009)

2.4 Open hearth furnace steel

This process covers the production of steel in an air furnace fired with gas or fuel oil. The charges are pig iron and steel scrap. Ferroalloys, deoxidizers and ore are also used as charge. The composition of charge may influence the quality of steel. Necessary air and fuel gases are heated up to 1100 °C and then led to the working space of furnace, after which combustion the furnace gases reach a temperature of 1700– 1800 °C and heat the charge in the oxidising atmosphere. The process emissions of the open hearth furnace consist of particulates and heavy metals. In an open hearth furnace dust generation depends on three basic processes mechanical impact of furnace atmosphere and charge, combustion, and chemical processes. [23] The flow of gases in furnace chamber entrainment of fine particles of charge in the initial process of heating and in the refining process. Whereas chemical processes take place in fluid metal increase the dust generation. Rising CO bubbles throw particles to the surface of the melt which are then entrained by furnace gases, thereby increasing the dust load. Introduction of ore materials into the furnace affects slag generation and results also in an increase in furnace gas dust generation. [11]

Dust concentration in furnace gas heating changes during the process. Whereas the concentration as individual periods depends on a whole range of factors, of which the following are the most important:

- ✓ Type of charge material;
- ✓ Type of process used;
- ✓ Technical condition of the furnace;
- ✓ Type of fuel;
- ✓ Application of oxygen during the smelting and refining processes.

2.5 Basic oxygen furnace

Carbon accounts for 4–4.5 % of the weight of pig iron. In its solid state pig iron is tough and brittle and rolling is impossible. This can only be done by lowering the carbon content to 1 % or (in many cases) even lower (European Commission, 2001). This is the steel production process. The first step concerned the removal of carbon. In blast furnace process the carbon left from the coke breaks the iron/oxygen bond in the ore by binding itself to CO and CO_2. [6] .The oxygen-blown in a converter which has a refractory lining and is mounted in such a way that it can be tilt. Inside iron is turned into steel by blowing almost pure oxygen on to the surface of the molten metal, causing undesirable substances to be combusted. The refining process can be enhanced by ‘bottom stirring’ with argon gas by porous bricks in the bottom lining in certain phases of the process. This produces a more intensive circulation of the molten steel and an improved reaction between the gas and the molten metal. The oxidation of the various elements can be accompanied by the release of a great deal of heat.

A complete cycle consists of the following phases: charging scrap and molten iron, blowing, sampling and temperature recording, and tapping. In a modern steelwork, 300 tonnes of steel are produced in a 30 minute cycle. At the end of the refining process the ladle filled with molten steel is conveyed to the continuous casting machine. Continuous casting, in which billets or slabs are cast direct from molten metal, replaces the traditional method of pouring molten steel into moulds to produce ingots which, when solidified, are reheated and rolled into slabs or billets. Continuous casting not only saves time and energy, but also improves the quality of the steel and increases the yield. The process gas from the converter contains large amounts of CO and is hot. When the energy from the BOF gas is recovered (waste heat recovery and/or BOF gas recovery), the basic oxygen furnace becomes a net producer of energy. In a modern plant, energy recovery can be as high as 0.7 GJ/Mg steel (European Commission, 2001).

2.6 Electric furnace steel

In an electric arc furnace non-alloyed and low-alloyed steel is produced from polluted scrap. The scrap is mainly produced by shredding vehicles and does not have a constant quality. By carbon electrodes electric energy is added to the scrap in the furnace which raising the temperature to 1700 °C. Fluxes are then added depending on the desired quality of the steel. A batch process is used. Each cycle consists of the same steps: charging of scrap, preheating, refining with addition of other material and tapping. Emissions are produced during each step of a cycle. Several abatement techniques are used to reduce the dust emissions. The interior of the furnace is covered with fire-resistant coating.[16]

In an electric arc furnace plant, besides carbon monoxide and carbon dioxide, dust is the main emission. Sixty percent of the dust particles are smaller than ten microns. Because polluted scrap is used, the dust contains heavy. Emissions of PAH depend on the coating material used. The total energy input for this process is between 2300 and 2700 MJ per Mg of steel producer of which 1250–1800 MJ/Mg is from electricity. The oxygen demand is 24–47 m^3 /Mg steel [6]

2.7 Furnace operations

The electric arc furnace operates as a batch melting process producing batches of molten steel known "heats". The electric arc furnace operating cycle is called the tap-to-tap cycle and is made up of the following operations. [16]

- Furnace charging
- Melting
- Refining
- De-slagging
- Tapping
- Furnace turn-around

Modern operations aim for a tap-to-tap time of less than 60 minutes. Some twin shell furnace operations are achieving tap-to-tap times of 35 to 40 minutes.

2.8 Storage and handling of raw materials

Figure 13. Storage and handling of raw materials [5]

Scrap metal is stored normally outside on large, uncovered and often unpaved ground as shown in figure 13. The ferrous scrap metal is loaded into baskets by magnets or grabs. Scrap is purchased based on specific international specifications which minimise non-metallic inclusions. The handling minimises any rogue non-magnetic material like stones, wood or non-ferrous. Depending upon the types and qualities of scrap being processed, handling operations may also lead to inorganic (dust) and organic emissions under certain weather conditions. Some types of scrap may also give rise to noise emissions during handling. Some scrap sorting is carried out to reduce the risk of including hazardous contaminants. The scrap may be loaded into charging baskets in the scrapyard. In some cases, the scrap is preheated in a shaft or on a conveyor. With the single shaft furnace, at least 50 % of the scrap can be preheated. A double shaft furnace which consists of two identical shaft furnaces (a twin shell arrangement). The scrap is partly preheated by off-gas and partly by side wall burners. A very efficient shaft furnace design is the finger shaft furnace. The finger shaft design uses a unique scrap retaining system with fingers which allow the preheating of 100 % of the scrap amount. The first basket is preheated during the refining of the previous heat and the second during meltdown of the first one. Scrap can be preheated to a temperature of approximately 800 °C prior to the final melting in the furnace vessel.

2.9 Refractory

Any material can be portrayed as a "refractory" on the off chance that it can withstand the Activity of grating and at high temperatures. The different blends of working conditions, in which refractories are utilized, make it important to make a scope of recalcitrant materials with diverse properties. Headstrong materials are made in changing blends and shapes relying upon their applications. [24] These materials should

- ✓ Can bear high temperatures
- ✓ Can able to bear sudden changes of temperatures
- ✓ Withstand activity of liquid metal slag, glass, hot gasses, and so forth
- ✓ Withstand load at administration conditions
- ✓ Withstand burden and grating powers
- ✓ Conserve heat
- ✓ Have low coefficient of warm development

Melting point

Unadulterated substances soften in a split second at a particular temperature. Most stubborn materials comprise of particles fortified together that have high dissolving temperatures. At high temperatures, these particles dissolve and form slag.[18] The softening purpose of the obstinate is the temperature at which a test pyramid (cone) neglects to bolster its own particular weight.

Size

The size and state of the refractories is a piece of the outline of the heater, since it influences the strength of the heater structure. Precise size is critical to legitimately fit the headstrong shape inside the heater and to minimize space between development joints.

Bulk density

The mass thickness is valuable property of refractories, which is the measure of hard-headed material inside of a volume (kg/m3). An increment in mass thickness of a given unmanageable expands its volume dependability, heat limit and imperviousness to slag infiltration.

Porosity

The clear porosity is the volume of the open pores, into which a fluid can enter, as a rate of the aggregate volume of the stubborn. This property is critical when the headstrong is in contact with liquid charge and slag. A low obvious porosity keeps liquid material from infiltrating into the headstrong. An expansive number of little pores is for the most part wanted to a little number of huge pores.

Cold crushing strength

The chilly pulverizing quality is the resistance of the stubborn to smashing, which for the most part happens amid transport. It just has a roundabout pertinence to unmanageable execution, and is utilized as one of the markers of scraped area resistance. Different pointers utilized are mass thickness and porosity.

Pyrometric cones and Pyrometric cones equivalent (PCE)

The "stubbornness" of (obstinate) blocks is the temperature at which the hard-headed twists on the grounds that it can no more bolster its own particular weight. Pyrometric cones are utilized as a part of artistic commercial enterprises to test the unmanageability of the (headstrong) blocks. They comprise of a blend of oxides that are known not at a particular restricted temperature range. Cones with diverse oxide organization are set in grouping of their dissolving temperature nearby a line of stubborn blocks in a heater. The heater is terminated and the temperature rises. One cone will twists together with the recalcitrant block. This is the temperature range in oC above which the hard-headed can't be utilized. This is known as Pyrometric Cone Equivalent temperatures. [7]

Creep at high temperature

Creep is a period subordinate property, which decides the misshaping in a given time and at a given temperature by a stubborn material under anxiety.

Effect on Volume at high temperatures

The constriction or extension of the refractories can happen amid administration life. Such lasting changes in measurements may be because of:

- ✓ The changes in the allotropic structures, which cause an adjustment in particular gravity
- ✓ A compound response, which delivers another material of modified particular gravity
- ✓ The arrangement of fluid stage
- ✓ Sintering responses
- ✓ Fusion tidy and slag or by the activity of alkalis on fireclay refractories, to shape soluble base alumina silicates.

Thermal conductivity

Warm conductivity relies on upon the substance and mineralogical arrangement and silica substance of the obstinate and on the application temperature. The conductivity more often than not changes with rising temperature. High warm conductivity of a stubborn is attractive when warmth exchanges however brickwork is required. Low warm conductivity is alluring for protection of warmth, as the hard-headed goes about as a cover. Extra protection rations warm yet in the meantime builds the hot face temperature and henceforth a superior quality unmanageable is required. As a result of this, the outside tops of open-hearth heaters are ordinarily not protected, as this could bring about the rooftop to fall. Lightweight refractories of low warm conductivity find more extensive applications in low temperature heat treatment heaters, for instance in cluster sort heaters where the low warmth limit of the unmanageable structure minimizes the warmth put away amid the irregular warming and cooling cycles. Protecting refractories have low warm conductivity. This is normally accomplished by catching a higher extent of air into the structure. A few illustrations are: Naturally happening materials like asbestos are great protectors yet are not especially great refractories. [7]

Table 1:Melting point of metals.

KEY MATERIALS	**MELTING TEMPERATURES (°C)**
Iron	1530
Nickel	1452
Copper	1083
Aluminum	659
Zinc	419

Table 2: Melting point of pure compound.

Compounds	**Melting point (℃)**
MgO (pure)	2800
CaO(limit)	2571
SiC pure	2248
MgO (90-95%)	2193
Cr2O3	2138
Al2O3(pure sintered)	2050
Fireclay	1871
SiO2	1715

Acidic refractories

Acidic refractories comprise of basically acidic materials like alumina and silica. They are not influenced by acidic materials, but rather effectively influenced by fundamental materials. They incorporate substances, for example, silica, alumina, and flame mud block refractories. Eminent reagents that can assault both alumina and silica are hydrofluoric corrosive, phosphoric corrosive, and fluorinated gasses. At high temperatures, acidic refractories might likewise respond with limes and essential oxides.

High alumina refractories

Alumina silicate refractories has more than 45 percent alumina are by and large termed as high alumina materials. The alumina fixation ranges from 45 to 100 percent. The recalcitrance of high alumina refractories increments with expansion in alumina rate. The uses of high alumina refractories incorporate the hearth and shaft of impact heaters, earthenware furnaces, bond ovens, glass tanks and pots for liquefying an extensive variety of metals.

Silica brick

Silica block (or Dinas) is an unmanageable that contains no less than 93 percent SiO_2. The crude material is quality rocks. Different evaluations of silica block have discovered broad use in the iron and steel softening heaters and the glass business. Notwithstanding high combination point multi-sort refractories, other vital properties are their high imperviousness to warm stun (spalling) and their high hard-headedness. The extraordinary property of silica block is that it doesn't start to diminish under high loads until its combination point is drawn closer. This conduct stands out from that of numerous different refractories, for instance alumina silicate materials, which start to circuit and crawl at temperatures significantly lower than their combination focuses. Different points of interest are flux and stag resistance, volume strength and high spalling resistance.

Neutral refractories

These are utilized as a part of ranges where slags and environment are either acidic or essential and are artificially steady to both acids and bases. The primary crude materials have a place with, however are not limited. The regular cases of these materials are alumina (Al_2O_3), chrome (Cr_2O_3) and carbon.

Fireclay refractories

Firebrick is the most widely recognized type of recalcitrant material. It is utilized widely as a part of the iron and steel industry, nonferrous metallurgy, glass industry, ceramics ovens, bond industry, and numerous others. Table 3 demonstrates that the dissolving point (PCE) of fireclay block diminishes with expanding polluting influence and diminishing Al_2O_3. This material is frequently utilized as a part of heaters, ovens and stoves in light of the fact that the materials are generally accessible and moderately modest.

Table 3. Properties of typical fireclay bricks (Energy Efficiency Guide for Industry in Asia)

Brick type	**Percentage SiO_2**	**Percentage Al_2O_3**	**Percentage other constituents**
Super Duty	49-53	40-44	5-7
High Duty	50-80	35-40	5-9
Intermediate	60-70	26-36	5-9
High Duty (Siliceous)	65-80	18-30	3-8
Low Duty	60-70	23-33	6-10

Oxide refractories (Alumina)

Alumina unmanageable materials that comprise of aluminium oxide with little hints of debasements are known as immaculate alumina. Alumina is a standout amongst the most synthetically stable oxides known. It is mechanically extremely solid, insoluble in water, super warmed steam, and most inorganic acids and alkalis. Its properties make it suitable for the moulding of cauldrons for intertwining sodium carbonate, sodium hydroxide and sodium peroxide. It has a high resistance in oxidizing and diminishing climate. Alumina is widely utilized as a part of warmth handling commercial ventures.

Basic refractories

These are utilized on regions where slags and climate are fundamental; they are steady to basic materials however could respond with acids. The fundamental crude materials fit in with the RO gathering to which magnesia (MgO) is an exceptionally normal case. Different samples incorporate dolomite and chrome-magnesia. For the first 50% of the twentieth century, the steel making procedure utilized counterfeit percales (cooked magnesite) as a covering material for the heater.

Chromite refractories

Two sorts of chromite refractories are recognized: Chrome-magnesite refractories which for the most part contain 16-35% Cr_2O_3 and 42-50 % MgO. They are made in an extensive variety of characteristics and are utilized for building the basic parts of high temperature heaters. These materials can withstand destructive slags and gasses and have high hard-headedness. Magnesite-chromite refractories almost have 62% MgO and 9-20% Cr_2O_3. They are suitable for administration at the most noteworthy temperatures and for contact with the most essential slags utilized as a part of steel softening.

Zirconia refractories

Zirconium is crucial to balance out it before application as a hard-headed, which is accomplished by fusing little amounts of calcium, magnesium and cerium oxide, and so on. Its properties depend for the most part on the level of adjustment, amount of stabilizer and nature of the first crude material. Zirconia refractories have a high quality at room temperature, which is kept up to temperatures as high as 15000 C. They are in this manner valuable as high temperature development materials in heaters and ovens. The warm conductivity of zirconium dioxide is much lower than that of most different refractories.

Magnesite

Magnesite refractories are synthetically fundamental materials, containing no less than 85 percent magnesium oxide. Great quality magnesite as a rule results from a CaO-SiO_2 proportion of fewer than two with a base ferrite focus, especially if the heaters lined with the obstinate work in oxidizing and diminishing conditions. The slag resistance is high especially to lime and iron rich slags.

2.10 Form of refractories

Refractories can be distinguished on the basis of chemical composition, end use and methods of manufacture as shown below.

Classification of refractories based on chemical composition

Table 4: Classification of refractories based on chemical composition [20]

Classification method	Examples
Chemically	
ACID which combines with bases	Silica, Semisilica, Aluminosilicate
BASIC which consists of metallic oxides	Dolomite, Magnesite, etc
NEUTRAL which neither or nor combine with acids or bases	Pure Alumina, Fireclay bricks, etc
Special	Silicon Carbide, Carbon etc

Method of manufacture	Dry press process, hand moulded, fused cast, chemically bonded etc

Monolithic

Monolithic are one piece casts in the shape of equipment such as a ladle. They are quickly replacing the old type fired refractories in many applications including industrial furnaces. The main advantages of monolithic are. Special skill for installation not required, faster application method, Elimination of joints which is an inherent weakness, Considerable scope to reduce inventory and eliminate special shapes, heat savings, better spalling resistance, greater volume stability. Monolithic are used as ramming, casting etc.

Insulating materials

Protecting materials extraordinarily lessen the warmth misfortunes through dividers. Protection is accomplished by giving a layer of material with low warmth conductivity between the interior hot surface of a heater and the outer surface, along these lines keeping the temperature of the outside surface low. Protecting materials may be arranged into the accompanying gatherings. Insulating blocks, Insulating castables, Ceramic fibre, Calcium silicate, Ceramic covering Insulating materials owe their low conductivity to their pores while their warmth limit relies on upon the mass thickness and particular warmth. Air protecting materials comprise of moment pores loaded with air, which have a low warm conductivity. Over the top warmth influences all protection material unfavourably, yet at what temperatures this happens shifts broadly. In this manner the decision of a protecting material must be founded on its capacity to oppose heat conductivity and on the most elevated temperature it will withstand. A standout amongst the most broadly utilized protecting materials is diatomite, otherwise called kiesel guhr, which comprises of a mass of skeletons of moment sea-going plants stored a great many years prior on the beds of oceans and lakes. Its synthetic piece is silica polluted with earth and natural matter. An extensive variety of protecting refractories with wide blends of properties is currently accessible.

Castables and concretes

Solid linings of heater segments can be developed by throwing stubborn protecting cements, and stamping lightweight totals into spot that are suitably reinforced. Different applications incorporate the bases of passage oven autos utilized as a part of the artistic business. The fixings are like those protection materials utilized for making piece refractories, aside from that cements contain either Portland or high-alumina concrete.

2.11 Slag

Slag function in Steelmaking:

Cover the circular segments in the EAF and LF and shield the refractories from bend flare.

- ✓ Improve the nature of the steel by engrossing deoxidation items (SiO_2, Al_2O_3) and incorporations (clean the steel)
- ✓ Dephosphorize in the heater and desulfurize in the spoon
- ✓ Protect the metal from oxidation
- ✓ Protect the metal from nitrogen and hydrogen assimilation
- ✓ Insulate the steel to minimize heat misfortune
- ✓ Be completely good with the unmanageable covering

Low quality of slag

- ✓ Do nothing to enhance the nature of the steel
- ✓ Be inconsistent with the unmanageable holder and break up it to fulfil its answer prerequisites.
- ✓ A "terrible" spoon slag contain an expansive extent of reducible oxides (FeO and MnO) that will respond with the steel to bring about Al, Si, and Mn blurring Where slags come and how is the slag shaped - The building squares of slag.

The organization of a slag is typically communicated as far as the part oxides (or fluorides) on a weight percent premise. For instance a slag could have the accompanying systems

CaO wt%	55
SiO_2 wt%	20

MgO wt%	8
Al_2O_3 wt%	12
CaF_2 wt%	5

Source of These component

CaO Lime (CaO 98 %)

Dolomite (CaO 58 % & MgO 39 %)

Ca Aluminate (45% CaO 45% & Al_2O_3 53%)

Refractories dolomite

MgO Dolomite (CaO 58 % & MgO 39 %)

Magnesia (MgO 92%)

Refractories Mag-C and Dolomite

SiO_2 Si in the scrap ($Si + O_2 = SiO_2$)

Steel deoxidation

Refractories (High Alumina)

Al_2O_3 Al in the scrap ($2Al + 3/2O_2 = Al_2O_3$)

Steel deoxidation ($3O + 2Al = Al_2O_3$)

Ca-Aluminate (CaO 45% & Al_2O_3 53%)

Bauxite (>82% Al_2O_3)

Refractories (High Al_2O_3)

FeO Scrap ($2Fe + O_2 = 2FeO$)

MnO Scrap ($2Mn + O_2 = 2MnO$)

Steel deoxidation (O + Mn = MnO)

CaF_2 - Fluorspar (CaF_2 90%)

Example

Slag composition in a furnace by a mass-balance approach

Consider the following additions to a furnace: [12]

Table 5: Flux composition

	Amount(kg)	% CaO	% MgO	% Al_2O_3
Lime	600	100		
Dolomite	600	60	40	
Ca-Aluminate	400	45		55
Al (100%)	440			

(Conversion factor for Al to Al_2O_3 is 1.89)

CaO Contributions

Lime:	600 x 1	= 600
Dolomite:	600 x 0.6	= 360
Ca-Aluminate:	500 x 0.45	= 225
		1185kg

MgO Contributions =

Dolomite:	600 x 0.4	**240kg**

Al_2O_3 Contributions

Ca-Aluminate:	400 x 0.55	= 220
Deoxidation	440 x 0.75 x 1.89	= 623
		843kg

Total Slag Amount: 1185 + 240 + 843 = 2268kg

% CaO = 1185/2268 x 100 = **54.2**

% MgO = 240/2268 x 100 = **10.9**

% Al_2O_3 = 843/2268 x 100 = **34.8**

Slag basicity

Basicity Index for oxidized slags (B_3)

$$B3 = \frac{\%CaO}{\%SiO_2 + \%Al_2O_3}$$

Basicity Index for reduced slags (B_5)

$$B_5 = \frac{\%\ \text{Total basic components}}{\%\ \text{Total acidic components}} = \frac{\%CaO + \%MgO}{\%SiO_2 + \%Al_2O_3 + \%CaF_2}$$

It is normal to additionally add FeO and MnO to the acidic parts in the B5 proportion, gave that their aggregate (FeO + MnO) is under 5%. [4]

A balanced slag ("creamy") –

Ideal for refractory protection and metallurgical requirements as shown in figure 14.

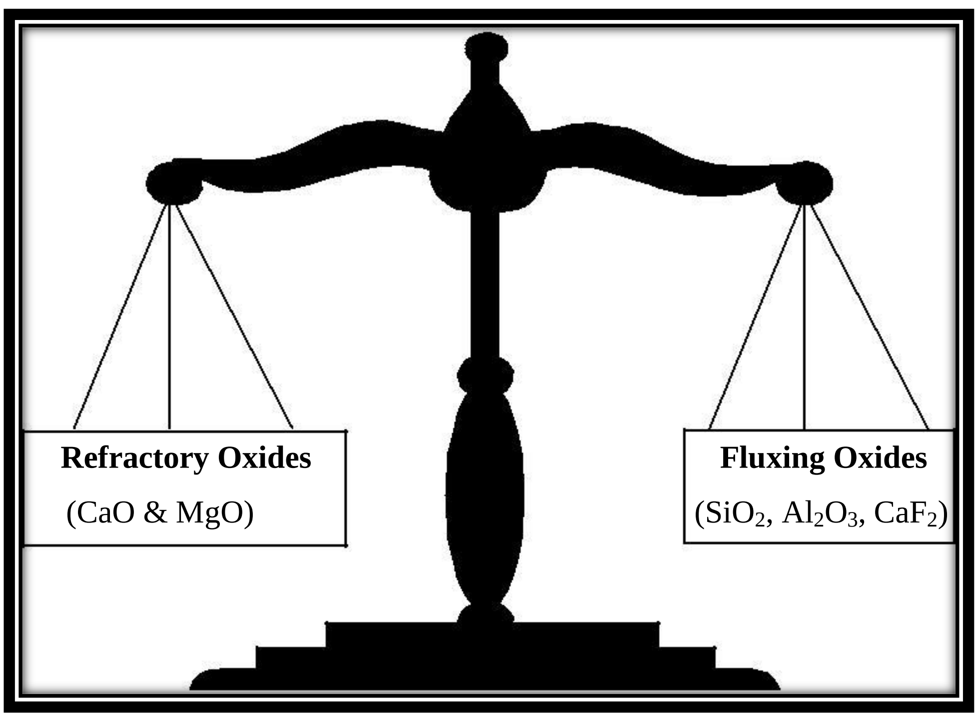


Figure 14. Example of balanced slag by Baker Refractories

The addition of too much CaO and MgO –

Slag too stiff or solid - little metallurgical benefit. Little or no refractory protection as shown in figure 15.

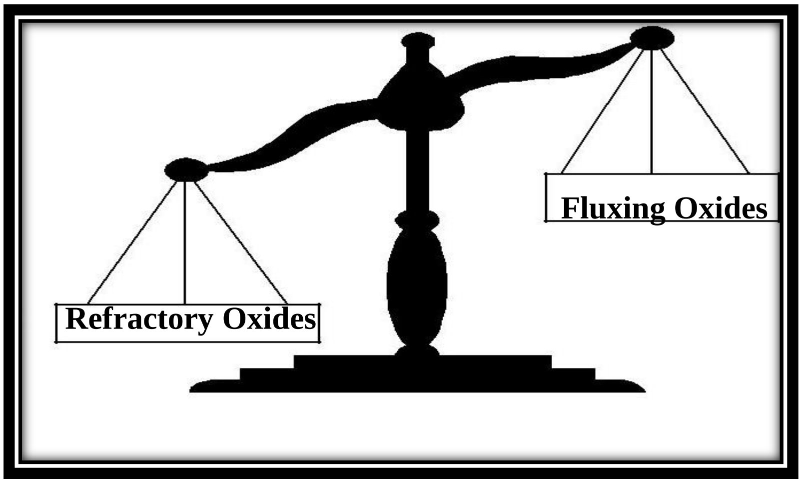


Figure 15. Example of too much CaO and MgO by Baker Refractories

The addition of too little CaO and MgO -

Slag too fluid - little metallurgical benefit, very aggressive toward refractory as shown in figure 16.

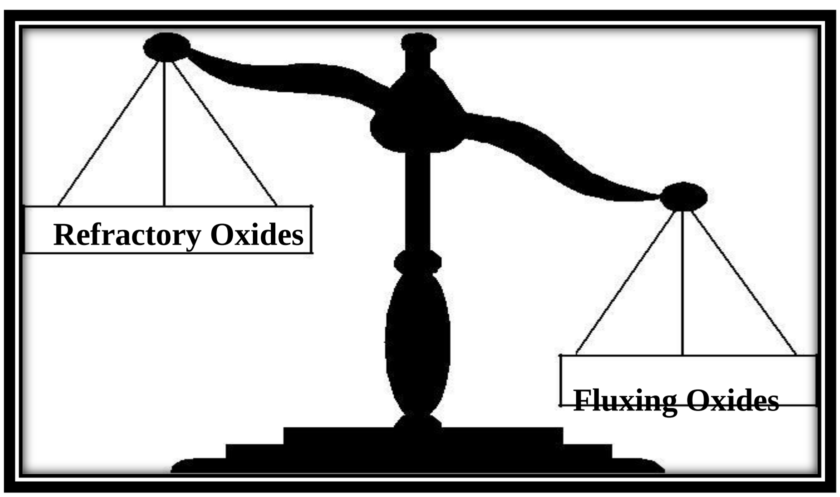


Figure 16. Example of too little CaO and MgO by Baker Refractories

Generally **minimum** B_5 basicity ratio of 1.5 is required (60% refractory oxides and 40% fluxing oxides) to obtain a good furnace slag.

Classification of Slag

Dried up - Too much CaO (and/or MgO)

Soft - CaO/MgO soaked, Ok for refractories however not ideal for desulfurization

Rich - Just CaO/MgO soaked, good for steelmaking and refractories (Ideal)

Watery - Too fluid, forceful to the refractories

The accompanying disentangled stage outline of the CaO-Al2O3 framework can be utilized to characterize the consistency (thickness) of slags.

3. CASE STUDY AND COST & EFFICIENCY CALCULATIONS

3.1 Ideal Condition

The efficiency of a furnace can be determined by measuring or calculating melting time for steel through Power Consumption.

Standard power consumption for steel induction furnace is 625 kWh/ton.

Power consumption at standard kw/kg ratio for some metal as per follow:

Cast Iron melting: 550-600 kWh/ton.

SG Iron melting: 550-650 kWh/ton.

MS/SS melting: 600-680 kWh/ton.

Aluminium melting: 650-700 kWh/ton.

Abbas Steel group almost produce 300tons billets per day in two shifts

So 300/16 =1.875 ton/h at the recovery of almost 100%.

=1.875 ton/h (Finished Product)

Required Power = (1.875 ton/h) x 625 kWh//ton

= 11,718.75 kW

Melting rate for steel at 11,718.75 kW can be calculated using following methods

$$\frac{\text{Power kW}}{\text{Weight of metal in ton}} = \frac{\text{Standard Power Consumption of Induction furnace}}{\text{ton}}$$

If the nominal capacity of steel Induction furnace is 1.875 ton & selected Induction Power supply is 11718.75 kW then melting time to melt 1.875 ton of steel at 11718.75kW can calculated

11718.75kW x Time/1.875ton = 625kWh/ton

Time = 1 h

Electricity cost calculation

Electricity rate at 15 PKR /kW.

In 1 h = 11718.75 kW power required to produce 18750 kg (1.87 ton) molten metals.

= 11718.75/h x 16 h

= 187500 power for 1 day

Molten metal required = 18750kg x 16 h

= 300 ton

625 kW for 1 ton = 625 x 15

= 9375 PKR /ton/120

= 78.125 **€**

Key performance indicators (time, cost, machining life)

Before change (TIME, COST)

The efficiency of a furnace of Abbas Steel with Acidic lining is determined with following calculations.

Abbas Steel group almost produce 300ton billets per day in two shifts

So 300/24 =12.5 ton/h with the recovery of Scrap at 66% so 456 ton Scrap/24 h used to get 300 ton finished products.

=1.25 ton/h (End Product)

Required Power = (1.9ton/h) x 625kWh/1000kg

= 11,875kw

Melting rate for steel at 11,875 kW can be calculated using following methods

$$\frac{\text{Power kW}}{\text{Weight of metal in ton}} = \frac{\text{Standard Power Consumption of Induction furnace}}{\text{ton}}$$

If the nominal capacity of steel Induction furnace is 1.25ton & selected Induction Power supply is 11,875 kW then melting time to get 1.25ton of steel at 11,875 kW can be calculated

11,875kW /1.25ton = Time x 625 kW (1 hr)/ton

Time = 1.35 h

Electricity cost calculation

Electricity rate at 15 PKR/kW.

In 1 hour = 11875 kW power required to produce (19 ton) molten metals.

= 11875/h x 24

= 285000 power for 1 day

Molten metal required = 1.25ton x 24 h

= 300 ton

Therefore,

285000/300 = 950 kW/ton

= 950 x 15

= 14250 PKR/ton

1 € at 120 PKR

= 14250/120

= 118.75 € /ton

According to this situation consumption of Scrap & Electricity for One month.

Table 6. Showing Scrap & Electricity Consumption

TIME (t)	SCRAP (HMS+SHREDDED+LMS) (ton)	FINISHED (ton)	ELECTRICITY at 625 (kWh/ton)
Per hour	19	12.5	11,875 kW
Per day/24hours	456	300	285,000 kW
Per Month	13,680	9,000	8,550,000 kW

Cost of Scrap = 13,680 x 30,000

= 410400000 PKR/120

= 3,420,000 €

Electricity Cost = 8,550,000 x 15 PKR

= 128,250,000 PKR/ 120

= 1,068,750 €

3.2 Effect on energy consumption before changing process.

Before Changed process (With Induction Furnace) as mention in figure 17.

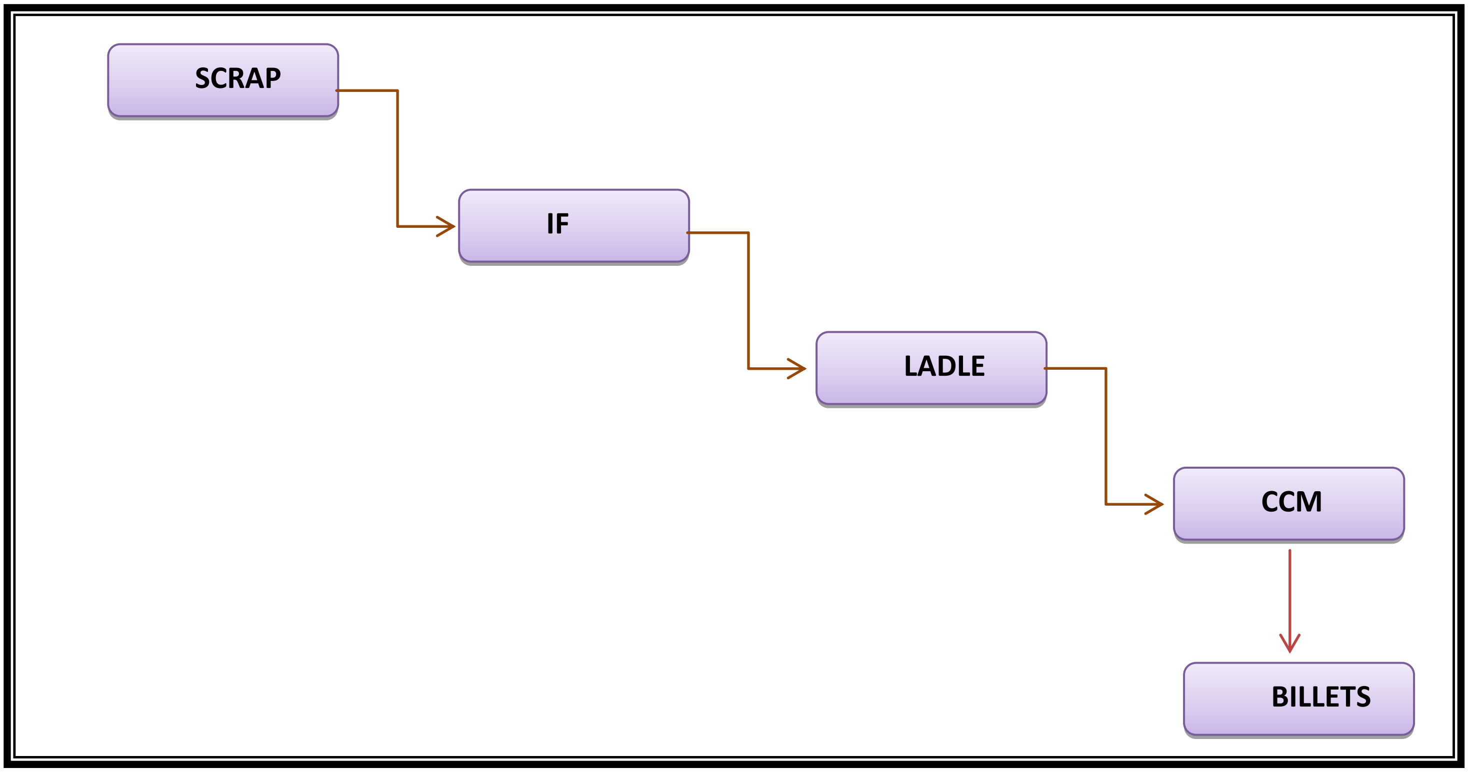


Figure 17. Steel Manufacturing Process Steps

In One hour the Electric consumption is 625 kW for 19 tons Scraps to melt it at the temperature of 1640 C.

So, for One day in 24h two shifts 456 tons Scraps are used which consumed 285,000 kW.

So, for One month

13,680 tons Scraps are used and consumed electricity 8,550,000 kW.

= 8,550,000 x 15

= 128,250,000 PKR/120

= 1,068,750 €

Calculation of Billets

Cross Sectional Area	=	width x thickness	= mm^2
Mass per metre	=	A (mm^2) x 0.00785	= kg/m
Metres/ton	=	1000/kg/m	= metres [19][9]

Weight of Billet = Cross section area x density

= L x B x H x density

= 6000 x 100 x100 x 0.00785/1000

= 0.471 ton/6 m

Before change **(Acidic Lining)**

19000 kg Scrap (per hour) = 1.254 ton (Finished product at the recovery of 66%)

= 1.254/0.471

= 26.6 billets/ h

In 720 hours (One Month) = 720 x 12540/471

= 19,169.4 billets

Refractories Cost

Before change (Acidic Lining)

One acidic lining gives around **8** heats

152 ton Scrap metals in **1** lining = **456/152 =3** Lining required for one day.

One furnace required **1.5ton** acidic refractory lining.

Therefore,

9 ton acidic lining used to melt **456 ton** Scraps in one day.

For **30** days **270** ton Lining used to melt **13,680 ton** Scraps.

9 x 6,500 PKR/kg = 58,500 PKR/day

270 x 6500 PKR/kg = 1,755,000 PKR /month/120

= 14,625 €/month

Recovery of molten metal from Slag

Before (Acidic Lining)

Recovery of metals from slag at the recovery rate of 30 %.

Where rejection of molten metals at 34%.

So,

1,368 tons scrap = 1,368 x 34% = 465 ton rejected slags/month

Therefore,

30% of 465 ton = 140 ton/month

140 x 60,000 = 8,400,000 PKR /120

= 700,000 €

465-140 = 325 ton waste

325 x 1000 = 325,000 PKR/120

= 2700 €

Key performance indicators (time, cost, machining life)

After change (time, cost)

The efficiency of a furnace of Abbas Steel with Basic lining is determined with following calculations.

With the use of Basic lining in their furnace Abbas Steel group almost produce 401tons billets per day in two shifts

So 401/24 =16.7 ton/h with the recovery of Scrap at 88% so 456 tons Scrap/24 h used to get 401 tons finished products.

=1.67 ton/h

Required Power = (1.9 ton/h) x 625kWh/ton

= 11,875kW

Melting rate for steel at 11,875 kW can be calculated using following methods

$$\frac{\text{Power KW}}{\text{Weight of metal in ton}} = \frac{\text{Standard Power Consumption of Induction furnace}}{\text{ton}}$$

If the nominal capacity of steel Induction furnace is 1.67ton & selected Induction Power supply is 11,875 kW then melting time to melt 1.67ton of steel at 11,875 kW can calculated

11,875kW /1.67ton = Time x 625kW(1 hr)/1000kg

Time = 1.8 h

Electricity cost calculation

Electricity rate at 15 PKR/kW.

In 1 hour = 11,875 kW power required to produce 19 ton molten metals.

= 11,875/h x 24 h

= 285,000 power for 1 day

Molten metal required = 1.67ton x 24 h

= 400.8ton

Therefore,

285,000/401 = 710 kW/ton

= 710 x 15

=10,650 PKR

1 **€** at 120 PKR

= 10,650/120

= 89 € /ton

According to Current situation consumption of Scrap & Electricity for One month.

Table 7. Showing Scrap & Electricity Consumption

TIME (t)	SCRAP (HMS+SHREDDED+LMS) (ton)	FINISHED (ton)	ELECTRICITY at 625 (kWh/ton)
Per hour	**19**	**16.7**	**11875 kW**
Per day/24h	**456**	**401**	**285000 kW**
Per Month	**13680**	**12038**	**8550000 kW**

Cost of Scrap = 13,680 x 30,000

= 410,400,000 PKR/120

= 3,420,000 €

Electricity Cost = 8,550,000 x 15 PKR

= 128,250,000 PKR/ 120

= 1,068,750 €

3.3 Effect on energy consumption after changing process

After Changed process (With Induction Furnace + LADLE REFINING FURNACE) as mention in figure 18.

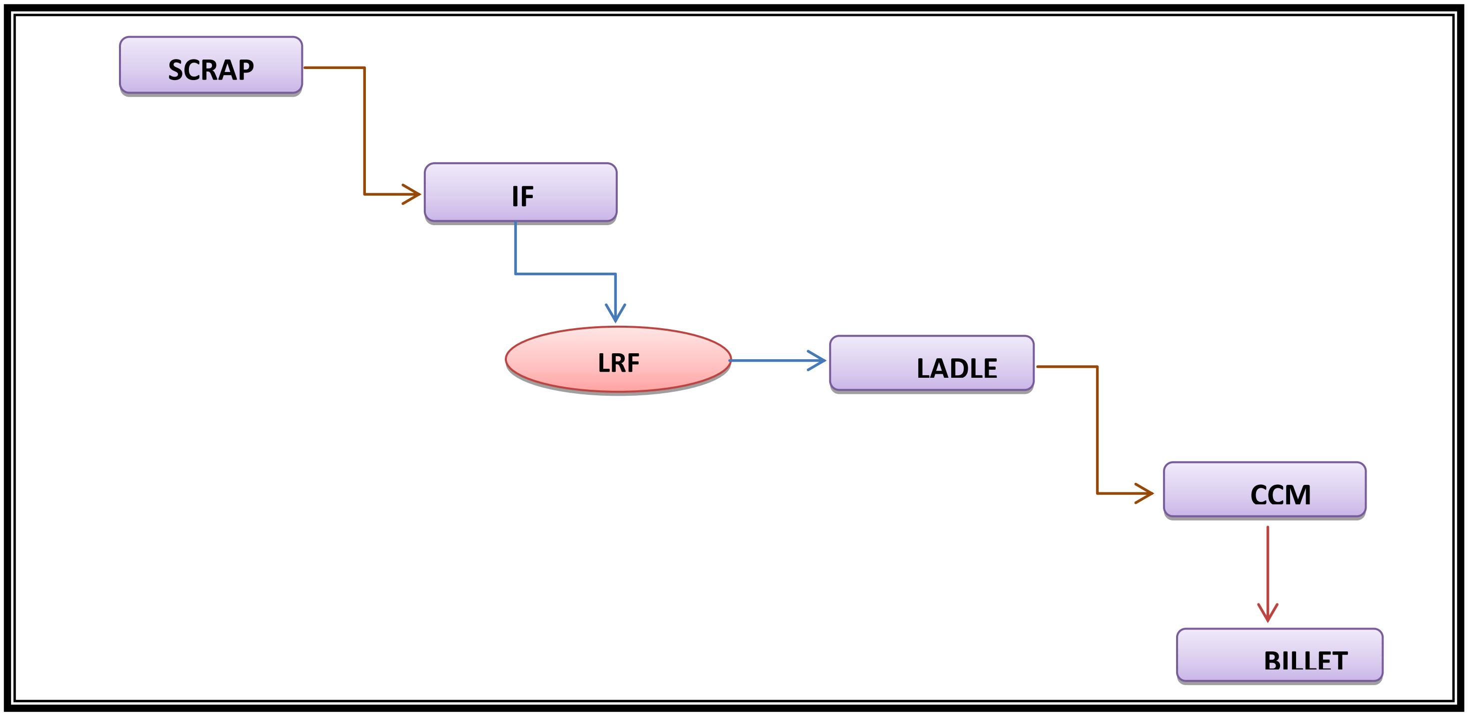


Figure 18. Steel Manufacturing Process Steps

According to the experiment we take out molten metals from Induction Furnace at the temperature of 1380 to 1400C at the electric consumption of 450 to 480 kW in One hour for 19 ton Scraps.

After tapping molten metals from Induction furnace it will transport to ladle refining furnace which takes 80kW to increase the molten metals temperature from 1400C to 1630 to 1640 ^{0}C.

Electricity(IF + LRF) = 480 + 80

= 560 kW

= 13,680 x 560

= 7,660,800 kW/month

= 7,660,800 x 15

= 114,912,000 PKR/120

= 957,600 €

Calculation of billets

Cross Sectional Area	=	width x thickness	= mm^2
Mass per metre	=	A (mm^2) x 0.00785	= kg/m
Metres/ton	=	1000/kg/m	= metres [19][9]

Weight of billet = Cross section area x density

= L x B x H x density

= 6000 x 100 x100 x 0.00785/1000

= 0.471 ton/6 m

As it is (Basic Lining)

1.9ton Scrap (per hour) = 1.67ton (Finished product at the recovery of 88%)

= 16700/471

= 35.4 billets/h

So, in 720 hours (One Month) = 720 x 16700/471

= 25,528.6 billets/month

Refractories cost

After Change (Basic Lining)

One acidic lining gives around **14** heats

266 ton Scrap metals in **1** lining **= 456/266 =1.7** Lining required for one day.

One furnace required **1.5**ton basic refractory lining.

Therefore,

5 ton acidic lining used to melt **456** ton Scraps in one day**.**

For **30** days **150** ton lining used to melt **13,680** ton Scraps**.**

5 x 8500 PKR/kg = 42,500 PKR/day

150 x 8500 PKR/kg = 1,275,000 PKR/month/120

= 10,625 € /month

Recovery of molten metal from Slag

After change (BASIC)

Recovery of metals from slag at the recovery rate of 30 %.

Where rejection of molten metals at 12%.

So,

1,368 ton scrap = 1368 x 12% = 165 ton rejected slags/month

Therefore,

30% of 165 ton = 50 ton/month

50 x 60,000 = 3,000,000 PKR /120

= 25,000 €

165-50 = 115 ton waste

115 x 1000 = 115,000 PKR/120

= 958 €

Recovery of molten metal from slag (Basic + LRF)

Recovery of metals from slag at the recovery rate of 30 %.

Where rejection of molten metals at 12%.

1,368 ton scrap = 1,368 x 12% = 165 ton rejected slags/month

Therefore,

30% of 165 ton = 50 ton/month

50 x 60,000 = 3,000,000 PKR /120

= 25,000 €

165-50 = 115 ton waste

115 x 1000 =115000 PKR/120

= 958 €

3.4 Cost comparison

Table 8: Shows Cost Comparison with Acidic Lining

S.NO	Cost Comparison for 1 Month(30 days)			Selling Price(PKR)/ton	
		EXPENSE			
	Utilities/Materials	**ACIDIC**			
		PKR	**€**	**PKR**	**€**
1	Electricity(8,550,000 kW)	128,250,000	1,068,750	60,000 x 9,000	500 x 9,000
2	Scrap(13,680 tons)	410,400,000	3,420,000		
3	Ferroalloys(216 tons)	34,560,000	288,000		
4	Fluxes(400 tons)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	27,000,000	225,000		
7	Refractories(270 tons)	1,755,000	14,625		
8	Man power	40,000,000	333,333		
9	Recovered metal from slag			8,400,000	700,000
10	Waste			325,000	2,700
	SUM	**644,865,000**	**5,373,874**	**548,725,000**	**5,202,700**

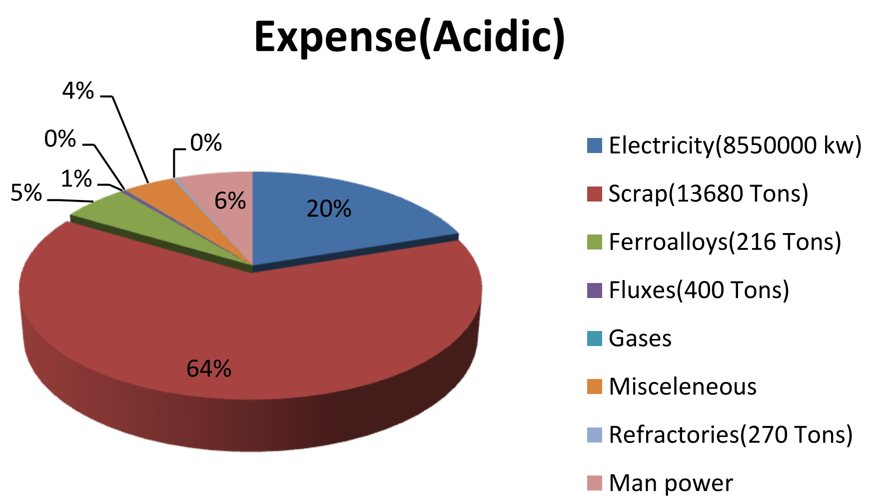


Chart 1: Shows expense in percentage.

Table 9: Shows Cost Comparison with Basic Lining

S.NO	**Cost Comparison for(9000 ton metals) 1 Month(30 days) Basic Lining**			**Selling Price(PKR)/ton**	
	Utilities/Materials	**Basic**			
		PKR	**€**	**PKR**	**€**
1	Electricity(8,550,000 kW)	128,250,000	1,068,750	60,000 x 12038	500 x 12,038
2	Scrap(13,680 ton)	410,400,000	3,420,000		
3	Ferroalloys(180 ton)	28,800,000	240,000		
4	Fluxes(400 ton)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	27,000,000	225,000		
7	Refractories(270 ton)	1,755,000	14,625		
8	Man Power	40,000,000	333,333		
9	Recovered metal from slag			3,000,000	25,000
10	Waste			115,000	958
	SUM	**639,105,000**	**5,325,874**	**725,395,000**	**6,044,958**

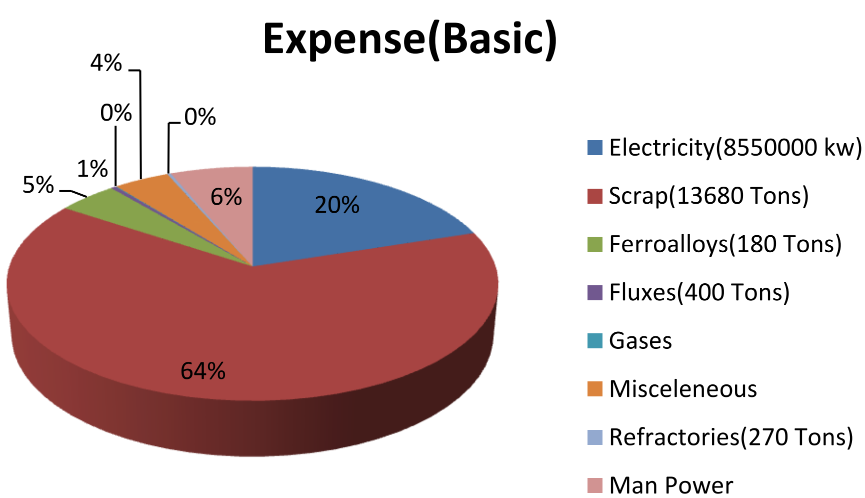


Chart 2: Shows expense in percentage.

Table 10: Shows Cost Comparison with LRF

S.NO	Cost Comparison for(9000 ton metals) 1 Month(30 days)			Selling Price(PKR)/ton	
	Utilities/Materials	BASIC + LRF			
		PKR	€	PKR	€
1	Electricity(7,660,800 kW)	114,912,000	957,600	60,000 x 12,038	500 x 12,038
2	Scrap(13,680 ton)	410,400,000	3,420,000		
3	Ferroalloys(180 ton)	28,800,000	240,000		
4	Fluxes(400 ton)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	54,000,000	450,000		
7	Refractories(270 ton)	1,755,000	14,625		
8	Man Power	40,000,000	333,333		
9	Ladle Refining Furnace	57,750,000	481,250		
10	Recovered metal from slag			3,000,000	
11	Waste			115,000	
	SUM	**710,517,000**	**5,920,974**	**725,395,000**	**6,044,958**

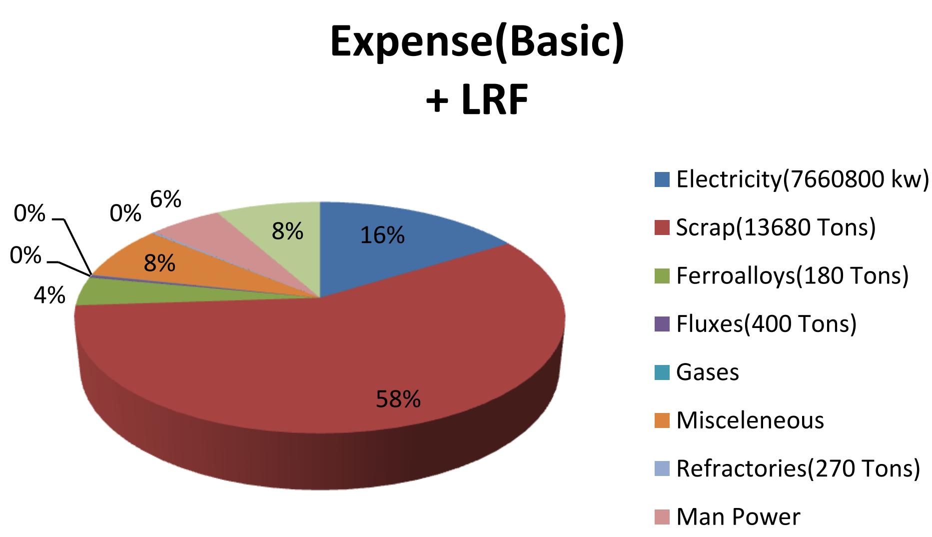


Chart 3: Shows expense in percentage.

3.5 Break event point for ladle refining furnace

Break even in units = Total Fixed Cost/Price – Variable Cost [17]

= 481250/500 – (Electricity, Scrap, Ferroalloys, Fluxes, Gases, Miscellaneous, Refractories, Man Power)

= 481,250/500-(79.5+282+27.73+20+1.6+37.3+1.2)

= 481,250/500- 449.3

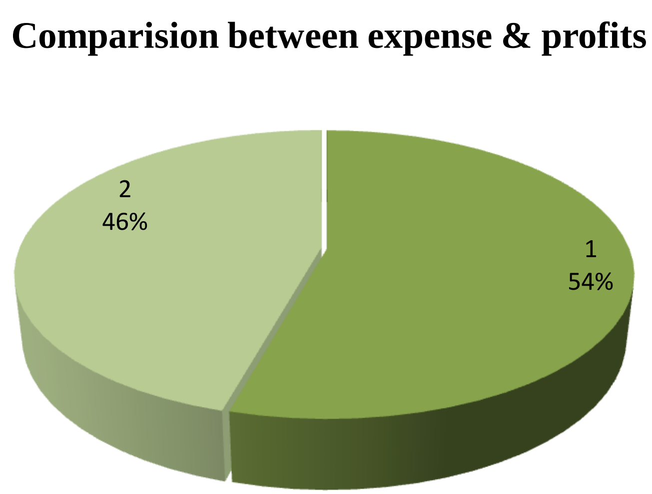
= 9,492 tons/401.2 ton per day

= 23.6 days the amount of Ladle refining furnace recovered

3.6 Expense & profits comparison

Table 11: Shows Expense & Profits Comparison with Acidic Lining

Cost Comparison for 1 Month(30 days)		
	EXPENSE	**Selling Price(PKR)/ton**
Utilities/Materials	**ACIDIC**	**ACIDIC**
	PKR	**PKR**
Electricity(7,660,800 kW)	114,912,000	60,000 x 9,000
Scrap(13,680 ton)	410400000	
Ferroalloys(180 ton)	28,800,000	
Fluxes(400 ton)	2,400,000	
Gases	500,000	
Miscellaneous	54,000,000	
Refractories(270 ton)	1,755,000	
Man Power	40,000,000	
Ladle Refining Furnace		
Recovered metal from slag		8,400,000
Waste		325,000
SUM	**652,767,000**	**548,725,000**



`**Chart 4**: Shows expense & profits in percentage.

3.7 Expenses

Table 12: Shows Expense & Profits Comparison with Basic Lining

Cost Comparison for 1 Month(30 days)		
		Selling Price(PKR)/ton
Utilities/Materials	**BASIC**	**BASIC**
	PKR	**PKR**
Electricity(7,660,800 kW)	128,250,000	60,000 x 12,038
Scrap(13,680 ton)	410,400,000	
Ferroalloys(180 ton)	28,800,000	
Fluxes(400 ton)	2,400,000	
Gases	500,000	
Miscellaneous	27,000,000	
Refractories(270 ton)	1,755,000	
Man Power	40,000,000	
Ladle Refining Furnace		
Recovered metal from slag		3,000,000
Waste		115,000
SUM	**639,105,000**	**725,395,000**

Comparision between expense & profits

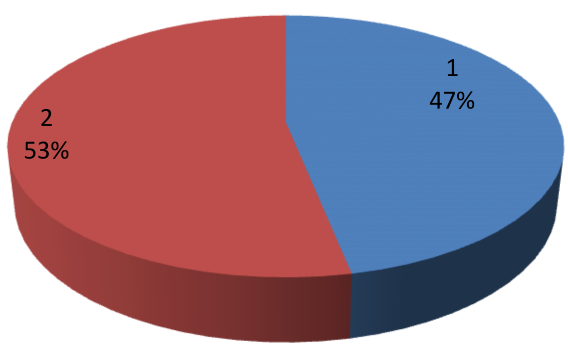


Chart 5: Shows expense & profits in percentage

Table 13: Shows Expense & Profits Comparison with Basic & LRF Furnace

Cost Comparison for 1 Month(30 days)		
		Selling Price(PKR)/ton
Utilities/Materials	**BASIC + LRF**	**BASIC + LRF**
	PKR	**PKR**
Electricity(7,660,800 kW)	114,912,000	60,000 x 12,038
Scrap(13,680 ton)	410400000	
Ferroalloys(180 ton)	28,800,000	
Fluxes(400 ton)	2,400,000	
Gases	500,000	
Miscellaneous	54,000,000	
Refractories(270 ton)	1,755,000	
Man Power	40,000,000	
Ladle Refining Furnace	57,750,000	
Recovered metal from slag		3,000,000
Waste		115,000
SUM	**710,517,000**	**725,395,000**

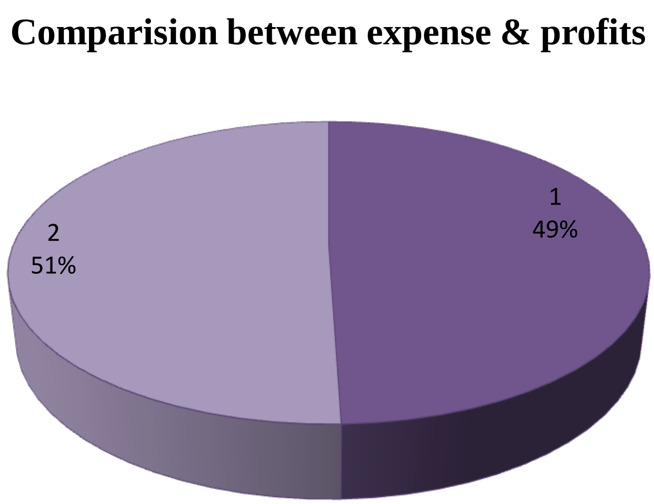


Chart 6: Shows expense & profits in percentage

3.8 Analysis and solution development

This project was completed within the span of six months. The author was given the task by the management of Abbas steel to analyse the factors which affects the production process and production lost and also proposed an analytical solution for the betterment of facing issues.

Author follows the following procedure to analyse the problem causing factors.

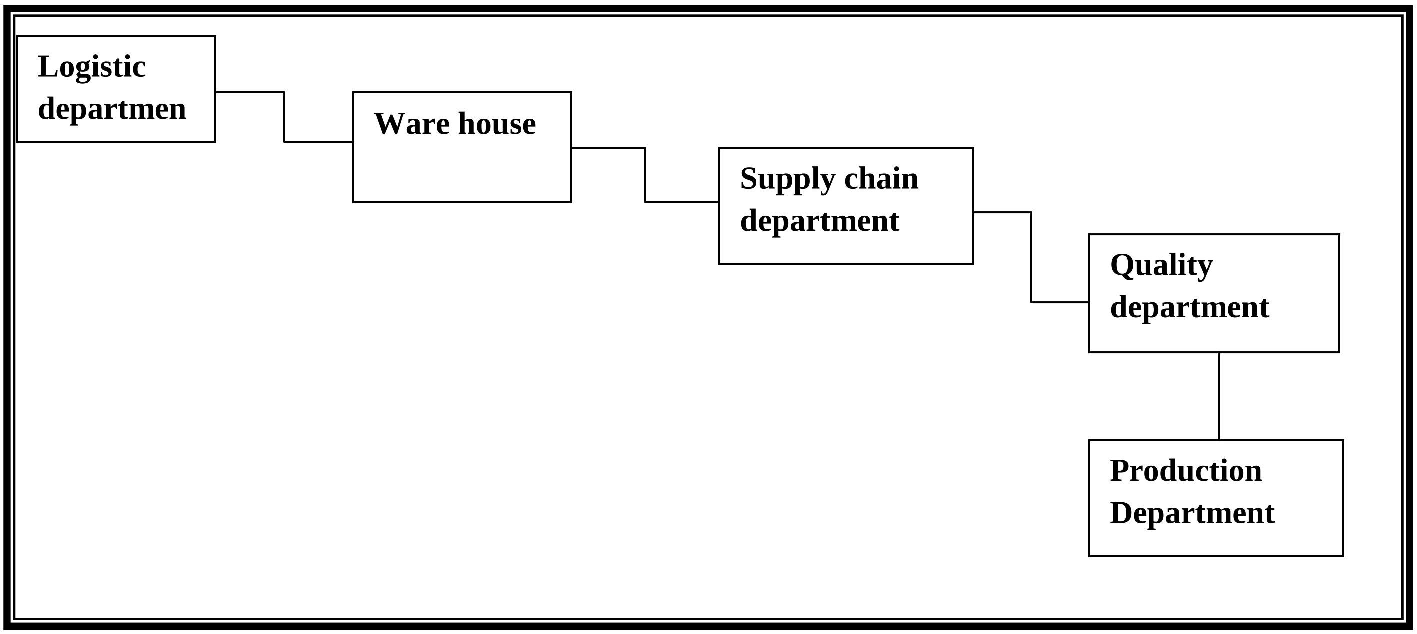


Figure 19. Author's studies areas of Abbas steel

Author started investigation step by step from one department to another department. After gathering the reports in logistic department for previous couple of months and thoroughly studied the all procedure which was followed by Abbas steel group. It was concluded that Abbas steel follow effective procedure and tools for logistics and there was not any problem which effects on their production lost.

In warehouse the condition of all the spare parts and accessories thoroughly checked. The study was also focused on Abbas steel inventory level and analysed all the facts and figures to verify the efficiency and effectiveness of the information system of Abbas steel and author didn't find any issue regarding warehouse.

Further move on to the supply chain management Abbas steel has particular infrastructure for the supply chain management. They are following standard route for the sourcing, multiple sourcing and using fast and effective systems. So they are not facing problems related to raw materials, spare parts and other required accessories etc.

Author's next concerned was quality department where Abbas steel is following standard equipment for the quality of products. For the production of low carbon steel the composition of different elements like carbon content, manganese, sulphur and silicon contents are most important to analyse the content of these elements and they have good laboratory with highly advance equipment's like spectrometer by which they inspect the elements contents and adjust it with the desire level.

Next was production department which was of great concerned for finding out the reasons of issues to get deep technical knowledge of all equipment which is being used in the production department. Here author analyses each and every furnace and all the equipment which were using in the production department. The greater concerned was furnaces like induction furnace, ladle furnace, tundish and continuous caster. After couple of months analysing the production process, production flow, view the production reports and concerned with the technical people from technical department and finally author come to the conclusion that the production level is continuously decreasing. Where Abbas steel was following their own production process and the purpose of having their own production flow is to reduce the cost and increase the production levels.

Solution development

After the investigation and analysis of couple of months author proposed the solution with experiment as well as with proof of calculation.

The proposals are as follows.

- ✓ Abbas steel should use basic refractories like chrome-magnesite and magnesium oxide instead of using acid refractories because the environment of furnace is basic in nature and they are steady to basic materials however could respond with acids.
- ✓ Production process or production flows should be standard.
- ✓ Proper soughing of steel scrap.

✓ Also the cost and production flow calculation for one month is simulated by arena software to compare the actual improvement without any mistakes.

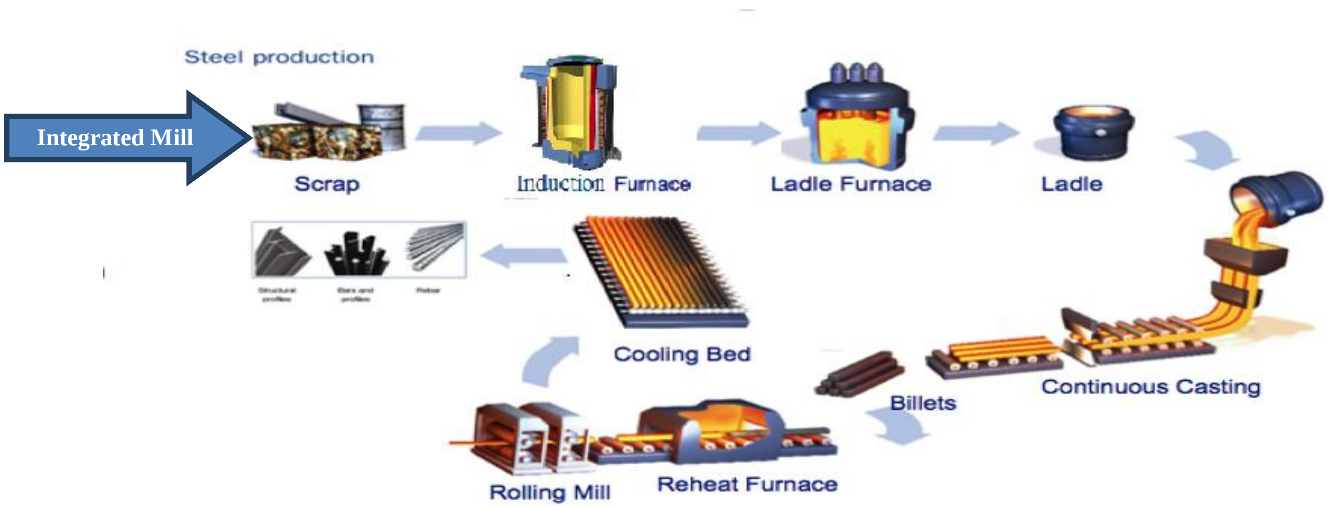


Figure 20: Manufacturing process (Alter Ego 2012)

3.9 Quality

Chemical analysis of a low carbon steel by spectrometer

- C (Carbon)
- S (Sulphur)
- P (Phosphorous)
- Si (Silicon)
- Mn (Manganese)
- Al (Aluminium)
- Cu (Copper)
- Cr (Chromium)
- V (Vanadium)
- Mo (Molybdenum)
- Ni (Nickel)

Carbon equivalent Formula = C + Mn/6 + Si/7

Effect of alloying element in steel

Carbon(C)

The most vital constituent of steel. It raises rigidity, hardness, and imperviousness to wear and scraped spot. It brings down pliability, sturdiness and machinability.

Manganese (Mn)

A deoxidizer responds with sulphur to enhance forge ability. It increments rigidity, hardness, hardenability and imperviousness to wear. It diminishes inclination toward scaling and twisting. It builds the rate of carbon-infiltration in carburizing.

Phosphorus (P)

Builds quality and hardness and enhances machinability. On the other hand, it includes stamped weakness or chilly shortness to steel.

Silicon (Si)

Act as deoxidizer. It expands ductile and yield quality, hardness, forges ability and attractive porousness.

Sulphur (S)

Enhances machinability in free-cutting steels, yet without adequate manganese it produces weakness at red warmth. It diminishes weldability, sway sturdiness and pliability.

Chemical composition of low carbon steel

Table 14: Shows Chemical Composition of low carbon steel (patentimages.storage)

Element	Percent by weight
C	0.20-0.40
Mn	0.5-1.5
Si	0.5-1.5
S	0.05 max
P	0.05 max
Cr	14-18
Ni	2.0-5.0
Cu	2.0-4.0
Mo	1.0 max
Nb	1.5-2.5

Abbas steel products composition

Table 15: Chemical Composition of low carbon steel (Asg metal ltd)

S.No	C%	Si %	Mn %	P %	S %	Carbon Equivalent	Final Grade
1	0.17	0.11	0.31	0.05	0.03	0.24	SAE-1015
2	0.3	0.32	1.26	0.05	0.02	0.56	Grade-60
3	0.33	0.31	1.23	0.05	0.03	0.58	commercial
4	0.22	0.18	0.65	0.037	0.024	0.35	SR24

Table 16: Chemical Composition of low carbon steel(SAE- AISI)

S.No	C%	Si %	Mn %	P %	S %	Grade
1	0.13-0.18	-	0.30-0.60	$\leq$ 0.040	$\leq$ 0.050	SAE-AISI 1015
2	0.28 to 0.34	-	0.6 to 0.9	0 to 0.04	0 to 0.05	SAE-AISI 1030
3	0.32 to 0.38	-	0.7 to 1.0	0 to 0.04	0 to 0.05	SAE-AISI 1037
4	0.18 to 0.23	-	0.6 to 0.9 %	0 to 0.04	0 to 0.05	SAE-AISI 1021

Properties of different grade of low carbon steel

SAE-AISI 1015(SAE-1015) [20]

Density	7.83 g/cm3 (489 lb/ft3
Elastic Modulus	210 GPa (30 x 106 psi)
Elongation at Break	22 to 33 %
Specific Heat Capacity	450 J/kg-K
Strength to Weight Ratio	47 to 54 kN-m/kg
Tensile Strength- Ultimate (UTS)	370 to 420 MPa (54 to 61 x 103 psi)
Thermal Expansion	11.8 µm/m-K

SAE-AISI 1030(Grade-60)

Density	7.80 g/cm3 (487 lb/ft3
Elastic Modulus	210 GPa (30 x 106 psi)
Elongation at Break	15 to 23 %
Specific Heat Capacity	450 J/kg-K
Strength to Weight Ratio	64 to 71 kN-m/kg
Tensile Strength-Ultimate (UTS)	500 to 550 MPa (73 to 80 x 103 psi)
Thermal Expansion	11.9 µm/m-K

SAE-AISI 1037(commercial)

Density	7.79 g/cm3 (486 lb/ft3)
Elastic Modulus	210 GPa (30 x 106 psi)
Elongation at Break	14 to 21 %
Specific Heat Capacity	450 J/kg-K
Strength to Weight Ratio	71 to 78 kN-m/kg
Tensile Strength- Ultimate (UTS)	550 to 610 MPa (80 to 88 x 103 psi)
Thermal Expansion	11.9 µm/m-K

SAE-AISI 1021(SR24)

Density	7.82 g/cm3 (488 lb/ft3)
Elastic Modulus	210 GPa (30 x 106 psi)
Elongation at Break	18 to 27 %
Specific Heat Capacity	450 J/kg-K
Strength to Weight Ratio	58 to 64 kN-m/kg
Tensile Strength- Ultimate (UTS)	450 to 500 MPa (65 to 73 x 103 psi)
Thermal Expansion	11.9 µm/m-K

Elastic Modulus

It is the ratio of stress produce to a body to the resistance produced by the body. To heat treated and work hardened metals it could be same even as ductility drops and strength rises. [20]

Elongation at Break

Elongation at break is some time known as fracture strain. It is the ratio between and initial length and changed length when the breakage of the test specimen done. Elongation at break shows the capacities and capability of a material to withstand changes of shape without cracking. [20]

Specific Heat Capacity

The amount of heat required to raise the temperature of the unit mass of a given materials by a given amount of temperature. Specific heat varies with temperature.

Strength to Weight Ratio (Specific Strength)

The ratio of ultimate tensile strength to density.

Tensile Strength

Tensile strength is the resistance of a material to breaking under tension at which mechanical failure occurs.

Thermal Expansion

The amount of change in a linear dimension per unit temperature.

Summary:

Abbas Steel group is the group of three rolling mills which were built in 1990s and they are dealing with variety of different steel products like deform bars, tor bars, twisted bars, angles, channels etc. For production of these products the essential items are billets, ingots and blooms, so to produce billets and ingots Abbas Steel group set an another company and merge into a group, the purpose of setting this company is to produce billets and ingots from their own company so they can produce steel parts without any problem. From the starting of 2013 Abbas steel was facing different challenges regarding billets and ingots like production process, cost issues, refractories adjustment, furnace performance, slag issues, scrap identifications, quality problems, production volume and the big concerned for them was energy consumptions.

According to the furnace manufacturer the acidic refractories would give 15 heats with the consumptions of electricity 625 kw/ton with good quality, but their results were opposite and giving around 7 heats with the consumptions of around 750 kw/ton. After 7 heats they have to change the refractory that means the efficiency of furnace and refractory was 50 to 60% which also consumed 20 to 30% more energy than the desires results and also consumed more fluxes and ferroalloys. Abbas steel was using scraps as light metal scrap, heavy metal scrap and shredded with the combination of different ratios. By using acidic lining in their furnace the recovery of molten steel was around 66% which was too low as they assume around 90% recovery, in this condition Abbas steel was in great lost. This problem was over controlled by changing the refractory lining in their furnaces instead of using acidic refractory they start using basic refractories with different ratios of chrome-magnesite and magnesium oxide. By using basic refractories the recovery of molten steel is increased from 66% to around 87% and hence they are getting around 13 to 14 heats by one refractory lining and other factors working well.

For producing billets and ingots world follows the particular production process or route like steel scraps, electric arc furnace, ladle furnace, ladle and continuous casting machine. To execute this operation different small private company follows different production process or route like steel scraps, induction furnace, ladle and continuous caster to eliminate the process and usage of electric arc furnace and ladle refining furnace which is itself very expensive equipment so Abbas steel was also following the same procedure but this procedure was ineffective and unbeneficial because to produce one ton molten steel the electric consumption should be around 625 kw where it was

around 750 kw so after installing the ladle refining furnace in between induction furnace and ladle they control the consumption of electricity which is the most important cost factor. They start flow the steps like tap the molten steel from induction furnace at the temperature around 1350 ^{0}C at the electric consumptions of 550 kw and treat the molten steel in ladle refining furnace to get the desire refine products where ladle refining furnace consumes 80 kw. By changing the combination of production process from scrap, induction furnace, ladle and continuous casting machine to scrap, induction furnace, ladle refining furnace, ladle furnace and caster to minimize the consumptions of electricity from 750 kw to around 625 kw. Now Abbas steel group is in profits with optimization of production process and resolve lots of their issues.

Kokkuvõte

Tänapäeval on hea kvaliteedi ja teostusega terasetootmise järele suur nõudlus ning kõik tootmisettevõtted keskenduvad suurele tootlusele ja hea kvaliteediga toodetele,. Selleks, et kliendid saaksid tooted kätte õigeaegselt, tuleb hoiduda tootmisprotsesside seisakutest ja see hoiab ära ka toodede vähese tootluse. Abbas Steel grupp on väga hea mainega ettevõte ja on üks parimaid terasetoodete ja –osade tootjaid. Abbas Steel grupp on kõige suurem pikkade terastoodete tootja maal. See on asutatud 1988. Grupp kehtestas ennast kiiresti kui kõrgekvaliteediliste korduvkuumvaltsitud toodete tootja ja see ajendas ka laienemise 1989 aastal Al-Abbas Steels (PVT) LTD'ga. 1996 aastal tekkis Abbas Engineering Industries. See oli teadlik otsus alles jätta nimi "Abbas" kõikidesse firmade nimedesse. Praeguseks koosneb Abbas Steel grupi kombinatsioon automaatsetest ja käsivaltsimis korduvvaltsimispinkidest, et toota ligikaudu 200,000MT terast nagu ka mitmed terasetootjate müügipunktid üle maa. Arusaamine, kes on nende kliendid ja kuidas nad majandavad enda ettevõtet, võtab aega. Saades paremini teada, mis on nende klientide turud ja tooted, on nad paremas positsioonis, et nende eesmärke täita. Abbas Steel grupi lai tooteulatus võimaldab varustada erinevaid turgusid ehitustööstuses. Mõne aasta jooksul on neil olnud probleeme seoses toodetega, tootmisprotsessidega, maksumuse ja mahuga ning see on toonud kaasa palju kadu tootmises. Autorile anti ülesanne, et välja mõelda nende probleemide põhjused ja pakkuda välja efektiivsemad lahendused, seega valiti toorikute ja valuplokkide analüüsimine ja tootmisvoo parandamine. Abbas steel on toorikute ja valuplokkide suurtootja. Nende päevatootlus on ligikaudu 300 tonni toorikuid.

Lõputöö peamine eesmärk on õppida kõiki tootmisprotsesse, seadmeid, pinke ja tehnikaid tundma, et kontrollida tootmisprotsesse, seadmete efektiivsust, tuua välja parim lahendus tootmise parandamiseks. Samuti on rõhk sellel, et toota võimalikult vähese kuluga, parima kvaliteediga ning välja mõelda probleemi põhjused ja pakkuda välja optimaalne lahendus. Selle eesmärk ei ole ainult tootmisvoo suurendamime/parandamine ning kvaliteetsete toodete saavutamiseks, kuid on ka sujuvate tootmisprotsesside väljamõtlemine arvestades standardeid. Samuti ka kulude hindamine, kvaliteedistandardite sättimine, tootmisprotsesside jälgimine ja ajakavade sättimine nii nagu on nõutud.

Abbas Steel grupil on kolm valtsimistehaset ja on ehitatud 1990ndatel. Nad tegelevad erinevate terastoodetega nagu valtstraadi, deformeeritud terasjuppide, painutatud terasjuppide, terasrõngaste, külmtõmmatud traadi, šahtide, painutatud terase kui ka kanaliseerunud terasega. Nagu eelnevate toodete valmistamine, on ka valuplokkide ja toorikute valmistamine oluline. Selleks, et toota valuplokke ja toorikuid, määras Abbas Steel grupp uue firma ja laiendas selle ühte gruppi. Peamine idee, miks loodi üks grupp, oli eesmärk toota toorikuid ja valuplokke ilma probleemideta. Samuti oli Abbas Steel Group 2013ndast aastast alates silmitsi suurte probleemidega, mis käsitleb nende kulude kontrolli, energiatarbimist, kvaliteeti, tootmismahtu ja tootmise optimiseerimise tasemeid.

Vastavalt sulatamisahjule, tulekindlate toodete tootja võimaldab anda 15 soojusühikut koos 625 kW/t hea kvaliteediga elektritarbimisega, kuid nende tulemused olid vastupidised ja andsid hoopis 7 soojusühikut 750kW/t elektritarbimisega. Pärast 7 soojusühikut peavad nad muutma tulekindlaid tooteid, see tähendab, et sulamisahjude efektiivsus ning tulekindlad materjalid olid 50 kuni 60%, mis samuti kasutasid 20 kuni 30% rohkem energiat, kui oli eeldatud ning seega kasutati rohkem kiirgusvooge ja ferrosulameid. Abbas steel grupp kasutas kergmetallist, raskemetallist vanametalli ja nende kombinatriooni erinevates suhetes. Kasutades sulamisahjul happelist katet, sulatatud terase taastumine oli ligikaudu 66%, mis oli liiga madal. Eeldati, et terase taastumine oleks ligikaudu 90%, seetõttu oli Abbas steel grupp ka suures kahjumis. See problem parandati, kui vahetati ära happelised katted sulatamisahjudel. Selle asemel, et kasutada happelisi tulekindlaid materjale, nad hakkasid kasutama tavalisi tulekindlaid materjale, mis koosnesid erinevatest kihtidest kroomitud magnesiidist ja magneesiumoksiidist. Kasutades uusi tulekindlaid materjale, sulatatud terase taaskasutamine suurenes 66% pealt kuni ligikaudu 87% peale ja seega nad saavutasid ligi 13 kuni 14 soojusühikut ühe sulatamisahju pealt ja seega ka teised tegurid töötasid hästi.

Selleks, et toota valuplokke ja toorikuid jälgitakse kindlat rada, mis koosneb terase sissekandest, elektriahjust ning kulbi ja valuseadme pidevast kasutamisest. Protsessi täideviimiseks väikefirma poolt, kasutatakse teistsugust moodust, mis koosneb terase sissekandest, induktsiooni sulamisahjust, kulbi ja valuseadme pidevast kasutamisest, et elimineerida elektrikaarahi ja kulbiahi, mis on mõlemad väga kallid. Abbas steel järgis sama protseduuri, kuid see protseduur oli väga ebaefektiivne ja kasutu, kuna ühe tonni sulatatud terase tootmiseks on elekritarbimine ligikaudu 750kW, kuigi peaks olema ligikaudu 625kW. Pärast vahepealset kulbi rafineerimise ahju installeerimist induktsiooniahju ja kulbiga suutsid nad saavutada kontrolli elektrikasutuse üle, mis on samuti ka kõige olulisem kuluallikas. Nad hakkasid kasutama sulaterast induktsiooni sulatusahjus tempertatuuril, mis oli ligikaudu 1350 kraadi ja elektritarbimine oli 550kW. Samuti hakkasid nad sulatatud terast töötlema kulbi refineerimisahjus, et saada soovitud täiustatud tooted, kus kulbi rafineerimisahju elektritarbivus on 80kW. Vahetades tootmisprotsessi kombinatsiooni, elektritarbivus vähenes 750kW pealt 625kW peale. Praeguseks hetkeks on Abbas steel grupp saavutanud olukorra, kus nad on kasumis, kuna nad on suutnud oma tootmisprotsesse optimiseerida ja lahendada mitmeid probleeme.

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APPENDIXES

Appendix 1: Effect on energy consumption before changing process. (Figure 17)

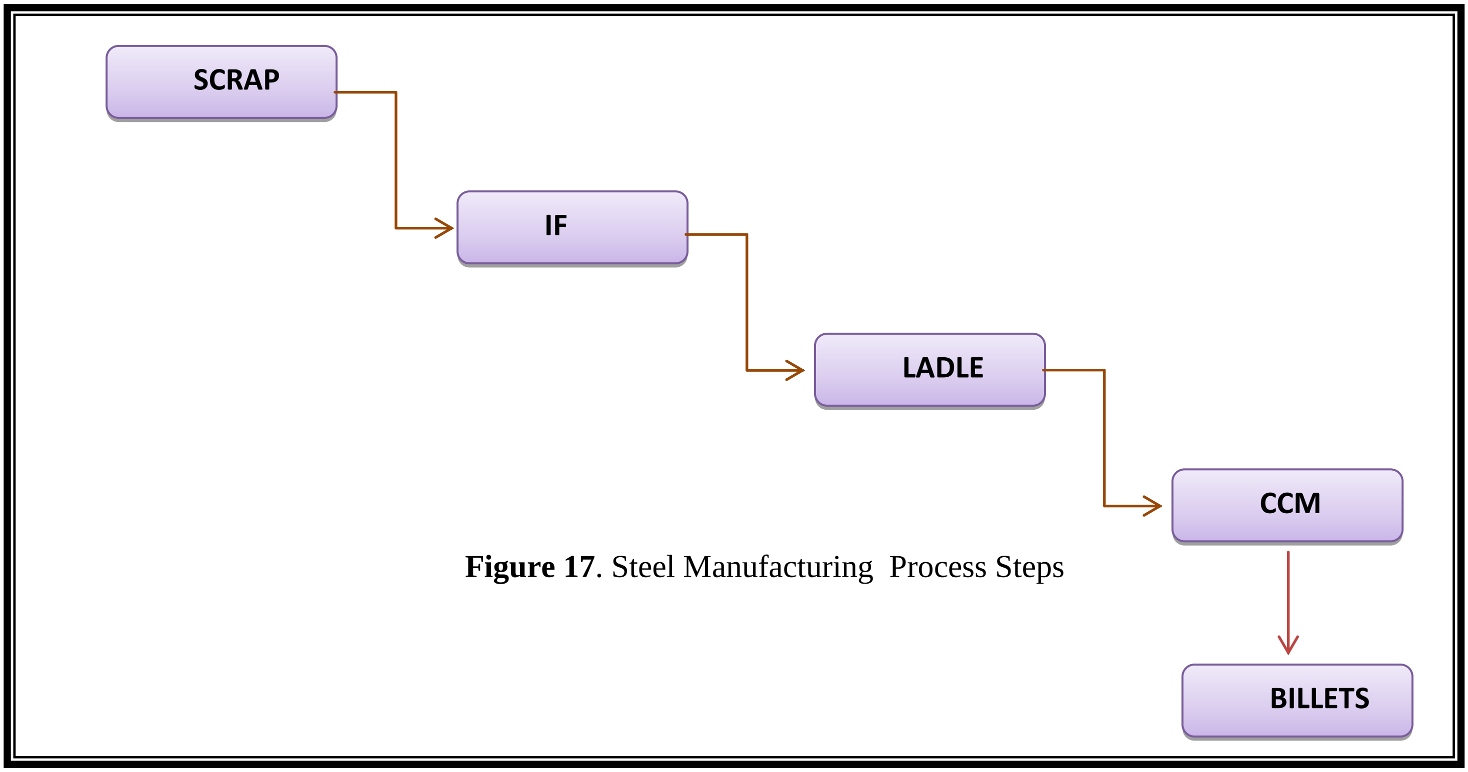


Figure 17. Steel Manufacturing Process Steps

Appendix 2: Effect on energy consumption after changing process. (Figure 18)

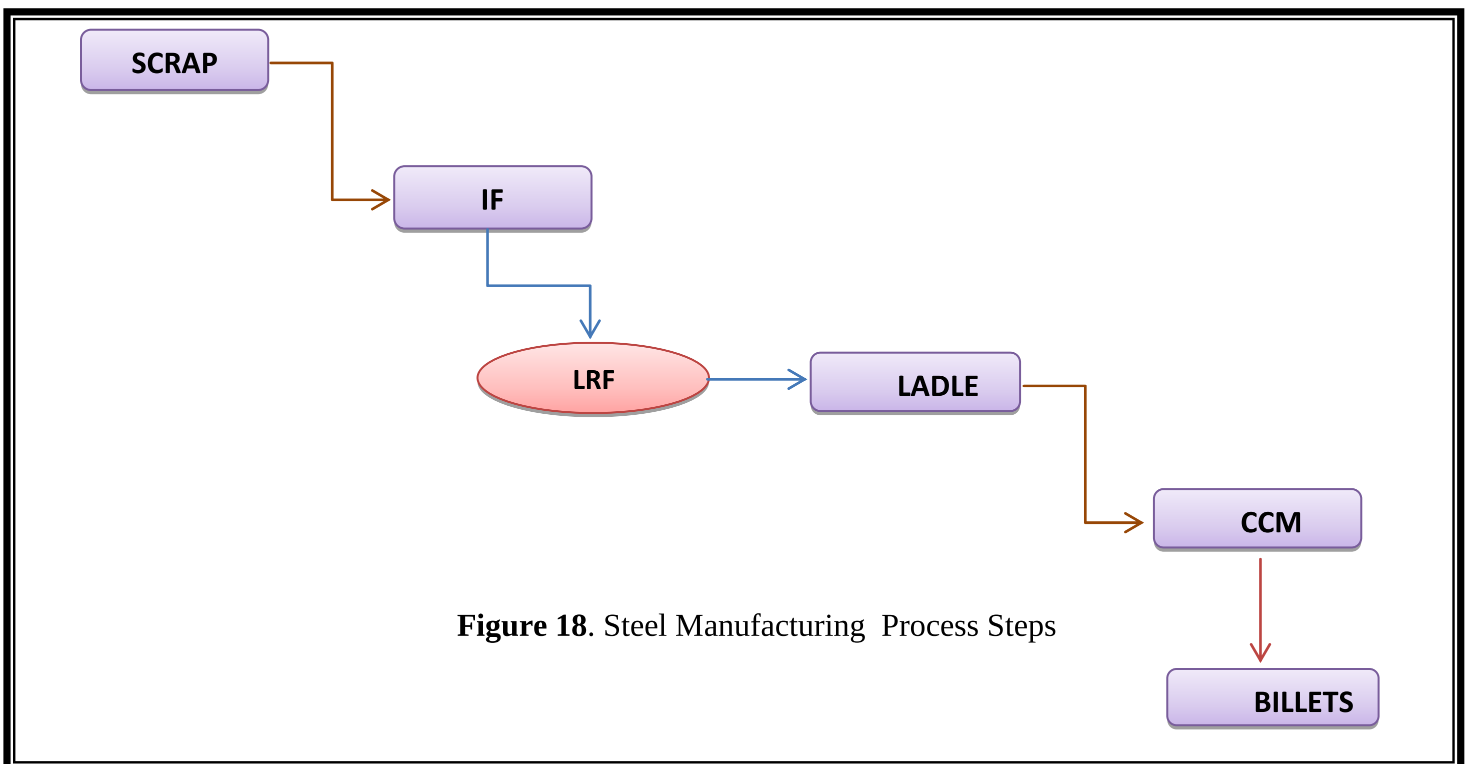


Figure 18. Steel Manufacturing Process Steps

Appendix 3: Properties of typical fireclay bricks (Table3)

Brick type	Percentage SiO_2	Percentage Al_2O_3	Percentage other constituents
Super Duty	49-53	40-44	5-7
High Duty	50-80	35-40	5-9
Intermediate	60-70	26-36	5-9
High Duty (Siliceous)	65-80	18-30	3-8
Low Duty	60-70	23-33	6-11

Appendix 4 Cost Comparison with Acidic Lining (Table 7)

S.NO	Cost Comparison for 1 Month(30 days)			Selling Price(PKR)/ton	
		EXPENSE			
	Utilities/Materials	ACIDIC			
		PKR	€	PKR	€
1	Electricity(8550000 kW)	128,250,000	1,068,750	60000 x 9000	500 x 9000
2	Scrap(13680 Tons)	410,400,000	3,420,000		
3	Ferroalloys(216 Tons)	34,560,000	288,000		
4	Fluxes(400 Tons)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	27,000,000	225,000		
7	Refractories(270 Tons)	1,755,000	14,625		
8	Man power	40,000,000	333,333		
9	Recovered metal from slag			8,400,000	700,000
10	Waste			325,000	2,700
	SUM	**644,865,000**	**5,373,874**	**548,725,000**	**5,202,700**

Appendix 5 Cost Comparison with Basic Lining (Table 8)

S.NO	Cost Comparison for(9000 ton metals) 1 Month(30 days) Basic Lining			Selling Price(PKR)/ton	
	Utilities/Materials	Basic			
		PKR	€	PKR	€
1	Electricity(8550000 kW)	128,250,000	1,068,750	60000 x 12038	500 x 12038
2	Scrap(13680 Tons)	410,400,000	3,420,000		
3	Ferroalloys(180 Tons)	28,800,000	240,000		
4	Fluxes(400 Tons)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	27,000,000	225,000		
7	Refractories(270 Tons)	1,755,000	14,625		
8	Man Power	40,000,000	333,333		
9	Recovered metal from slag			3,000,000	25,000
10	Waste			115,000	958
	SUM	**639,105,000**	**5,325,874**	**725,395,000**	**6,044,958**

Appendix 6 Cost Comparison with Basic Lining (Table 9)

S.NO	Cost Comparison for(9000 ton metals) 1 Month(30 days)			Selling Price(PKR)/ton	
	Utilities/Materials	BASIC + LRF			
		PKR	€	PKR	€
1	Electricity(7660800 kW)	114,912,000	957,600	60000 x 12038	500 x 12038
2	Scrap(13680 Tons)	410,400,000	3,420,000		
3	Ferroalloys(180 Tons)	28,800,000	240,000		
4	Fluxes(400 Tons)	2,400,000	20,000		
5	Gases	500,000	4,166		
6	Miscellaneous	54,000,000	450,000		
7	Refractories(270 Tons)	1755000	14,625		
8	Man Power	40000000	333,333		
9	Ladle Refining Furnace	57750000	481,250		

10	Recovered metal from slag			3,000,000	
11	Waste			115,000	
	SUM	**710,517,000**	**5,920,974**	**725,395,000**	**6,044,958**

Appendix 7 Expense & profits comparison (Table 10)

Cost Comparison for 1 Month(30 days)		
	EXPENSE	**Selling Price(PKR)/ton**
Utilities/Materials	**ACIDIC**	**ACIDIC**
	PKR	**PKR**
Electricity(7660800 kW)	114,912,000	60000 x 9000
Scrap(13680 Tons)	410400000	
Ferroalloys(180 Tons)	28,800,000	
Fluxes(400 Tons)	2,400,000	
Gases	500,000	
Miscellaneous	54,000,000	
Refractories(270 Tons)	1755000	
Man Power	40000000	
Ladle Refining Furnace		
Recovered metal from slag		8,400,000
Waste		325,000
SUM	**652,767,000**	**548,725,000**

Appendix 8 Expense & profits comparison (Table 11)

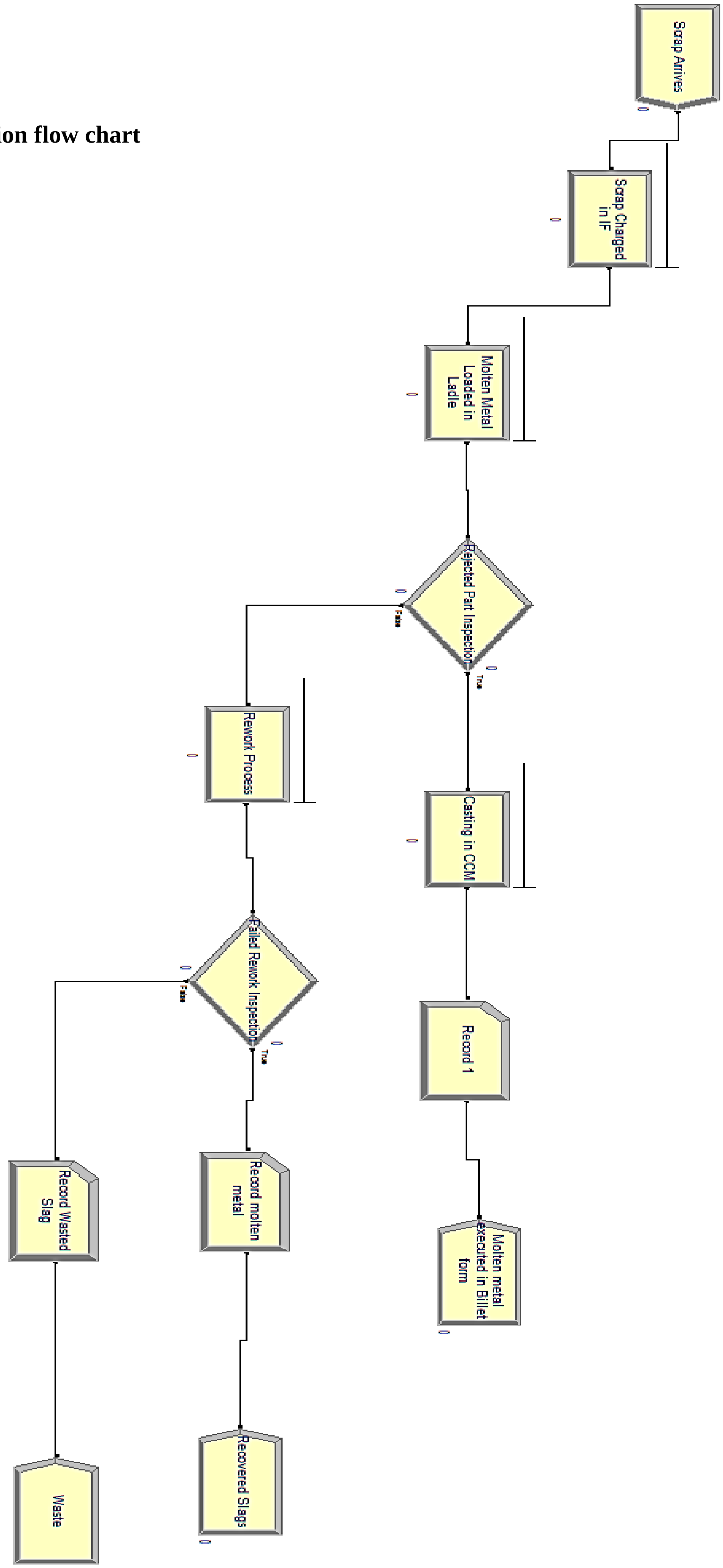
Cost Comparison for 1 Month(30 days)		
		Selling Price(PKR)/ton
Utilities/Materials	**BASIC**	**BASIC**
	PKR	**PKR**
Electricity(7660800 kW)	128250000	60000 x 12038
Scrap(13680 Tons)	410400000	
Ferroalloys(180 Tons)	28,800,000	
Fluxes(400 Tons)	2,400,000	
Gases	500,000	

Miscellaneous	27,000,000	
Refractories(270 Tons)	1,755,000	
Man Power	40,000,000	
Ladle Refining Furnace		
Recovered metal from slag		3,000,000
Waste		115,000
SUM	**639,105,000**	**725,395,000**

Appendix 9 Expense & Profits Comparison with Basic & LRF Furnace (Table 12)

Cost Comparison for 1 Month(30 days)		
		Selling Price(PKR)/ton
Utilities/Materials	**BASIC + LRF**	**BASIC + LRF**
	PKR	**PKR**
Electricity(7660800 kW)	114,912,000	60000 x 12038
Scrap(13680 Tons)	410400000	
Ferroalloys(180 Tons)	28,800,000	
Fluxes(400 Tons)	2,400,000	
Gases	500,000	
Miscellaneous	54,000,000	
Refractories(270 Tons)	1,755,000	
Man Power	40,000,000	
Ladle Refining Furnace	57750000	
Recovered metal from slag		3,000,000
Waste		115,000
SUM	**710,517,000**	**725,395,000**

Appendix 10 Simulation flow chart



Appendix 11 Simulation result

17:35:31 **Category Overview** January 4, 2016

Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

System	Average
Number Out	719

Unnamed Project

Replications: 1 Time Units: Hours

Entity

Time

VA Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	1.6099	0.011959978	1.5000	1.8333

NVA Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	0.00	0.000000000	0.00	0.00

Wait Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	0.00	0.000000000	0.00	0.00

Transfer Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	0.00	0.000000000	0.00	0.00

Other Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	0.00	0.000000000	0.00	0.00

Total Time

	Average	Half Width	Minimum Value	Maximum Value
Scrap	1.6099	0.011959978	1.5000	1.8333

Other

Number In

	Value
Scrap	721.00

Number Out

	Value
Scrap	719.00

WIP

	Average	Half Width	Minimum Value	Maximum Value
Scrap	1.6090	0.012467186	0.00	2.0000

Unnamed Project

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Casting in CCM.Queue	0.00	0.000000000	0.00	0.00
Molten Metal Loaded in Ladle.Queue	0.00	0.000000000	0.00	0.00
Rework Process.Queue	0.00	(Insufficient)	0.00	0.00
Scrap Charged in IF.Queue	0.00	0.000000000	0.00	0.00

Other

Number Waiting	Average	Half Width	Minimum Value	Maximum Value
Casting in CCM.Queue	0.00	(Insufficient)	0.00	0.00
Molten Metal Loaded in Ladle.Queue	0.00	(Insufficient)	0.00	0.00
Rework Process.Queue	0.00	(Insufficient)	0.00	0.00
Scrap Charged in IF.Queue	0.00	(Insufficient)	0.00	1.0000

Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Instantaneous Utilization

	Average	Half Width	Minimum Value	Maximum Value
CCM	0.2789	0.015856556	0.00	1.0000
Induction Furnace	1.0000	(Insufficient)	0.00	1.0000
Ladle	0.08321759	(Correlated)	0.00	1.0000
Ladle 2	0.2469	0.028216351	0.00	1.0000

Number Busy

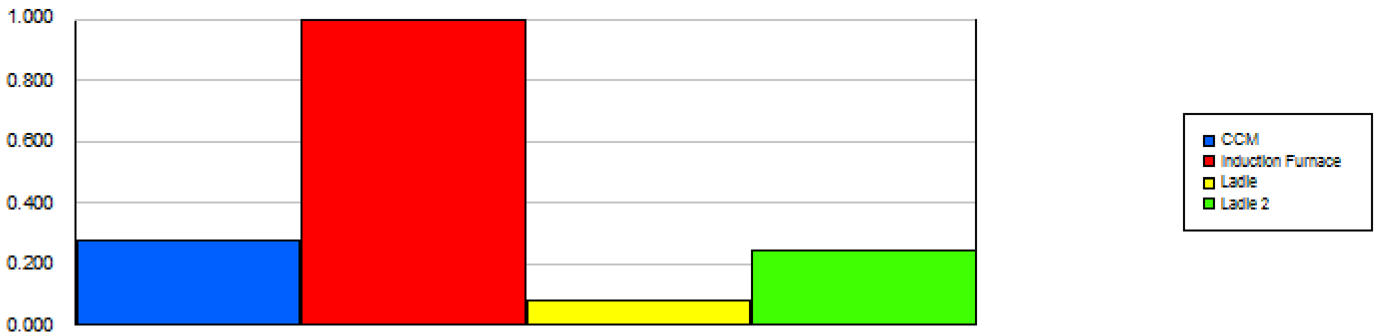
	Average	Half Width	Minimum Value	Maximum Value
CCM	0.2789	0.015856556	0.00	1.0000
Induction Furnace	1.0000	(Insufficient)	0.00	1.0000
Ladle	0.08321759	(Correlated)	0.00	1.0000
Ladle 2	0.2469	0.028216351	0.00	1.0000

Number Scheduled

	Average	Half Width	Minimum Value	Maximum Value
CCM	1.0000	(Insufficient)	1.0000	1.0000
Induction Furnace	1.0000	(Insufficient)	1.0000	1.0000
Ladle	1.0000	(Insufficient)	1.0000	1.0000
Ladle 2	1.0000	(Insufficient)	1.0000	1.0000

Scheduled Utilization

	Value
CCM	0.2789
Induction Furnace	1.0000
Ladle	0.08321759
Ladle 2	0.2469



Unnamed Project

Replications: 1 Time Units: Hours

Resource

Usage

Total Number Seized

	Value
CCM	482.00
Induction Furnace	721.00
Ladle	720.00
Ladle 2	237.00

User Specified

Counter

Count

	Value
Record 1	482.00
Record molten metal	77.0000
Record Wasted Slag	160.00