ALL INDIA INDUCTION FURNACES ASSOCIATION

AIIFA

INDUCTION FURNACE NEWSLETTER

VOL. No. XXII
ISSUE No. 8, August, 2022

What's Inside

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Innovative Approaches for High Quality Steel Production by Induction Furnace

Kamal Aggarwal
Hon. Sec. General,AIIFA

Introduction : Steel Quality means the combination of all the properties like chemical composition within the range, specified physical properties e.g., Yield strength, Ultimate Tensile strength, hardness, ductility, corrosion and heat resistance in different media or atmosphere and defect free e.g., internal soundness, free from surface defects, steel cleanliness in products, homogeneity of the products etc. which are the demand of customers.

Present day's Customers are ready and willing to pay more for high quality steel grade products as they reduce processing cost at their end maintaining high quality steel end products satisfying their customers as the entire process is a chain system of Q (quality), It is the common idea of some producers and user industries that steel is just a pre-set combination of iron & carbon which are likely to meet all the properties but there are more than 3,500 different steel grades which are differentiated by presence of varying amount of carbon and other alloying elements as specified in different steel grades. Induction furnace melting steel products are commonly divided as Bar, Forging, Flat products.

Bar products from Induction Furnace Steel: Normally bar products, possess a smooth surface finish that is machinable if needed and display excellent mechanical properties. In addition, products are easy to weld, form, cut, shape, machine and ideally suited for bending, cold forming/ heading, peeling applications that require a lower amount of strength used in construction and infrastructural applications Bar products are classed as Merchant Bar quality (MBQ) and Special Bar quality (SBQ).

Merchant Bar Quality Steel: Products are mostly used in non-critical applications in construction and infrastructure as standard products meeting nominal composition and properties against standard. where operational activities involve bending, forming, punching and welding. Products are referred to a wide range of long semi-finished steel products that are used by steel fabricators to produce a number of various steel products. as Angle, (equal, un-equal angle of different dimensions, round bar/ Flat bar/Square bar, Cannel, Joist etc. in different sizes which are used in construction and structure directly that require welding products. MBQ steels, is manufactured to specified sizes with appropriate chemical limits to meet a set of properties, where the end use is non-critical. MBQ bars, is made from unconditioned billets. The bars may have liberal tolerances controls. The surface and core defects are wide and not well quantified. The bar manufacture may involve mild bending, hot forming, punching and welding. The quality norms in terms of internal porosity, surface seams are also liberal.

Special bar quality (SBQ) steel: These are a class of long steel products engineered for tough applications, such as bearings, crankshafts, gears and drill-string components. The higher the application load, the more “special” the SBQ Steel long product produced, may be divided into Merchant Bar Quality [MBQ] and Special Bar Quality [SBQ]. Special Bar Quality is a term used in long product industry, where an assured stress level in the application can be met by the specified alloy and special steel. They are long

5. Railways Axles, rails, wheel forgings, fastners, piston rods, flange, housing pieces, wagon parts like screw couplings and other for wagons, cushioning device components, pin and steel liners, traction gears; wheels, axles, brake disks, drive unit mechanisms, and joints, for high-speed rail transport, fastners, crankshafts, Portal axles for rails, connecting rod for diesel engine, claw lock for rails.

6. Marine / Ship Building Propeller Shafts, Rudder Stock, Intermediate Shaft, Pinion Shaft, Forged Plates, Forged Rounds and others. Crank shaft, connecting rod, Marine engine Bolts, crank shaft, connecting rod Biomedical

7. Surgical stainless steel [316, 440, 420]

8. Mining Equipment Shafts, crusher forgings, bearing, drill rigs to drill bits, Rock drilling equipment, Crusher Shafts, Excavator Shaft, Transmission Shafts, Grinding Mill Rolls, Pinions, front spindle, etc.

9. Agriculture parts for loaders, farm equipment, land diggers, ploughs, gears, shafts, levers and spindles to tie rod ends, spike harrow teeth and cultivator shafts.

10. Steel Mill Components Rolls & Roll Blanks used in rolling mills like, Table Rolls, Coiling Rolls, Leveler Rolls, De-scaler Rolls, Work Rolls, Backup Rolls, chain steels, hooks Oil & Gas Mud pump forgings, Body Block Forgings, Cross Forgings, Forged Valves.

11. Forgings. oil string Surface: Gate valve Body surface, casing head surface, shell surface, blow out preventor, Annular BOP for surface and sub-surface drilling

12. Sub Sea: Spool body, subsea Christmas tree, connector for sub sea drilling, Mandrel for sub sea Christmas tree,

13. Shale Gas: crankshaft for fraction pump, fluid end fraction pump, machined fluid end Thermal Power Plant High temperature fastener, valve forgings, turbine forgings, valves, pipes and fittings, hydraulic shafts, flanges, valve bodies and stems, tees, elbow reducers, saddles, rock cutter bits, drilling hardware, and high-pressure valves and fittings, shafts, Rotor, Turbine Shafts and others. valves, pipes and fittings, hydraulic shafts, steam turbine rotors [High Pressure, Intermediate pressure], steam turbine exciter shaft, heat exchanger tube sheet Hydro turbine Generator Shafts, Rotor, Turbine Shafts, fasteners

Besides above parts, High strength low alloy special bar quality steels are used to manufacture components/ parts for Windmills, Petro-Chemical, Aviation, Aero-space, Defense Nuclear industry Power Industry, Fertilizer plant, Windmill Main Shafts, wind turbine components, bearings and seamless tubes, transmission gear blanks, Transmission rings, crane wheel drives, gear box hollow shafts Chemical & Petrochemical Pressure vessel for crude refining, Shafts (Round and Square) in Fertiliser Plants, Refinery, Petrochemical, Cement, Sugar, Chemicals etc.

Application of Common Grades in Bar & Forgings: Cr-Ni steel, Cr-Mo steel, Cr-Mo-Ni steel, Cr-Mo-Ni-V steel, Boron/ Ti/ Nb added steel.

steel manufacturing process and through upgrades to its industrial ecosystem, India wants to join advanced steel making countries like Japan and South Korea. The decision is part of India's playbook of creating global manufacturing champions in India and bring the country on a par with global steel making majors such as South Korea and Japan. The aim is to help India specialty steel production reach 42 million tonnes (MT) by 2026-27.

In 2020-21, India imported 6.7 MT of steel, out of which 4 MT was specialty steel, worth INR 300 billion (US$4.04 billion). Through the PLI scheme, India wants to plug this gap in market demand by sourcing domestically and creating products for export. The PLI scheme is expected to draw investments worth approximately INR 400 billion (US$5.37 billion) and expand capacity of specialty steel by 25 million ton (MT), from 18 MT in 2020-21 to 42 MT in 2026-27. Apart from gaining technological know-how and boosting exports, the government also envisages the scheme will generate employment for over half a million people.

In related developments, the government recently approved an MoU between India and the Russian Federation on cooperation regarding coking coal that is used to make steel.

According to Union Minister of Steel, Ram Chandra Prasad Singh, steel is a deregulated sector in India. It is dominated by six major players – four in the private sector and two in the public sector. The private sector contributes about 86 percent of India's steel production and the public sector contributes about 14 percent.

Rules and guidelines for the PLI scheme released for specialty steel will benefit both major and secondary steel makers, such as MSMEs (downstream enterprises). (Ref: India Briefing – from Dezan Shira & Associates). PLI schemes announced so far related to production of specialty steel from Induction furnace.

Grade GroupWise Steel Production from Induction Furnace: Normally, steel produced from IF is categorized into four groups—Carbon steel (accounts for **85-90%** of total steel production in India and rest **10-15%** in the category of alloy & special steels). However, much usage of special steels in different industrial applications are High strength Low alloy steel which are alloyed with other elements, usually molybdenum, manganese, chromium, or nickel, in amounts of up to about 10% by weight to improve the yield strength, hardness, ductility, harden ability, of products and sections. This group contributes about 75-80% in alloy & special steels. In the steel industry, high-grade high-quality steel considered for stainless steel. However, the steel grades are grouped as:

1. **Carbon Steel (low, Medium, High) :** Owing to reliability, durability, versatility and strength, carbon steel is the ideal material for use in construction of large structures such as buildings, warehouses, bridges, reinforcing structures, columns, roofing, cladding, strengthening structures and exterior walls. Being important component in Reinforced Cement Concrete (RCC) buildings used in the form of rebar's of various diameters. High-rise tall buildings are being built with RCC. Industrial and commercial building construction segment has adopted all steel construction much better than residential segment by use of carbon steel due to the value of time saved by way of faster construction times, thereby facilitating earlier revenue flows.

3. **Case hardening Alloy Steel** – In this grade material processing method is used to increase the hardness of the outer surface of metal components. Case hardening results in a very thin layer of metal that is notably harder than the larger volume of metal underneath of the hardened layer.

4. **Steel for Hardening & Tempering** - Hardening and tempering of engineering steels is performed to provide components with mechanical properties suitable for their intended service. Steels are heated to their appropriate hardening temperature {usually between 800-900°C), held at temperature, then "quenched" (rapidly cooled), often in oil or water. This is followed by tempering (a soak at a lower temperature) which develops the final mechanical properties strength and ductility, relieves stresses.

The actual conditions used for all three steps are determined by steel composition, component size and the properties required for end applications. Hardening and tempering can be carried out in "open" furnaces (in air or combustion products), or in a protective environment (gaseous atmosphere, molten salt or vacuum) if a surface free from scale and de-carburization (carbon loss) is required ("neutral hardening", also referred to as "clean hardening").Two specialized quenching options can be applied in special circumstances: Mar tempering (also known as "mar quenching") uses an elevated-temperature quench (in molten salt or hot oil) which can substantially reduce component distortion.

This process is limited to selected alloy-containing steels and suitable section sizes. Aus tempering can be applied to thin sections of certain medium- or high-carbon steels or to alloy-containing steels of thicker section. It requires a high temperature quench and hold, usually in molten salt, and results in low distortion combined with a tough structure that requires no tempering. It is widely used for small springs and pressings. Hardening and tempering develops the optimum combination of hardness, strength and toughness in an engineering steel and offers the component designer a route to savings in weight and material.

Components can be machined or formed in a soft state and then hardened and tempered to a high level of mechanical properties. Hardening from open furnaces is often employed for products such as bars and forgings that are to be fully machined into components afterwards. Neutrally clean hardening is applied to components that require surface integrity to be maintained; examples include nuts, bolts, springs, bearings and many automotive parts. Neutral clean hardening is carried out under tightly-controlled conditions to produce a precision component needing the minimum of final finishing.

5. **Spring Steel** - Spring steel having high yield strength with unique ability to be formed, shaped, and post heat treated allowing to be a general use steel. High Temperature Steel

6. **Creep Resistance Steel** - Creep strength in the ferritic steels achieved by alloying with elements that will provide enhanced strength at high temperatures. Chromium (Cr) and molybdenum (Mo) are the two principal alloying elements but vanadium (V) and niobium (Nb) may also be added.

7. **Nitriding Steels** - Steel treated by a highly specialized surface hardening process known as nitriding that diffuses nitrogen into the surface of steel products to create a case-hardened surface. These

Production has been rising in recent years and the trend is expected to continue into 2022. Despite being the world's largest producer by far, China's production is seen constrained by State regulations; but elsewhere in the world production is set to rise. As a result, in 2022, world stainless steel production is forecast to set a record of 58.2 million tonnes (mt) registering a growth of 2.5 per cent, according to UK-based research institute MEPS that specializes in steel market.

All the above grade groups are safely and successfully produced from induction furnace taking various needed actions and measures. Induction furnace melting units are using different capacity furnaces for batch production on expectation of lot production against customers which varies normally ranging from 5-15T, though there are exceptions. These units are melting carbon and alloy steels which play vital role in various engineering/ manufacturing processes around the world. Products are further used in many other industrial applications working out conversion cost. In steel making, the non-linear characteristics, many times, cause huge disturbance during its operation affecting power quality degradation in the power system. The utilization part of melt cycle is most important factor for effective control of power consumption by proper planning and scheduling heats.

Production Cycle: Entire production cycle is mostly depending on melt cycle, the costliest operation inclusive of raw material, power cost heat finishing cost etc. where maximum power is continuously applied to the furnace for melting and charge is added when technology improvement improves melt shop performance. In melting shop, non-production cycle like temperature dip or analysis sample, waiting time for an analysis result and pouring the furnace for tapping to make the furnace empty. Thus, Production Cycle is the “melt cycle” and the “non-productive cycle”. Utilization is the “melt cycle” divided by the “production cycle” expressed as a percentage. If the melting cycle is of 50 minutes and the “non-production” cycle is of 40 minutes, then the “production cycle” is 90 minutes. The 50minute “melt cycle” divided by the 90- minute “production cycle” times 100 gives an “utilization” of 55%. This non-production cycle needs to be reduced to improve performance of IF unit.

Furnace Charge Preparation: Furnace Charge for producing high quality steel is the total charge comprising of scrap (properly segregated and analyzed preferably known composition), sponge iron, any scrap substitute like return scrap, recycled scrap, pig/ cast iron – known composition. The charge material should be weighed and charged manually or mechanized way to be properly fitted in the furnace otherwise time may be wasted for improper size. The initial furnace charging needs to be as quick as possible and of sufficient density to allow maximum power. The initial charge needs to be added to the furnace as quickly as possible. For optimum performance, the density should not be less than 1,750 kg per cubic metre and the furnace must be filled to level of 40-50% of furnace capacity. The slag produced during melting should be maintained as viscous which can be easily raked out. Mechanism for scrap heating from IF heat needs to be examined considering cost.

Rusty scrap should be avoided as much as possible, preferably keep in close scrap yard particularly in monsoon period. Rust is usually invasive and corrosive, eating and etching the metal. When acidic substances (including water) come in contact with scrap mainly stored in open yard, rust begins to form as a result of corroding steel after the iron (Fe) particles have been exposed to oxygen and moisture. How quickly steel rusts typically depends on how much steel is exposed to moisture and air, the levels of both

maximum use of elements already in the charge. Based on the feedback from a spectrograph and the furnace load cells, the computer will calculate the “trim” materials required. Once all the necessary data has been loaded, a computer system will generally provide all required information.

Modern power supplies automatically control the power being applied to the furnace as the condition in the furnace changes (Fig. 9). The goal is to get the energy into the charge as quickly and efficiently as possible. The power supply able to deliver maximum power throughout the “melt cycle”, always achieves the best melt rate. As the charge goes through “Currie”, the voltage applied to the coil is allowed to increase. This increase gives two advantages - it will influence power usage ensuring maximum kilowatts continuously applied to the coil. Secondly, a high coil voltage means that the voltage induced into the charge is higher. therefore, the contact heating in the charge is more efficient. Typically, this results in a ten percent improvement in the melting rate as compared to a power supply where the power draw drops as the charge passes through “Currie”. Melt cycle screen Computer systems are available which will help manage the “melt cycle. The final tapping temperature is entered into the display.

Composition Adjustment: Trim addition of ferro -alloys should be weighed and charged into the furnace. Immediately full power should be able to superheat the charge and create surface movement to increase the contact area. Entire melt cycle particularly trim addition, composition, superheating melt, melt weight and power consumption may be controlled with the help of computer.

Argon purging process is a method where rinsing of liquid steel in the teeming ladle is carried out through injection of inert gas into the steel bath. Argon (Ar) gas is preferred for rinsing since it is not only inert in nature but its solubility in steel is also very low, purging is carried out from ladle bottom to enhance reaction rates, eliminate thermal and composition gradients and remove non-metallic inclusions from the steel. In such a process, argon gas bubbles formed in the liquid steel move up to the slag-metal interface under the action of buoyant forces and finally reach the top layer of slag phase. The rising gas bubbles push the liquid steel up at local area, thereby inducing a turbulent re-circulatory flow enhancing the rate of chemical and thermal homogenization as well as accelerating the absorption of harmful non-metallic inclusions into an overlying slag phase. Addition of Bottom pouring and hot topping compound are carefully added during ingot teeming of liquid steel.

Conclusion: In the present competitive market where only quality and cost are the determinant factors for survival gaining overall performance, the production philosophy has been changed from the traditional and conventional ways of steel production Charge-Melt-Tap by induction furnace steel making units as simply conversion process of solid ferrous charge to liquid steel and shaping products for customers prir to 2000, but the concept has been changed to add values in each stage of operation. Now, there is challenges in front of IF steel making and processing units which demand improvement of activities focusing on improving quality and yield of product and process reducing loss/ wastage of materials. IF units may like to examine setting up of secondary refining facilities at their melt shop.

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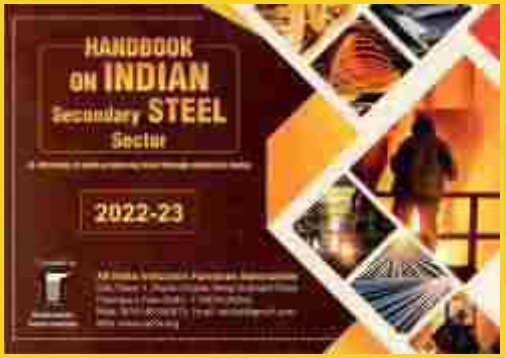

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Note: Price of Handbook Rs. 20,000/- exclusive of GST with effect from 1st April 2022