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What's Inside

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Improving Performance of Mini Steel Plants (Induction Furnace Melting)

P. Mishra
Sr. Executive Director, AIIFA, Delhi

Introduction : Mini steel plants having induction furnace as steel making units and other down stream processing units execute customer orders with the objective to satisfy customers starting from raw material planning & procurement, production scheduling against specified orders, controlling quality at all the processing stages optimizing cost and yield as well as logistical handling throughout the entire production chain. The entire process chain in mini steel plants is planned creating an optimized production plan for the ingot/ continuous casting, rolling/ forging and heat treatment which combines consistent and even utilization of the melt shop, processing units and delivery of the finished products to the customer.

The steel industry particularly IF & EAF melting is one of the highest energy consuming industries in India. It also contributes to greenhouse gas (GHG) emission, but at low level compared to other steel making process. Global steel production status is shown below (A,**B) -**

A. Crude Steel Production by Leaders (Million Tones)

Rank in 2018	Country	2018	2017	2016	2015	2014
1	P. R. China	928.3	831.7	786.9	803.8	822.7
2	India	106.5	101.4	95.5	89.6	87.3
3	Japan	104.3	104.7	104.8	105.2	110.7
4	United States	86.7	81.6	78.5	78.9	88.2

B. Zone-Wise Global Steel Production in 2018 & 2017 vis-à-vis % Growth – (Released figures by World Steel Association)

Country/Zone	Year	Mt	% Growth	Year	Mt	%Growth
NAFTA	2017	145.0	+3	2018	147.3	+1.6
EU	2017	166.6	+2.0	2018	166.9	+0.08
Other Europe	2017	44.2	+4.5	2018	46.1	+4.4
CIS	2017	54	+2.3	2018	55.8	+1.8
Middle East	2017	55.7	+4.6	2018	57.8	+3.7%
Asia & Oceania	2017	1071.4	+1.1	2018	1069.7	-0.02
Central & South America	2017	43.5	+6.2	2089	45.6	+4.9
Africa	2017	36.6	+4.5	2018	38.3	+4.6
World Total	2017	1616.1	+1.8	2018	1626.7	+.07%

Commenting on the global steel outlook, Mr T.V. Narendran, Chairman of the World Steel Economics Committee said, "In the next couple of years the global economic situation is expected to remain favorable with high confidence strengthening recovery of investment levels in advanced economies particularly from

steel production. India is the second largest steel producing country in the world produced 106.5 million tonnes of crude steel in 2018, next to China's 928.3 million tonnes. Mini steel plants as secondary steel sector contribute to about 70 percent of long (non-flat) steel production in the country comprising of small sized induction furnace units, using mostly outdated technologies consuming large quantities of energy.

Some of the key sectors/sub-sectors in mini steel plants in the country are as follows:

1. Electric Induction Fce Sector –
   - (A). Producing Ingots for Forging or Rolling Units or Sale,
   - (B). Producing Concast Billet/ Bloom being re-rolled or forged.
   - (C). Foundry for Steel Casting
2. Steel Re-rolling Mill (SRRM) Sector – Rolling Concast Billet/ Bloom or Pencil Ingot.
3. Spong Iron / DRI Sector,
4. Electric Arc Furnace (EAF) Sector and down stream processing units.

The majority of the units from the secondary steel sector lacking in energy efficient technologies and mostly run as family business being busy in managing day-to-day operations.

In today's business culture and environment, mini steel plants, producing carbon, alloy & special steels should always give priority for customer satisfaction supplying quality products at optimum price to stay in the global competitive market. To-day's Customers are more knowledgeable about steel grades, products, properties for end use applications at their ends. To achieve success, it is important to have proper planning and scheduling right from sourcing raw materials till making finished products to be able to adequately manage customer expectations against order. Now, it has become truly the defining factor that makes or breaks the reputation of a plant as such, customer relations practices by timely delivering quality products are crucial to the success of any plant.

Common facets are to have a good plan for supplying quality products optimizing product and process cost managing customers' expectations. In order to adequately manage customer expectations on product, the most important aspect to the management is to carefully examine the customer need studying the technical delivery conditions of products ordered, expectation vis-à-vis process standards, capability of processing equipment and their limitations. However, Need of customers may vary for end uses which should be clearly understood by the producers before accepting any order discussing ins and outs of the customers. For successful transformation in the total process during order execution, management should actively look for ways to get desired performance by total improvements establishing goals in every areas by the planning system for achieving objectives. However, main objective of entrepreneurs should be focused towards:

- More & More Revenue Earning by way of
- Smooth & Un-interrupted Production in Cleaner & Greener ways against order,
- Cost Reduction in entire Process Chain from Procurement of raw materials to final products,
- Risk Reduction prioritizing Equipment Health & Safety,
- Time Reduction i.e. Avoiding delays and better Utilization of Equipments,
- Quality & Productivity Improvements, Customer Satisfaction,
- Process & Product Development,
- Improved Knowledge Transfer.

Processing Stage Integration in IF Melting units

MSP-(IF→Ingot/ConCast→Rolling/Forging→HeatTreatment→Insp/Testing→Desp→Feed Back		
Inputs	Processing	Outputs
Scrap	Induction Furnace	Ingot/ Continuous Casting
Scrap Substitute	Continuous Casting	Bloom/ Billet
Variuos Additives	Rolling	Rolled Products
Energy, Water	Forging	Forged Products
Labor	Heat Treatment	Annealing/ Hardening/ Tempering
Equip	Q.C & Testing	Tested Quality Products
Customer Feed Back on Quality, Delivery Schedule		

Area-wise Actions help in achieving Better Results.:

Induction Furnace - Mini steel plants are producing carbon, alloy & special steels melting in induction furnace being operated by utilizing a strong magnetic field created by passing an electric current through a coil wrapped around the furnace which in turn creates a voltage and subsequently an electric current through, the furnace charge to be melted. The electrical resistance of the charge produces enormous heat sufficient to melt the charge. Presently, all the induction furnace units are keen to improve their operational efficiency starting from charge preparation with right mix of raw material e.g. ms scrap, sponge iron and other scrap substitutes in economical ways and melting stock, refining, teeming in mould or continuous casting as billet or bloom.

The main raw material for induction furnace steel making is the scrap which lacks elasticity in supply, price fluctuation. It is classified into three main categories as Internal scrap, Producer scrap Capital scrap. International sources of scrap are limited to few industrialized countries. Improvement in fabrication practice and increasing application of the continuous casting process have significantly reduced the available recycled scrap. But on the other hand scrap collected in the market is increasing with the economic development and the continuous reduction in the life span of consumer goods.

Availability of scrap is one of the important conditions to determine the location of a IF based steel plants. However, prices of the finished products made by the IF and processing units are greatly influenced by the prices of scrap contributing about 60-70% of the total production costs mainly for carbon and low alloy steels where charge mix optimization in melting achieve not only the right chemical composition but also helps in reducing cost. An optimal and constant production process in induction furnace steel making is only possible by controlling the metallurgical process within close limits, alloy recovery value and production monitoring. The power input provided for running an induction furnace during its melting operation has an important role on the overall energy consumption of the furnace which has to run at maximum power since beginning which increases melting rate reducing cycle time of heat. However, the essential input is availability of better cheap scrap and availability electric power at cheaper rate, State wise current power rate and IF production units (nos) shown below .

States	Energy Charges (INR/KWh) - Variable electricity charge				EIF Production Units (Nos)		
	2013-14	2014-15	2016-17	2017-18	2013-14	2014-15	2015-16
W.B	4.35	4.29	6.6	7.15	79	78	70
Odisha	3.95	4.0		4.25	110	93	73
Chhatitisgarh	3.8	3.8	5.3	5.6	66	66	75
Maharashtra	7.01	7.01	7.21	7.07	64	64	55
Gujrat	4.3	4.3	4.3	4.3	56	56	55
Punjub	6.31	6.33	6.33	6.33	125	125	115
Tamil Nadu	6.35	6.35	6.35	6.35	115	110	100
U.P	6.0	6.35	6.35	6.35	94	100	54

Energy efficiency issue has become most important for smooth running of electric steel making units EAFs & IFs and also for other manufacturing and industrial sectors where 25-30% of country's energy are consumed. Energy efficiency production playing important role in leading to multiple benefits in mini steel plants having IF units as such all possible measures are takin by individual units by improving process efficiencies. The higher electricity cost are forcing many IF units to shut down operation and even many units are afraid for plant expansion or modernization. However, in order to cut down these cost burdens , the government plans to introduce a new tariff structure in the country, under which high electricity tariff shall be charged to large domestic power consumers rather than industrial units. Categorization of large domestic consumers, having an electricity consumption of more than 800 units/month has already been done in most of the states. (Ref: Enincon Consulting IIp.2018, ND,India)

The up-scaling energy efficient production should be undertaken with the main objectives of

(i) Improve energy efficiency to save energy and consequently the money spent on fuels,

(ii) Mitigation of GHG emissions,

(iii) Improve productivity through technological support from Govt.

For energy efficient production in induction furnace, power factor should be maintained near to one ensuring no voltage drop from the source which is a measure of how effectively induction furnace is using electricity.

Improving the PF can maximize current-carrying capacity, improve voltage to equipment reducing power losses lowering electric bills. The simplest way to improve power factor is to add PF correction capacitors to the electrical system. PF correction capacitors act as reactive current generators. They help offset the non-working power used by inductive loads, thereby improving the power factor. The interaction between PF capacitors and specialized equipment, such as variable speed drives, requires a well designed system. Grade-wise tap temperature within tolerance range is to be calculated avoiding unnecessary superheat. However, energy charge should not be more than INR4/KWH.

Furnace Lining - Lining plays an important role also in overall performance of melt shop operation as well as saving energy. Due consideration should be given for selection of appropriate lining material, maintaining proper lining thickness and its sintering for energy saving. Thick lining reduces furnace crucible volume and hence the molten metal output is less resulting high specific energy consumption. Thin lining, on the other hand, though improves the power density but promotes heat loss from the side walls. Further, lining material with high thermal conductivity causes more heat loss. Long sintering cycle time consumes much energy for the first heat to get ready. All such factors are to be optimized and balanced. Improper lining results in pre-

mature failure, furnace lining and ramming activities to be done as per standard operating practice as suggested by furnace suppliers both for achieving optimum furnace life as well as power consumption. Slag deposition in lining needs to be avoided as far as possible. Considering cost, melting temperature, normal holding time of liquid steel and its volume, inductive stirring, alloy additions etc., suitable refractory material to be selected for lining.

As cost-effective product, silica - based refractories have long been the standard for using in induction furnace for advantages like:

1. Low cost mineral base,
2. Non or less wetting to liquid steel and slag,
3. Excellent thermal expansion properties for batch operation, low level of metal penetration through thermal cracks.

However, disadvantages observed in use of silica-based refractories e.g. Few common alloying elements reduce silica grain at melting temperature. Mechanical, chemical and thermal factors may erode furnace bottom and may affect lining life, If exposed to any basic slag by any means, chemical erosion can take place. High manganese steel can not be melted in acid lined furnace.

There has been development of using large grain size technology using grain size upto 12mm dia i.e. 60-100% larger than traditional grain size combining with new binding technology which may provide effective sintering.

Scrap Quality – Nature, size and quality of segregated scrap free from sand/dirt, oil/ grease in charge play another important role in reducing power consumption. Rusty scrap not only takes more time to melt but also contains less metal per charging. The return scrap from steel foundry i.e. runner and risers , normally, contain 2 - 5% sand which should be removed before charging in the furnace. For alloy addition, exact weights as per chemical composition of grade considering recovery and yield are to be calculated before charging without any delay. The maximum size of single piece scrap should not be more than ⅓rd of crucible diameter, sharp edge heavy or bulky scrap must be avoided to save furnace lining.

However, efficiency of melting in induction furnace depends on scrap mix, size, quality and charging mode. Lesser air pocket between scrap pieces lead to more power density and higher heat conductivity resulting faster melting with least energy consumption. Higher slag generation takes away more time for slag removal affecting furnace utilization and this should be removed quickly.

Steel Quality – Customer expectations are gradually rising because of competitiveness in the market place, and to remain competitive in their specific areas, OEMs are demanding higher quality from their suppliers. It is a fundamental premise of steel producing units that high-quality finished products cannot be produced in cost effective way from low-quality inputs even adhering standard process at processing stages. Quality deficiencies at ingot stage or during forging or rolling or even heat treatment may cause generation of sub-standard products. Mini steel units should adopt quality as a competitive strategy finding that they are better able to weather cyclical swings in their businesses and that their product costs are lower reaping benefits by exceeding the quality levels required. By this strategy, mini steel plants can carefully target revenue earning prioritizing improvements in terms of their effect on the organization's operational and financial goals, as well as overall business objectives. It has been well known that the individual or combined effect of carbon [C], phosphorus [P], sulphur [S], nitrogen [N], hydrogen [H] and total oxygen (T.O.) in steel can have a remarkable influence on steel properties, such as tensile strength, formability, toughness, weldability, cracking-resistance, corrosion-resistance, fatigue-resistance, etc. Also, clean steel requires control of non-metallic oxide inclusions and controlling their size distribution, morphology and composition.

Consistent quality is the expectation of all customers . If quality standard or services change on a whim, customer can be left feeling dazed and confused. It is also a sure fire way to lose any gained trust that has already been established. Maintaining consistency in customer relations also helps the customer to manage their own expectations because they will always know what to expect. Listening to customer concerns and complaints will help to determine where inconsistencies occur and what the shortcomings are. Consistency builds trust and trust leads to long lasting business relationships.

Steel product	Maximum allowed impurity fraction	Maximum allowed inclusion size
Automotive and deep-drawing Sheets	[C] $\leqslant$ *30 ppm, [N]* $\leqslant$ *30 ppm*	100 μm
Alloy steel for Pressure vessels	[P] $\leqslant$ *70 ppm*	
Alloy steel bars	[H] $\leqslant$ *2 ppm, [N]* $\leqslant$ *20 ppm, T.O.* $\leqslant$ *10* ppm	
Line pipes	[S] $\leqslant$ *30 ppm, [N]* $\leqslant$ *50 ppm, T.O.* $\leqslant$ *30* ppm	100 μm
Plates for welding	[H] $\leqslant$ *1.5 ppm*	
Bearings	T.O. $\leqslant$ *10 ppm*	15 μm
Heavy plate steels	[H] $\leqslant$ *2 ppm, [N]*=*30*-40 ppm, T.O.$\leqslant$ *20* ppm	Single inclusion 13 μm Cluster 200 μm

Material Properties – In the application areas, design of an engineering component involves three interrelated problems:

(i) Selection of proper material with desired composition, quality and properties,

(ii) Specifying a shape with tolerance level and

(iii) Choosing a manufacturing process i.e. forging or rolling, heat treatment conditions satisfying properties

Some customers are most concerned with characteristics such as Yield Strength, Ultimate Tensile Strength, Ratio of Yield and Tensile Strength, Shear Strength, Hardness value, Creep behavior at different temperatures, Fatigue strength, Fracture Toughness, Corrosion properties etc. Further, processing industries demand material characteristics like Thermal Properties Thermal expansion coefficient, Thermal conductivity, Specific heat capacity, Magnetic Properties, Fabrication Properties, Ease of machining, Ease of welding, Hardening ability, Formability etc.

Maintenance Quality & Cost – To optimize maintenance quality and cost, mini steel plants should analyze all the components of maintenance costs e.g. material costs, maintenance by contractors and own maintenance, etc. inclusive of saving possibilities, risk estimation and other major issues concerning maintenance. Possible solutions of the maintenance optimization can be represented by side condition for solution adapting the maintenance to the changed conditions, improving activity scheduling, capacities in the own maintenance with possible comprehensive strategy ensuring high work quality and improvement potential with spare part repairs building up skills and knowledge. However, maintenance strategy should be in line as:

1. Breakdown strategy (run to failure),
2. Condition based preventive maintenance (exchange after inspection),
3. Time based preventive maintenance (exchange after fixed period of time)

Overall Cost Aspect – The total cost covers all costs associated with the actual cost of raw materials, purchase and procurements of scrap, other raw materials, additives, power & fuel, labor cost, administration &contingencies charges etc. However, production cost of steelmaking in induction furnace varies depending on the conditions under which the plant handles the grade and products.

In the steel making scenario, it may be noted with concern that many induction furnace steel making units are fighting a grim but can not exist in the field of competitive global market for survival resulting making loss gradually and forced to shut their units/ shop. Actual production against the capacity of the units has dipped dramatically at many places mainly due to sharper drop of demand in the market and prices have crashed just when costs have gone up which have suffered cash losses. It is also observed that in the periodic cycles capacity utilization of IF units in most of the good times was more than 70% and even at the level of about 90% but same has come to a level of about 60% depressing the entrepreneurs mainly the higher energy rate forcing units un-competitive. Therefore, need of the hour is cost, quality, product yield optimization for only market driven products.

Operating Parameter Comparison - EAF & IF, Source: Ispat

FCe	Energy Cons KWH/T	Refractory Cons Kg/T	Electrode Cons Kg/T	Oxygen Cons NCum/T	Flux Cons Kg/T	Dust Gen. Kg/T	Noise level dB(A)	Slag Gen. Kg/T
EAF	490-510	4.1-4.2	2.4-2.6	15-25	25-28	6-12	95-120	65-72
IF	540-550	3.4-3.6	Nil	Nil	Nil	1-2	82-86	11-15

Above Parameters indicate Steel Cost through IF compared to EAF is Remunerative.

Expectation of Management and Customer – For all the needed actions for improvement in each activity, the communication followed by quick actions is key when it comes to effective expectation of results to satisfy both internal and external customer. Here, to provide good customer service, each operational/ production stages need to understand who are their customers, what they want and they are working for them. For example, raw materials are purchased by one department, products are manufactured by other departments like liquid steel by melting shop, liquid steel processing by continuous casting as bloom/ billet or ingot in pit side which are finally rolled or forged as products for final heat treatment and finishing. Internal customers expectations by departments can be stated as:

1. Melt shop to get right quality and quantity of scarp, various additives as well as timely support services from maintenance and other service units,
2. Pitside or Concast units to get good quality liquid steel with specified composition maintaining standards along with support services for production of quality products needed by next processing units.
3. The heat treatment shop has to look after the processing at its end to satisfy customers supplying products maintaining specified properties getting support from Quality Control units.

Internal customer satisfaction surveys measure perceptions and impressions of internal service, be it communication, productivity, quality and/or responsiveness. These are the concerns which are keeping all the units from working together better enhancing awareness and skill of working people with whom management should deal time to time.

In a mini steel plant, since IFs supply liquid steel to pitside for producing ingot or to continuous casting shop to cast bloom/ billet, here pit side and concast units are the customers of melt shop. Further, either forging or rolling units are customers of melt shop i.e. IF units.

Departments depend on each other in terms of quality, productivity and efficiency. If one section underperforms from standard, the entire chain is stretched. As such, identifying weak links may not be necessarily individual but should be considered as major concern for the management. And under achieving teams or areas having multiple problems need to be solved without any delay identifying process inefficiencies and turn them around for achieving desired performance. In such occasion, experts in the field may be consulted for improvement.However, quality of service and performance of internal customers has an impact on external customers, although in many cases, individual units might never have direct relationship with external customers. Continuous interaction and improved level of satisfaction of these internal customers is the key for success for the organization which, hopefully, satisfy external customers (as indicated below).

Actions to Establish Mini Steel Plant in Competitive Market – For effective functioning of newly set up mini steel plant, stage-wise different involved activities may help in achieving objective:

1. The primary objective is to be linked with other related industrial sectors for availability of raw material, various additives, related auxiliaries, power, water, expected orders from the consuming sectors, preferably nearness of both consuming sectors as well supplying agencies, infra-structural supports, deciding capacity of the induction furnace and other processing units in scientific ways keeping provision for expansion in cost-effective ways , Plant location factors considering above mentioned areas, nearness to supplying agencies and customers also influence the performance of the plant.
2. Raw materials preparation, preheating etc., design of melt shop and other units, organization structure, Manpower requirement/ availability, availability of contract labor in need based areas.
3. Deciding operating cost including raw materials, labor, supervision, electric power, repair, maintenance, refractory, additives etc., administration and sales expenses, interests etc., depreciation, amortization, financial analysis including mode of financing the project, sales realization, break-even analysis, internal rate of return, net present value etc.

Conclusion - Customers of steel and alloy steel products are truly becoming more demanding day by day which are forcing mini steel plants to improve product quality optimizing process cost focusing strategically on delivering increased customer satisfaction and service quality which is linked to improved plant performance, confirming the appropriateness of this strategy. Mini steel plants should also adopt the strategy to satisfy internal customers in different processing stages which will in turn help in achieving external customer satisfaction.

In spite of constraints and limitations in the process, efforts should be given at all the processing units to improve efficiencies in the process establishing as best practice which are directly or indirectly linked with each other in the upstream or downstream units, and such efficiencies, hopefully, optimize cost to give benefit to the customers.

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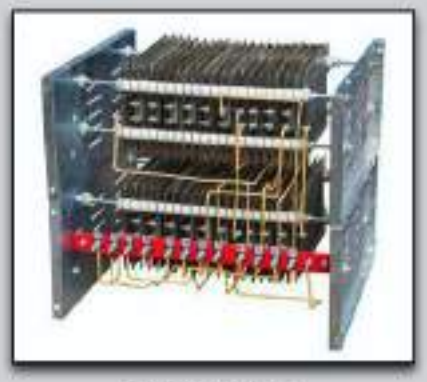

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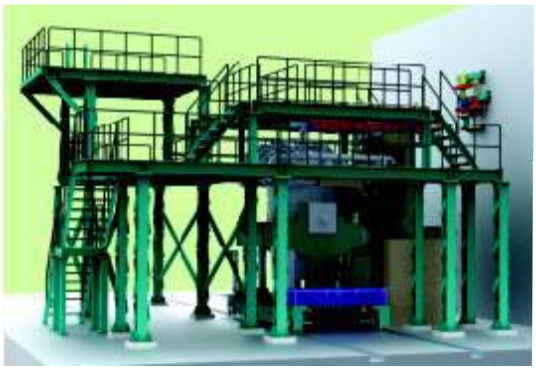

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