AIIFA SUSTAINABLE STEEL MANUFACTURERS ASSOCIATION

(FORMERLY KNOWN AS ALL INDIA INDUCTION FURNACES ASSOCIATION)

(Promoting Sustainability in Steel for Greener Future)

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What's Inside

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Low-Carbon Clean Steel Production by Induction Furnace

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Introduction:

As environmental awareness grows and sustainability becomes a key purchasing criterion, customers increasingly demand low-carbon, “clean” steel products. These products are characterized by a reduced carbon footprint, better air and water quality, and improved resource efficiency. The transition to such products is driven by stricter environmental regulations and consumer preference for eco-friendly solutions.

Steel produced through the **Induction Furnace (IF) route**, using recycled ferrous scrap and scrap substitutes, is emerging as a viable method for **low-carbon steel production**. This route has the potential to achieve near **100% carbon emission reduction** relative to traditional methods, outperforming even Electric Arc Furnace (EAF) technology, which achieves around 90% reduction. Both IF and EAF are significantly more efficient and environmentally sustainable than the conventional **Blast Furnace–Basic Oxygen Furnace (BF-BOF)** route.

Global Push for Decarbonization in Steel

With steel contributing approximately **6% of global CO_2 emissions** and **8% of energy-related emissions**, decarbonizing this hard-to-abate sector is imperative for achieving net-zero targets. Governments and industries globally are investing in decarbonization technologies, including:

- Hydrogen-based reduction
- Biomass substitution
- Carbon capture and storage (CCS)
- Renewable energy electrification

Despite innovation, **no single technology offers a complete solution**. BF-BOF, responsible for 71% of global production, remains the most challenging to decarbonize. In contrast, **DRI-EAF (5%)** and **secondary steelmaking through scrap (24–30%)**, including via EIF, offer better decarbonization pathways, particularly through electrification.

Key Challenges

The core challenges in decarbonizing steel include:

1. **Process Emissions**: CO_2 released during the chemical reduction of iron ore.
2. **High-Temperature Energy Needs**: Traditionally supplied by fossil fuels.
3. **Infrastructure Lock-in**: Long asset lifecycles of steel plants.
4. **Economic Pressures**: Small margins, labor politics, and global trade competitiveness.
5. **Rising Demand**: Despite climate concerns, global emissions continue to rise due to growing energy and material demand, particularly in industrial sectors like steel.

In India, this challenge is particularly acute as the industrial sector has grown rapidly over the last two decades (IEA, 2020), with steel being foundational to infrastructure, automotive, defence, and manufacturing.

India's Role and Strategic Shift

India ranks as the world's second-largest steel producer, and its growth is marked by an increase of 9.7% in 2024. Recognizing the need for sustainable practices, the Government of India is actively promoting:

- **Green Steel Mission**
- **National Green Hydrogen Mission (NGHM)**
- **India Green Steel Coalition (IGSC)**
- **Green Steel Taxonomy and Standards**

- **Support for EIF route and scrap utilization**
- **Investments in CCUS and renewable energy integration**

Global Benchmarking: Decarbonization Efforts by Leading Nations

- **Japan**: A pioneer in steel quality, Japan emphasizes lifecycle carbon reduction, including renewable energy use and carbon capture technologies.
- **European Union**: Aims for net-zero by 2050; transitioning to hydrogen-based steelmaking and boosting scrap recycling.
- **USA**: Benefits from EAF dominance and high recycling rates; government and private sectors accelerating low-carbon initiatives.
- **China**: Though often criticized for quality, it is aggressively scaling EAFs and hydrogen-based methods to meet its 2060 carbon neutrality goal.
- **Russia**: Has potential to convert DRI units to hydrogen and expand EAF capacity.
- **South Korea**: Supported by policy and industry players like POSCO, it is advancing hydrogen steelmaking and sustainable technologies.

Defining the Concepts

Green Steel

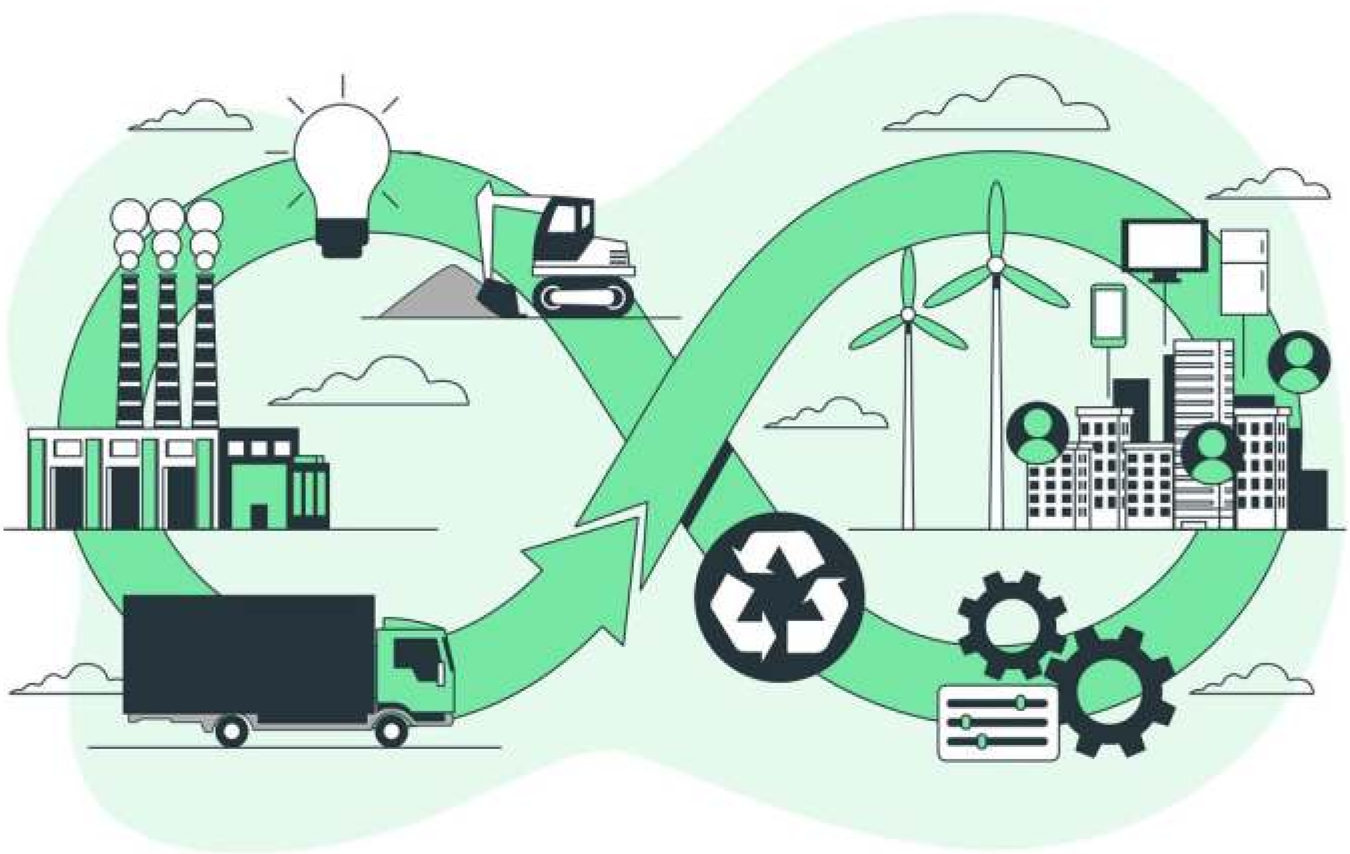
A holistic approach encompassing low-emission production processes, use of renewable energy, scrap recycling, and low-carbon logistics across the steel value chain. It aims to minimize the carbon footprint from raw material to final product.

Low-Carbon Steel

Refers to steel with a **low carbon content** (typically 0.05% to 0.30% by weight). It is mechanically favourable for forming and is used in a variety of applications but does not by itself imply clean production unless combined with sustainable manufacturing processes.

Clean Steel

Incorporates both **low-carbon composition** and **environmentally responsible production methods**. It often includes additional controls on impurities and emissions during production.



Conclusion: The Road Ahead

Induction Furnace-based steel production offers a compelling pathway for decarbonizing the Indian and global steel sectors. It combines **resource circularity (scrap-based input)** with **electrification potential**, making it one of the most adaptable and scalable solutions for near-term carbon reduction.

However, scaling this solution will require:

- Government policy support
- Financial incentives for clean tech adoption
- International cooperation on R&D
- Infrastructure upgrades for renewable power and green hydrogen
- A robust scrap collection and processing ecosystem

India's leadership in low-carbon EIF steel can become a global model—balancing industrial growth with environmental stewardship.

Advantages of Induction Furnace Steelmaking for Sustainability and Value Creation

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Introduction :

Globalization, economic growth, and a rapidly rising world population continue to place increasing pressure on natural resources. Recent studies indicate that current consumption patterns are unsustainable, raising concerns about the planet's ability to meet future demands.

Steel, however, stands out as one of the most sustainable materials known to mankind—permanent, infinitely recyclable, and the most recycled material globally. Investing in more sustainable steel production processes is a long-term commitment that delivers significant environmental benefits over the entire life cycle of green steel.

In particular, steel production through ferrous scrap using induction furnaces in the secondary sector presents compelling advantages. Compared to traditional blast furnace methods, this route significantly reduces energy consumption, lowers emissions, and conserves natural resources—thus contributing to cleaner products and a more circular economy.

Cleaner steel production focuses on minimizing environmental impact by enhancing resource efficiency and preventing pollution at its source. The cleaner production approach is not limited to environmental strategies alone; it also brings considerable economic and social benefits. These include:

- Reduced resource utilization and operating costs.
- Decreased waste generation, wastewater discharge, and emissions.
- Lower costs for waste treatment and disposal.
- Improved environmental performance and compliance with regulations.
- Enhanced productivity and operational efficiency.
- Strengthened competitive advantage in domestic and global markets.

India's steel industry today utilizes three main production routes: the Blast Furnace–Basic Oxygen Furnace (BF-BOF) route, Electric Arc Furnace (EAF), and Electric Induction Furnace (EIF). Steel produced through electric routes is often in batch mode, resulting in ingots or continuously cast billets, blooms, or rounds, which are then processed through forging or rolling.

Among these, induction furnace-based steelmaking has emerged as a sustainable and value-driven alternative. It offers lower carbon emissions, greater energy efficiency, and superior scrap recycling capabilities. Moreover, it enables precise temperature control and faster melting cycles—making it both economically viable and environmentally responsible.

Sustainability & Value Creation Benefits of Induction Furnace Steelmaking

Induction furnace (IF) steelmaking offers a range of environmental, operational, and economic advantages that align with global goals for sustainability and value creation. Key benefits include:

1. Reduced Carbon Emissions

Induction furnaces operate using electricity rather than fossil fuels, resulting in significantly lower direct emissions of carbon dioxide (Co), nitrogen oxides (NO_x), and other pollutants compared to conventional blast furnace-based methods.

2. Enhanced Energy Efficiency

Induction furnaces are highly energy-efficient, with studies showing notable reductions in energy consumption per ton of steel. Their ability to convert electrical energy directly into heat minimizes energy loss and boosts overall efficiency.

3. High Scrap Recycling Capability

Well-suited for melting and refining steel scrap, induction furnaces support circular economy principles by reducing dependence on virgin raw materials and maximizing resource efficiency.

4. Integration with Renewable Energy

Since induction furnaces are powered by electricity, they can seamlessly integrate with renewable energy sources like solar or wind power, further decreasing the carbon footprint of the steel production process.

5. Lower Water Consumption

Compared to other steelmaking processes, induction furnaces typically consume less water, contributing to reduced environmental impact and compliance with water conservation goals.

Productivity & Quality Control Benefits

1. Precise Process Control

The relatively straightforward melting process in induction furnaces allows for precise control over temperature and alloy composition, resulting in consistent and high-quality steel output.

2. Increased Productivity

Induction furnaces offer faster heating and melting cycles compared to traditional steelmaking methods, leading to shorter turnaround times and higher throughput.

3. Reduced Production Costs

Efficiency in energy use, reduced raw material requirements, and lower environmental compliance costs contribute to overall cost savings in steel production.

4. Versatility in Steel Grades

Induction furnaces are capable of melting and alloying a wide range of steel grades, making them suitable for diverse and specialized industrial applications.

5. Scalability & Flexibility

Induction furnace technology is easily scalable, making it ideal for both small-scale and large-scale operations. This scalability ensures adaptability to varying production demands and market requirements, including shorter lead times.

Key Cost Drivers in Induction Furnace Steelmaking

The operational costs associated with induction furnace steelmaking are influenced by several key factors. These cost drivers impact the overall efficiency, product quality, and profitability of the process. The primary cost drivers include:

1. Raw Materials

- **Scrap Metal**: A major feed material, the price and quality of scrap directly impact the cost of production.
- **Sponge Iron**: Used in cases where scrap availability is limited, adding to the raw material cost.
- **Ferroalloys (Fe-Alloy)**: Essential for alloying, these materials contribute to both cost and the desired steel properties.

2. Energy (Electricity)

- Induction furnaces rely on electricity for melting and refining, making electricity cost and availability a significant driver of operating expenses.

3. Refractory Materials

- Refractories used for furnace lining are critical for maintaining process integrity. Their quality, cost, and lifespan influence overall maintenance and operational costs.

4. Labor

- Skilled labor is necessary for operating induction furnaces efficiently. Labor costs are influenced by the complexity of the process and the need for specialized workers.

5. Product Quality & Yield

- Achieving high-quality output and maximizing yield from raw materials contribute to cost-efficiency, reducing material wastage and optimizing production.

6. **Customer Satisfaction**

- Consistently meeting customer demands for high-quality steel at competitive prices fosters strong business relationships and enhances market positioning.

Advantages of Induction Furnace Steelmaking

Induction furnace technology offers several operational advantages, making it an attractive option for producing high-quality, sustainable steel. The key benefits of IF steelmaking include:

1. **Capability to Melt Any Steel Grade**

- Induction furnaces are versatile, capable of melting a wide range of steel grades to meet international standards.

2. **High Material Yield**

- Induction furnaces achieve high yield from feed materials, maximizing resource efficiency and reducing raw material costs.

3. **Excellent Process Control**

- Induction furnaces provide precise control over the melting and alloying processes, ensuring consistent product quality and minimizing defects.

4. **Low Environmental Impact**

- Induction furnace operations are environmentally friendly, producing minimal emissions and ensuring cleaner workplaces, which aligns with global sustainability goals.

5. **Reduced Power Infrastructure Requirements**

- IF operations require less power infrastructure compared to traditional methods, making them viable in regions with limited energy resources.

Induction furnace steelmaking stands out as a sustainable, cost-efficient, and environmentally responsible method of steel production. The key cost drivers, including raw materials, energy, and labor, significantly influence the overall efficiency and competitiveness of the process. The advantages of IF steelmaking, such as its ability to handle various steel grades, high yield, precise process control, and low environmental impact, make it a preferred choice for modern steel producers seeking to meet both economic and sustainability goals.

Heat Losses in Induction Furnace (IF) Melting and Solutions to Minimize Losses

Induction furnace (IF) melting, while efficient, involves several heat loss mechanisms that can impact overall energy consumption and operational efficiency. Identifying and addressing these losses can lead to significant improvements in furnace performance and cost-effectiveness. Below are the primary heat losses in IF melting along with potential solutions to mitigate each loss:

1. **Heat Loss from Furnace Gases**

- **Description**: Furnace gases, including hot flue gases, are emitted from the top of the furnace during the melting process, carrying away a significant amount of heat.
- **Solution**:
  - **Improved Gas Management**: Installing heat recovery systems, such as air-to-air heat exchangers or waste heat recovery boilers, can capture the heat from the gases and use it for preheating combustion air or water, improving overall energy efficiency.
  - **Furnace Top Sealing**: Enhancing furnace top sealing to reduce gas leaks can help contain heat inside the furnace.

2. **Radiation Loss from Furnace Top**

- **Description**: Heat radiates from the top of the furnace due to the high temperatures involved in the melting process, contributing to energy loss.
- **Solution**:
  - **Thermal Insulation**: Installing reflective or insulating materials on the furnace top can reduce radiation loss by reflecting heat back into the furnace.

- **Advanced Furnace Design**: Modifying furnace design to include better heat containment features or reducing the exposed surface area can also mitigate radiation loss.

3. Conduction Loss from Refractory Lining

- **Description**: Heat is conducted through the furnace's refractory lining, transferring heat to the external shell and surrounding environment.
- **Solution**:
  - **High-Quality Refractories**: Using high-performance, low-conductivity refractories can reduce heat loss due to conduction. These materials should have a good thermal resistance to ensure minimal heat leakage.
  - **Insulation Layers**: Adding an insulating layer between the refractory lining and furnace shell can help retain more heat inside the furnace.

4. Radiation Loss from Furnace Body

- **Description**: The sides and body of the furnace radiate heat into the surrounding environment, which can be a significant loss at high operating temperatures.
- **Solution:**
  - **Insulating Furnace Body**: Applying thermal insulation or refractory coatings to the furnace body can minimize heat radiation and enhance overall thermal efficiency.
  - **Optimized Furnace Size and Shape**: Reducing the furnace surface area or optimizing its shape can help decrease the amount of heat lost through radiation.

5. Heat Loss in Cooling Water of the Coil

- **Description**: The water-cooled coils absorb heat from the furnace to maintain safe operational temperatures, leading to heat loss in the cooling system.
- **Solution**:
  - **Closed-Loop Cooling System**: Implementing a closed-loop cooling system can minimize the amount of heat lost to the external environment, as water can be recirculated and cooled more efficiently.
  - **Heat Exchange**: Installing heat exchangers to recover some of the heat from the cooling water before it is discarded can help reuse this energy, improving overall efficiency.

6. Heat Carried Over During Slag Removal

- **Description**: During the slag removal process, a portion of the heat from the molten metal is carried away along with the slag.
- **Solution**:
  - **Minimize Slag Volume**: Optimizing slag formation and removing it at the right time can reduce the amount of heat carried away with it.
  - **Enhanced Slag Removal Techniques**: Implementing more efficient slag removal techniques, such as using automated systems or controlling slag volume through better furnace control, can reduce heat losses during this phase.

Overall Recommendations to Minimize Heat Losses:

- **Optimize Furnace Design**: Improved furnace insulation, better sealing, and advanced refractory materials can significantly reduce heat loss.
- **Heat Recovery Systems**: Invest in waste heat recovery and thermal management systems to capture and reuse lost heat, reducing the overall energy demand.
- **Process Optimization**: Implementing better process controls and advanced technologies can help to maintain optimum temperatures and minimize unnecessary heat losses.

By addressing these heat loss mechanisms with targeted solutions, the induction furnace's overall energy efficiency can be greatly improved, leading to lower operational costs, reduced carbon footprint, and enhanced production performance.

Steel Power Factor in Induction Furnace Steelmaking

Indian induction furnace melting units typically utilize medium-frequency (MF) coreless induction furnaces, which feature highly conductive copper coils and transformer sheet lamination yokes. These furnaces can achieve efficiencies exceeding 80% in steel melting.

In a coreless induction furnace, a ceramic crucible is placed within a cylindrical copper coil. The electric current flowing through the copper coil generates an electromagnetic field, which induces eddy currents in the furnace charge. The resistance to these eddy currents (ohmic losses) generates heat, which melts the charge. This process effectively converts electrical energy into heat for steel production.

The **power factor** in induction furnaces is a key indicator of how efficiently electrical power is converted into useful work. It is defined as the ratio of **real power** (measured in watts) to **apparent power** (measured in volt-amperes). In a coreless induction furnace, the power factor is influenced by the inductive properties of the coil and the absence of a magnetic core.

A power factor close to unity (typically in the range of **0.7 to 0.85**) is crucial for optimal energy utilization in induction steelmaking. A higher power factor indicates that most of the electrical energy is being used efficiently for melting the charge, reducing electricity consumption and improving overall furnace performance. Conversely, a low power factor leads to higher current consumption, increased energy losses, and the potential for penalties from utility providers due to inefficient power usage.

S & P Problems in Steel Products

Customers generally consider high levels of Sulphur (S) and phosphorus (P) in steel as undesirable due to their negative impact on steel properties. Sulphur is regarded as an impurity that can adversely affect strength, ductility, and toughness, potentially causing brittleness and decreased performance. It forms brittle iron Sulphide (MnS) inclusions in the steel matrix, which act as stress concentrators. These inclusions hinder the steel's ability to deform plastically under stress, leading to reduced ductility and toughness. High Sulphur content can make steel brittle, especially at elevated temperatures (red heat), increasing its susceptibility to cracking and failure under stress.

Sulphur can also negatively affect weldability by forming Sulphur-rich inclusions at the weld interface, weakening the weld joint and making it more prone to cracking. Additionally, Sulphur can promote the formation of Sulphide compounds, which are more susceptible to corrosion, thus reducing the steel's corrosion resistance, particularly in certain environments.

While small amounts of Sulphur can enhance machinability by forming MnS inclusions that break chips during machining, excessive Sulphur can compromise other key properties. For machinable steel grades designed for small chip formation, a Sulphur content of 0.10% to 0.30% is typically used, improving machinability by facilitating chip breaking through manganese Sulphide inclusions.

Customers requiring steel products with a maximum Sulphur content of 0.020% often come from industries needing high-quality steel for applications demanding excellent weldability, machinability, and corrosion resistance. These industries include:

- **Automotive**: High-strength low-alloy (HSLA) steel, ultra-high-strength steel for load-bearing applications.
- **Aerospace**: Components requiring lightweight, strong materials with excellent weldability and corrosion resistance.
- **Construction & General Manufacturing**: Steel used in diverse applications where quality and performance are essential.

Certain steel grades, such as specific types of stainless steel, are designed to have very low

Sulphur and phosphorus levels to enhance corrosion resistance and other critical properties. For example, austenitic stainless steels (e.g., 310 or 317) typically have Sulphur and phosphorus levels below 0.003%. Other steel grades, like those used for tin mill black plates or truck cross members, also require low residual elements, including Sulphur, with internal specifications ranging from 0.010% to 0.020%, depending on the application.

To reduce Sulphur content in liquid steel from 0.04% to 0.02%, lime (CaO) is typically added to the steelmaking process. This aims to achieve a slag basicity that binds Sulphur as calcium Sulphide (CaS) and removes it from the steel. The amount of lime added varies depending on factors such as the initial Sulphur content, slag composition, and steelmaking process. However, approximately 6-7 kg of lime per ton of steel is usually added during tapping to reach the desired slag basicity and effectively lower Sulphur levels.

Sulphur Removal in Ladle Refining Process

Desulphurization in the Ladle Refining Furnace (LRF) is a critical step in secondary steelmaking to reduce Sulphur content in liquid steel, improving its mechanical properties and corrosion resistance. The process involves the transfer of Sulphur from molten steel to the slag phase using specific sulphurising agents and optimized process conditions.

Mechanism of Desulphurization in LRF

Sulphur is removed from the molten steel by chemical reactions with basic oxides such as **lime (CaO)** or **magnesium (Mg)**. These agents form compounds with Sulphur, producing a Sulphide-rich slag that can be easily separated. A typical desulphurization reaction is:

S (in steel) + **CaO** (in slag) → **CaS** (in slag)

To enhance reaction efficiency:

- **Argon or nitrogen gas stirring** is employed to improve mixing and facilitate the transfer of Sulphur to the slag.
- A **high-basicity slag** is maintained to maximize Sulphur absorption.
- **Controlled temperature** in the ladle is essential to ensure favourable thermodynamics for desulphurization.
- Use of **electromagnetic stirrers** or **argon bubbling** helps in better distribution and reaction kinetics.

Phosphorus and Other Impurity Control

Besides Sulphur, controlling elements like **phosphorus** and **carbon** is essential for achieving desired mechanical properties such as **corrosion resistance**, **weldability**, and **machinability** in steels. Certain steel grades, especially structural carbon steel tubes and low-alloy steels, require phosphorus levels to be maintained at **0.020% max**. These specifications also apply to alloy steel pipes, flanges, fittings, forgings, fasteners, and valves.

According to studies (e.g., ISROSET), **6–7 kg/ton of lime** is typically added during ladle tapping to attain optimal slag basicity for effective desulphurization and slag conditioning.

De-Sulphurisation in Induction Furnaces and Use of Synthetic Slag

Currently, approximately **40% of global steel production** is through **Induction Furnace (IF) routes**. However, IF-produced steel often has **high Sulphur content**, reaching up to **0.06% or more**, which is unsuitable for structural applications.

To address this, **synthetic slag** has been developed for Sulphur removal in induction furnaces. The design of this slag considers:

- **Sulphide capacity**
- **Sulphur partition ratio**
- **Viscosity and liquidus temperature**
- **Solubility of slag components**
- **Basicity**

The optimized composition of synthetic slag typically includes:

- **20–30 wt% SiO**
- **5–20 wt% Al O**
- **40–60 wt% CaO**
- **5–10 wt% MgO**

Performance of Synthetic Slag in IF

- For **Al-killed steels**, desulphurization efficiency can reach up to **84%** with **2–3 wt% synthetic slag** addition.
- For **non-killed steels**, a desulphurization rate of **32%** is achieved.
- Target Sulphur levels of **0.03–0.04%** can be reached within **10 minutes** using synthetic slag.
- The **Sulphur partition ratio** and **Sulphide capacity** improve with increased **basicity** of the synthetic slag.

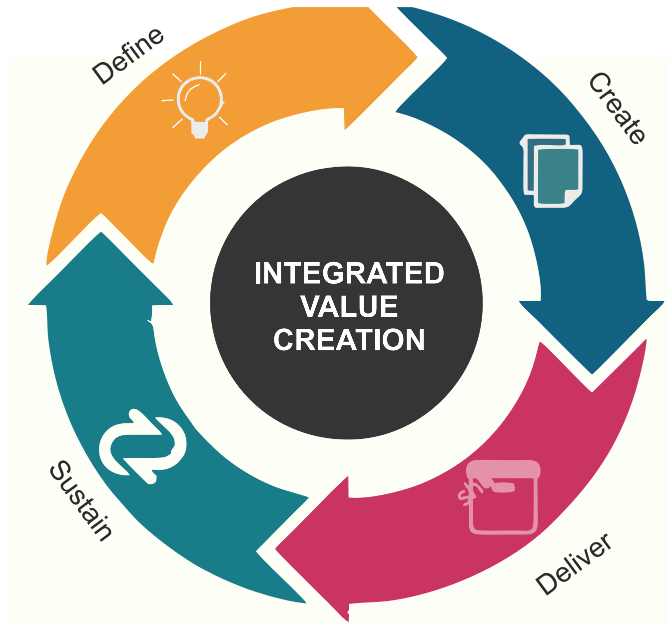
This combination of process optimization, material control, and slag engineering forms the foundation of effective Sulphur reduction in both LRF and IF routes, enabling the production of high-quality, low-Sulphur steels suitable for critical applications.

Sustainable Value Creation

Value creation in the context of sustainable steelmaking is driven by transformation and flexibility in adopting environmentally responsible practices. The implementation of sustainable processes in Induction Furnace (IF) steel production enables the identification and development of key elements that contribute to long-term value creation, primarily through in-depth production analysis.

Sustainable steel production using IF technology highlights several critical factors that support the achievement of these value creation goals. These elements not only contribute to operational efficiency and environmental compliance but also become defining attributes of a company's competitive advantage in the market.

Furthermore, strategic partnerships and collaborative efforts play a vital role in enhancing value creation. Such alliances foster innovation, resource optimization, and shared expertise—ultimately increasing the company's ability to remain competitive in a dynamic industrial landscape.



Integrated Value Creation Model in Steel Production

Conclusion:

Steel production must prioritize optimizing energy efficiency and utilizing high-quality recycled scrap that is free from residual or harmful elements that could degrade the final steel quality. Minimizing waste generation throughout the production process is essential. It is equally important to assess the sources of electricity and heat used in melting and hot working operations, with a focus on improving resource efficiency and reducing waste.

Management of Induction Furnace (IF) units should consider integrating a matching Ladle Refining Furnace (LRF) alongside the melting furnace. This would enable effective desulphurization, reducing sulphur levels to as low as 0.01%, which has become a critical requirement across many industrial applications.

For the production of special or highly critical steel grades, collaboration with nearby technical institutes is recommended to explore advanced solutions and ensure high-quality output.

AIIFA Signs Landmark MoU with IIT Bombay to Advance Sustainable Steel Manufacturing

Chhatrapati Sambhajinagar, Maharashtra – In a pivotal move to promote sustainable steel production through electric furnace technology, the AIIFA Sustainable Steel Manufacturers Association has signed a landmark Memorandum of Understanding (MoU) with the Indian Institute of Technology Bombay (IIT Bombay). The collaboration aims to strengthen recycling-based steelmaking and contribute to India's twin goals of environmental stewardship and enhanced steel output.

The AIIFA represents a significant cluster of steel manufacturers from Jalna and the broader Marathwada region—home to one of India's fastest-growing electric furnace-based steel industries. This partnership with IIT Bombay is seen as a strategic step toward solving critical technological challenges and driving innovation across the sector.

Speaking on the occasion, **Shri Yogesh Mandhani**, President of AIIFA, stated, "This collaboration is the result of two years of groundwork, including extensive industrial visits by IIT Bombay's faculty and research teams to understand the practical realities and opportunities in our member units. Through the MoU framework, our industries will present their technical and innovation needs to IIT Bombay, which will assign expert teams to co-develop cutting-edge solutions aimed at improving efficiency, quality, and safety in steel production."

He further emphasized that the initiative marks the beginning of a long-term, high-impact alliance. "As India targets an ambitious 300 million tons of steel production by 2030, sustainable and high-quality steelmaking is no longer optional—it is essential. This MoU aligns perfectly with the national vision of *Make in India* and *Atmanirbhar Bharat*, and reinforces our mission to make India a global leader in steel," he added.

Industry leaders and association members also highlighted that the collaboration is a response to the Ministry of Steel's growing emphasis on fostering R&D and robust academia-industry partnerships.

"This partnership with one of the country's most prestigious technical institutions will help unlock new pathways for sustainable growth, technological self-reliance, and global competitiveness. We also welcome similar collaborations with premier institutes across India to build a resilient and innovative steel ecosystem," Mandhani concluded.

Timely Service-Oriented Equipment Maintenance: A Strategic Enabler for Sustainable Steelmaking in Mini Steel Plants Using EIF & EAF Technologies

Prabhakar Mishra, Sr. Executive Director, AIIFA

Introduction

Mini steel plants (MSPs) in India are pivotal to decentralized steel production, primarily employing Electric Induction Furnaces (EIFs) and Electric Arc Furnaces (EAFs) for melting steel scrap and sponge iron/DRI to produce liquid steel. This is followed by ingot or continuous casting and subsequent processing through rolling or forging units. These units contribute significantly to India's steel output, especially in meeting the growing demand for specialty and construction-grade steels.

To sustain competitiveness and meet national environmental targets, ensuring high equipment availability through proactive maintenance strategies is essential. Timely service and upkeep of melting and downstream equipment are critical to reducing operational downtime, optimizing energy consumption, ensuring personnel safety, and improving overall plant efficiency—key drivers of sustainable steel production.

Importance of Equipment Maintenance in EIF & EAF-Based Operations

Effective maintenance is central to the uninterrupted and efficient operation of steel melting and processing units. In the context of EIF and EAF-based steelmaking, systematic maintenance yields the following benefits:

- **Operational Reliability:** Prevents unscheduled outages and stabilizes production cycles.
- **Energy Optimization:** Maintains furnace efficiency, reducing energy input per ton of steel.
- **Asset Longevity:** Extends equipment life, reducing frequent capital reinvestment.
- **Process Consistency:** Supports uniform metallurgical quality and reduces process deviations.
- **Workplace Safety:** Minimizes risks of hazardous events such as explosions, electrical faults, or refractory failures.

Advantages of Electric Furnace Steelmaking (EIF & EAF)

The EIF and EAF technologies offer distinct advantages aligned with India's decarbonization roadmap:

1. **Low CAPEX Footprint:** Requires less capital and infrastructure than integrated steel plants.
2. **Environmentally Cleaner:** Electric melting significantly curtails GHG emissions and pollutants.
3. **Raw Material Versatility:** Capable of utilizing steel scrap, sponge iron, and DRI, with strong domestic availability.
4. **Localized Production:** Allows for plant setup near consumption centers, reducing logistics costs.
5. **Modular Scalability:** Ideal for specialized production in flexible, small-batch operations.
6. **Green Transition Compliance:** Supports India's climate goals through efficient, cleaner production models.

Technical Distinctions: Induction Furnaces (EIFs) vs. Arc Furnaces (EAFs)

Induction Furnaces (EIFs)

- **Rapid Heating:** Electromagnetic induction provides fast and uniform heating profiles.
- **Enhanced Temperature Control:** Enables fine control for alloy steel and specialty grades.
- **Low Emissions:** Lower noise and particulate emissions contribute to better working conditions.
- **Efficient for Batch Melts:** High energy utilization efficiency for smaller batch operations.

Electric Arc Furnaces (EAFs)

- **High-Volume Capability:** Suitable for large-scale operations with high steel throughput.
- **Material Flexibility:** Efficient for melting high scrap-content charges.
- **Alloy Recovery:** Offers better alloy recovery in large-scale metallurgy.
- **Advanced Automation Integration:** Compatible with AI/IoT for process optimization.

Common Technical Challenges and Maintenance Imperatives

For Induction Furnaces (EIFs):

1. **Uneven Heating:** Often due to inductor coil wear, improper power tuning, or load mismatch.
2. **Refractory Degradation:** Accelerated by thermal shocks and corrosive slags.
3. **Electrical Failures:** Inverter malfunctions, capacitor degradation, and switching failures.
4. **Slag Accumulation:** Poor slag control affects yield and lining life.
5. **Bridging & Explosions:** Caused by charge density issues and moisture-induced thermal shocks.

For Electric Arc Furnaces (EAFs):

1. **Electrode Management:** Excessive consumption due to poor arc regulation or oxidation.
2. **Refractory Wear:** Especially at slag lines and tap holes due to aggressive thermal cycling.
3. **Skull Build-Up:** Solidified metal reduces effective furnace capacity.
4. **Power System Instability:** Inefficient harmonics control affects arc stability.
5. **Environmental Nuisances:** Noise, fumes, and dust emissions require rigorous abatement measures.

Operational Gains from Timely and Systematic Maintenance

- **Higher Plant Availability:** Ensures better utilization of installed capacity.
- **Productivity Enhancement:** Reduces unplanned outages and improves process efficiency.
- **Cost Optimization:** Decreases repair and energy costs by mitigating avoidable failures.
- **Extended Asset Lifespan:** Protects furnace and ancillary equipment investment.
- **Compliance & Safety Assurance:** Supports adherence to environmental and safety regulations.

Strategic Recommendations for Sustainable Equipment Maintenance

1. **Adopt Predictive Maintenance Technologies:** Use infrared thermography, vibration sensors, and AI-based diagnostics to predict failures before they occur.
2. **Upskill Workforce:** Develop technical proficiency in condition monitoring and root cause analysis.
3. **Standardize Maintenance Protocols:** Define SOPs for daily checks, periodic maintenance, and annual overhauls.
4. **Ensure Inventory Readiness:** Maintain critical spares stock (e.g., capacitors, electrodes, refractory bricks).
5. **Implement Digital Maintenance Systems:** Utilize CMMS (Computerized Maintenance Management Systems) for tracking equipment performance and maintenance history.

Conclusion

Robust and service-oriented maintenance practices are non-negotiable for sustaining the operational integrity and environmental compliance of mini steel plants utilizing EIF and EAF technologies. Preventive and predictive maintenance not only extends equipment life but also reinforces India's ambition to transition to low-carbon, resource-efficient steel production. With optimized service regimes, mini steel plants can emerge as agile, clean, and globally competitive players in the evolving steel landscape.

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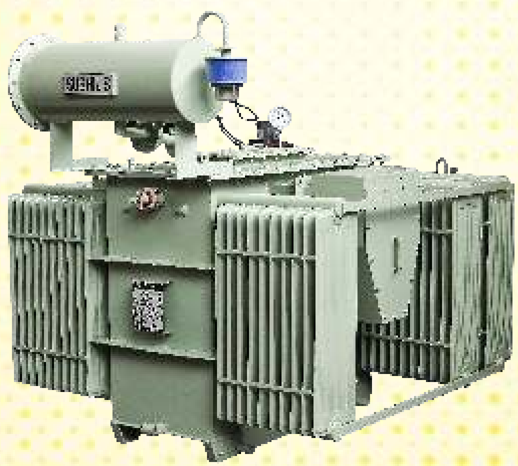
Scrap Lifting Circular Electro Magnet - PLC Controlled

Ladle and Sintering Preheater with Bottom Heater



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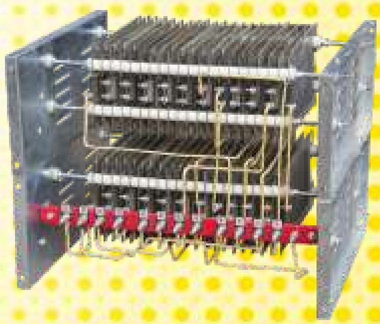

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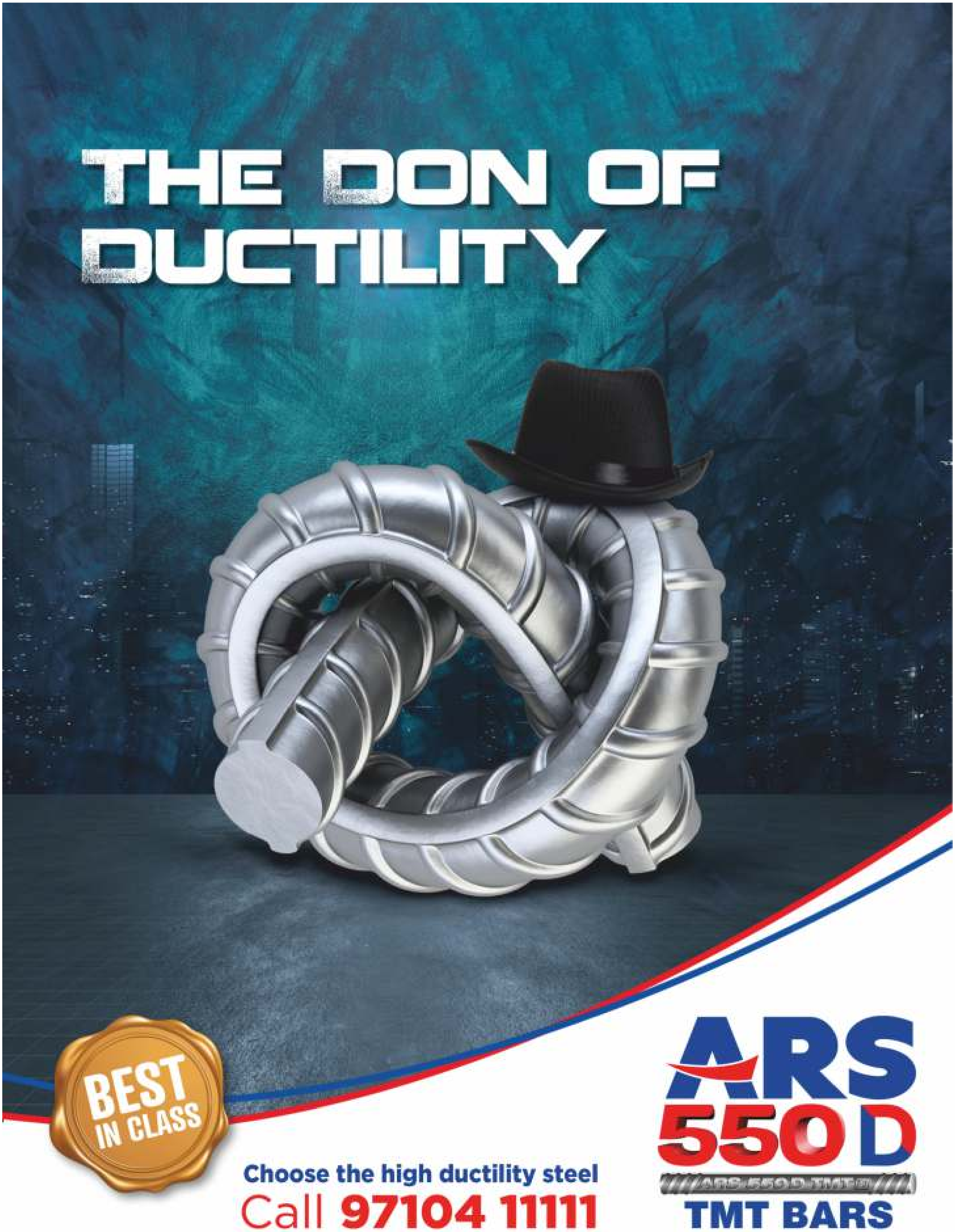
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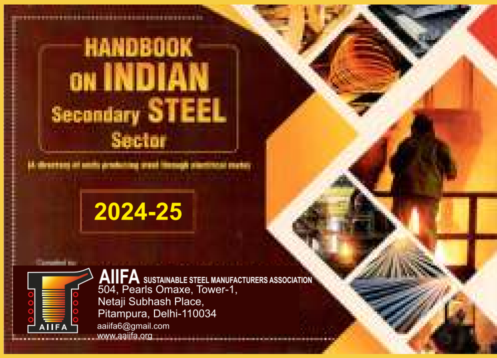

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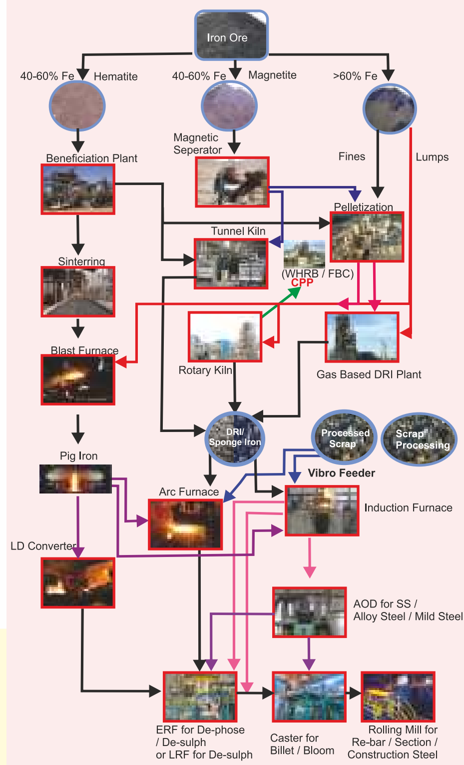

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