



IIM
Metallurgy
Materials Engineering

MET INFO

AUGUST 2025



The Indian Institute of Metals Delhi Chapter

**Jawahar Dhatu Bhawan
39 , Tughlakabad Institutional Area, M B Road
Near Batra Hospital, New Delhi-110 062**

Tele: 011-29955084

@ iim.delhi@gmail.com



www.iim-delhi.com

An Inhouse Publication

For internal Circulation Only

CONTENTS

	Description	Page
1	IIM Delhi Chapter Executive Committee: 2025-26	3
2	IIM Delhi Chapter Executive Committee Members: Contact details	4
3	Copper Smelting Technology Trends	5
4	Steel v/s Carbon Fibre	9
5	Robotics and AI in Modern Steel Manufacturing	10
6	Coking Coal Export Import Projections	21
7	Carbon Clean Launches Global Innovation Centre in India	21
8	Cleaner Ironmaking Options - As US firms Retreat from Green Steel	23
9	Press Hardening Steel Grades: Unlocking Strength Through Innovation	26
10	Chemistry Wall Clock	31
11	Tensile Testing: Engineering Stress-Strain Curves vs. True Stress-Strain Curves	31
12	Recycling Critical to self-reliance	36
13	Institution of AC Wadhawan Memorial Lecture by IIM Delhi Chapter	37
14	India Steel Conclave 2025 – <i>Enhancing Steel Demand to 500 MT for Viksit Bharat</i>	38
15	Chapter Relations Committee Meeting and Annual General Meeting of IIM	38
16	India's Macroeconomic Indicators	38
17	Know Your Members	39

The material and information contained here are for general information purpose only. We have given source of information, wherever possible. While we make every endeavour to keep the information accurate and correct, we do not take any responsibility of correctness, accuracy and reliability with respect to information contained in the newsletter.

Editor-in-Chief	R. K. Vijayavergia
Associate Editors	R. K. Singhal, Chandana Arjun
Consulting Editor	S. C. Suri

IIM DELHI CHAPTER
EXECUTIVE COMMITTEE: 2025-26



Manoranjan Ram
Chairman



Deepak Jain
Vice Chairman



K R Krishnakumar
Hon. Secretary



R K Narang
Hon. Treasurer



M P Sharma
Hon. Jt. Secretary



Ms Chandana Arjun
Hon. Jt. Secretary

Members



K K Mehrotra



R K Vijayavergia



N K Kakkar



Dr. Ramen Datta



N Vijayan



G I S Chauhan



B R Jain



R K Singhal



R K Sinha



Neeraj Nautiyal



Vijay Gupta



Ashok Kumar

Special Invitee



Prof. S Basu

Executive Committee Members: Contact Details

Name / Designation	Affiliation	Contact No / E-Mail
Shri Manoranjan Ram <i>Chairman</i>	Vice President – Sales & marketing Danieli Group	9910014989 manoranjanram@yahoo.com m.ram@danieli.com
Shri Deepak Jain <i>Vice Chairman</i>	Former Dy. Director General (W) BIS	9868640986, 8368622619 deepakjain7177@gmail.com
Shri K R Krishnakumar <i>Hon. Secretary</i>	Ex CGM SAIL & Former Consultant, Ministry of Mines	9818277840; 01202773861 kuduvak059@gmail.com kuduvakrishna@yahoo.co.in
Shri Ramesh Kumar Narang <i>Hon. Treasurer</i>	Former Head (Corporate Affairs) BALCO New Delhi	9899298857 rknarang62@gmail.com
Shri M P Sharma <i>Hon. Jt. Secretary</i>	Scientific & Technical Consultant Aluminium Industries	9212202084; 9818508300 aluminiumconsultant@yahoo.com afimps@rediffmail.com
Ms Chandana Arjun <i>Hon. Jt. Secretary</i>	Manager - Design Technotherma India Pvt. Ltd	8547621796 chandanaacalicut@gmail.com
Shri K K Mehrotra <i>Member</i>	Ex CMD MECON Limited	9868112514; 01203645267 kishorekmehrotra@gmail.com
Shri R K Vijayavergia <i>Member</i>	Ex Executive Director (Operations), SAIL & Former Consultant, SRTMI	9650155544 rk.v.sail@gmail.com
Shri N K Kakkar <i>Member</i>	Former Vice President Somani Kuttner India Pvt. Ltd.	9871008505 nirmalkakkar@gmail.com
Dr. Ramen Datta <i>Member</i>	Ex General Manager, RDCIS, SAIL & Former Consultant, SRTMI	9958084110 dattaramen@gmail.com
Shri N Vijayan <i>Member</i>	Director Technotherma India Pvt. Ltd.	9818695690 technothermaindia@gmail.com
Shri G I S Chauhan <i>Member</i>	Ex Executive Director I/c, RDCIS, SAIL	9717302437; 7048993116 gisc.delhi@gmail.com
Shri B R Jain <i>Member</i>	Sr. Adviser Engineering Council of India	9313190011 jainbinay@gmail.com brjeci@gmail.com
Shri R K Singhal <i>Member</i>	Consultant, SRTMI & Ex Executive Director (Corporate Affairs), SAIL	9910055630 rksh.singhal@gmail.com
Shri R K Sinha <i>Member</i>	Ex Director (Operations) Modern Steels Ltd	8968684955 rksinha555@gmail.com
Shri Neeraj Nautiyal <i>Member</i>	Senior Vice President Yogiji Digi Pvt Ltd	9811956565 nautiyal_n@yahoo.co.in
Shri Vijay Kumar Gupta <i>Member</i>	Ex Director (Engg.) AIR & DD, New Delhi	9810135561 vijay_gupta_m@yahoo.com
Shri Ashok Kumar <i>Member</i>	Ex General Manager SAIL, New Delhi	8076904331 akdel12@gmail.com
Prof. Suddhasatwa Basu <i>Special Invitee</i>	FIPI Chair Prof. (HAG) IIT Delhi	7838134181 drsbasu@gmail.com

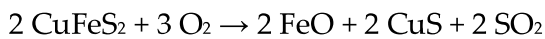
Copper Smelting Technology Trends

A HISTORY OF COPPER PROCESSING

Pyrometallurgy involves the treatment of ores at high temperature to convert ore minerals to raw metals, or intermediate compounds for further refining. Roasting, smelting and converting are the most common pyrometallurgical processes.

Roasting

Historically, copper concentrates have undergone roasting treatment processes. The roasting process is generally undertaken in combination with reverberatory furnaces. In the roaster, the copper concentrate is partially oxidised to produce "calcine" and sulphur dioxide gas. The stoichiometry of the reaction that occurs is:



Roasting is no longer common in copper concentrate treatment due to its use of energy inefficient reverberatory furnaces and the formation of dilute SO₂ roaster off gas that is not economically viable to capture. Due to these limitations of roasting, direct smelting is now the favoured route.

Smelting

The initial melting of the material is usually referred to as the smelting or matte smelting stage. It can be undertaken in a variety of furnaces, including the largely obsolete blast furnaces, reverberatory furnaces, flash furnaces, Isasmelt furnaces and more. The enriched copper product is known as matte or copper matte, and is typically a mixture of copper, iron and sulphur. The purpose of the matte smelting stage is to eliminate as much of the unwanted iron, sulphur and gangue minerals (such as silica, magnesia, alumina and limestone), while minimizing the loss of copper. This is achieved by reacting iron sulphides with oxygen (in air or oxygen enriched air) to produce iron oxides (mainly as FeO, but with some magnetite (Fe₃O₄)) and sulphur dioxide off gas and a fayalite slag. Copper sulphide and iron oxide can mix in the furnace, although can be separated when sufficient silica is added. The separate slag layer is subsequently formed, which contains the iron oxides. Adding silica also reduces the melting point of the slag.

The slag forming reaction is: $\text{FeO} + \text{SiO}_2 \rightarrow \text{FeO.SiO}_2$

Slag and matte form two distinct layers once separated. Slag is less dense than matte and therefore constitutes the upper layer, with the matte sinking and ultimately forming the lower layer. Copper can be lost from the matte in three ways: as cuprous oxide (Cu_2O) dissolved in the slag, as copper sulphide dissolved in the slag or as tiny droplets (or prills) of matte suspended in the slag.

A typical smelter has a life of 40 years thereafter technology changes. Operating temperature for this process varies between 200 to 2000°C, with 95% of the world's metal production benefiting from smelting processes. Smelting is the oldest and most effective processing technique with a long history of efficient operation. The changing environmental legislation with respect to off gas has changed the way smelting is currently being viewed. The technology to produce clean off gasses in order lower emission levels requires increased capital for scrubbing, electrostatic separators and bag filters. The advantages and disadvantages of smelting are listed below:

Advantages

- Reaction kinetics allow for high capacities
- Solid waste is easily separated and disposed
- Low OPEX
- Suited to large tonnages

Disadvantages

- Production of large volumes of toxic gaseous products
- Environmental issues require the cleaning of gaseous products
- Unable to treat low grades or complex concentrates
- High CAPEX (the minimum size is 400,000 tpa copper metal)

SMELTING OPTIONS

Reverberatory furnace smelting

The reverberatory furnace feed is added to the furnace through feed holes along the sides of the furnace. Additional silica is normally added to help form the slag. The furnace is fired with burners using pulverized coal, fuel oil or natural gas and the solid charge is melted. Reverberatory furnaces can additionally be fed with molten slag from the later conversion stage to recover the contained copper and other materials with a high copper content.

The main equilibration reaction is: $\text{Cu}_2\text{O} + \text{FeS} = \text{Cu}_2\text{S} + \text{FeO}$.

The slag and the matte form distinct layers that can be removed from the furnace as separate streams. The slag layer is periodically allowed to flow through a hole in the wall of the furnace above the height of the matte layer. The matte is removed by draining it through a hole into ladles for it to be carried by crane to the converters. This draining process is known as “tapping the furnace”. The matte taphole is normally a hole through a water-cooled copper block that prevents erosion of the refractory bricks lining the furnace. When the removal of the matte or slag is complete, the hole is normally plugged with clay, which is removed when the furnace is ready to be tapped again. Reverberatory furnaces were often used to treat molten converter slag to recover contained copper. The furnace feed would be introduced by pouring ladles carried by cranes. However, the converter slag is high in magnetite, some of which would precipitate from the converter slag (due to its higher melting point), forming an accretion on the hearth of the reverberatory furnace. This ultimately requires the furnace to be shut down in order to remove the accretion. The accretion formation limits the quantity of converter slag that can be treated in a reverberatory furnace. While reverberatory furnaces had very low copper losses to slag, they are not very energy efficient and the low sulphur dioxide concentrations in their off gases made its capture uneconomic. Consequently, smelter operators devoted a lot of money in the 1970s and 1980s to developing new, more efficient copper smelting processes. In addition, flash smelting technologies had been developed in earlier years and began to replace reverberatory furnaces. By 2002, 20 of the 30 reverberatory furnaces worldwide had been shut down.

Flash Smelting

Flash smelting was developed by Outokumpu in Finland and it is one of the most significant technical developments in the 20th century. Flash smelting accounts for over 50% of copper matte smelting globally. It involves blowing oxygen-rich air, dried Cu-Fe-S concentrate, silica flux and recycled materials into a 1250°C hearth furnace.

Once in the furnace, the sulphide mineral particles react rapidly with the oxygen gas. The products are (i) a molten copper-iron-sulphide matte with approximately 65% copper concentration, (ii) molten iron-silicate slag containing 1-2% copper and (iii) hot dust-laden off gas containing 30-70% SO₂. A great deal of heat is generated in the shaft due to the oxidation of the sulphides.

Mitsubishi Technology

The Mitsubishi process is a continuous copper smelting and converting technology using three furnaces. The three furnaces are linked with covered launders, through which all the molten materials are continuously transferred by gravity. Copper concentrate (Cu: 30%, S: 30%, Fe: 25%, Gangue minerals 15%) is fed into the smelting furnace through a lance pipe with oxygen enriched air, is then oxidized and melted by an exothermic reaction to form molten mixture of matte (Cu: 68%) and slag. The matte is separated from the slag by difference of specific gravity in the slag cleaning furnace. The matte is further oxidized to form blister copper (Cu: 98.5%) in the converting furnace.

Noranda Smelting

Noranda Smelting was developed in Canada and is performed in large cylindrical furnaces. This produces a super high-grade copper matte (72-75% copper) in addition to a high copper slag and low SO₂ off gas. These furnaces are steel barrels lined with around 500 mm of chrome-magnesia refractory. Industrial furnaces are 4.5 to 5.5 m in diameter and 18-26 m long. Air is injected through 35-65 tuyeres along the length of the furnace.

Sirosmelt

This process was developed by CSIRO in Australia. Most of the smelting energy comes from oxidizing the concentrate charge. Additional energy is provided by combusting oil, gas or coal fines blown through the vertical lance, as well as coal fines in the solid charge feed. The lance is submerged within the molten bath that results in the oxidation occurring directly in the melt.

Drying the feed is not necessary as the smelting reactions take place in the matte/slag bath rather than above it. Air, or oxygen enriched air, is blown into the Sirosmelt furnaces via a lance. Oxygen enriched air is typically 50-60 vol% oxygen, with significant levels of lance wear occurring if the oxygen content is higher. These furnaces are suited to small projects and are flexible in the regard that they can be fed concentrate to produce matte, or alternatively be fed matte to produce blister copper. This process can however result in foaming from certain concentrates.

Chinese Bottom Blowing Technology

China Engineering Corp. (ENFI) developed the technology and installed it at several smelters to test the concept beyond a pilot level. An oxygen bottom blowing copper

smelting process has been developed at Dongying Fangyuan Nonferrous Metals Co. Ltd. This is the first modern copper smelting technology developed in China, with the advantages of high oxygen enrichment, high productivity and low energy requirements.

After three years in operation, the new technology has shown to be one of the best copper smelting technologies in the world. The main feature of the bottom blowing smelting process is that high grade matte (up to 72 wt. % Cu) can be produced at relatively low temperatures with only 2-3 wt% Cu remaining in the slag. No extra fuel is required to smelt the concentrate containing 20 wt% Cu by using oxygen enriched air (70-75%). Quenched slag analysis shows that significant amounts of magnetite crystals are present at the operating temperature, indicating that the slag temperatures were much lower than the matte.

Steel v/s Carbon Fibre

The steel industry plays a vital role in decarbonization by transitioning to green steel production methods, which include utilizing renewable energy, hydrogen-based steelmaking, and carbon capture technologies. While carbon fiber offers lightweighting benefits, steel's recyclability, cost-effectiveness, and established infrastructure make it a more sustainable and scalable solution for large-scale decarbonization efforts.

Steel's Role in Decarbonization:

Transition to Green Steel

The steel industry is actively working to reduce its carbon footprint through various methods, including:

- **Renewable Energy Integration:** Shifting from coal-based to renewable energy sources for steel production.
- **Hydrogen-Based Steelmaking:** Utilizing hydrogen as a reducing agent in Direct Reduced Iron (DRI) processes, which significantly reduces carbon emissions.
- **Carbon Capture, Utilization, and Storage (CCUS):** Implementing CCUS technologies to capture and store or utilize CO₂ emissions from steel plants.
- **Scrap Recycling:** Increasing the use of recycled steel in Electric Arc Furnaces (EAF), which is a lower-emission production route.

- **Infrastructure and Scalability:** Steel production benefits from established infrastructure and established recycling processes, making it more scalable for large-scale decarbonization efforts than carbon fiber.

Advantages of Steel over Carbon Fiber

- **Recyclability:** Steel is highly recyclable, and recycling processes are well-established, making it a more circular material compared to carbon fiber, which is more difficult and costly to recycle.
- **Cost-Effectiveness:** Steel is generally more cost-effective than carbon fiber, especially for large-scale applications, making it a more practical choice for widespread decarbonization efforts.
- **Established Infrastructure:** The steel industry has a vast and well-established infrastructure for production, processing, and distribution, which carbon fiber lacks at the same scale.
- **Lightweighting:** While carbon fiber offers significant weight reduction advantages, steel can be engineered to be lighter and stronger through advanced metallurgy and design, reducing the need for carbon fiber in many applications.
- **Lower Carbon Footprint in Production:** Although steel production has a high carbon footprint, the industry is actively working to reduce it through the technologies mentioned above, and in some cases, green steel production can achieve a lower carbon footprint than some carbon fiber production methods.

Robotics and AI in Modern Steel Manufacturing

The Critical Need for Robotics and AI in Modern Steel Manufacturing

Steel manufacturing represents one of the most demanding industrial environments on Earth, where extreme temperatures, hazardous gases, and massive machinery create an inherently dangerous workplace for human workers. The traditional approach to steel production, particularly in blast furnace operations, has long required workers to enter hazardous areas for routine inspections and maintenance, exposing them to temperatures exceeding 1,500°C and toxic environments filled with carbon monoxide and other dangerous gases. This reality has driven the global steel industry to seek innovative solutions that can maintain operational excellence while prioritizing worker safety and operational efficiency.

The convergence of robotics and artificial intelligence in steel manufacturing has emerged as a transformative force, offering unprecedented opportunities to revolutionize how these critical industrial processes are managed and monitored. POSCO, South Korea's leading steel manufacturer and the world's seventh-largest steel producer, has positioned itself at the forefront of this technological revolution through its comprehensive Smart Factory initiative, which began in 2016 with the goal of applying automation and AI models to manufacturing processes. This strategic approach to digital transformation culminated in POSCO's recognition as the world's first steelmaker to achieve "Lighthouse Factory" status by the World Economic Forum in 2019, acknowledging the company's leadership in utilizing Fourth Industrial Revolution technologies.

The implementation of robotics and AI in steel manufacturing addresses multiple critical challenges simultaneously. First, it significantly reduces worker exposure to hazardous environments, as traditional inspection methods required personnel to enter dangerous areas such as blast furnace windboxes, where high-temperature gases and toxic fumes create life-threatening conditions. Second, it enhances operational efficiency by enabling continuous, automated monitoring and data collection that surpasses human capabilities in terms of consistency, accuracy, and frequency. Third, it supports predictive maintenance strategies that can prevent catastrophic equipment failures and reduce unplanned downtime, which in steel manufacturing can cost millions of dollars per day.

The integration of advanced robotics platforms like Boston Dynamics' Spot robot with sophisticated AI-powered fleet management systems represents a paradigm shift in how steel manufacturers approach facility management and quality control. These systems combine autonomous navigation capabilities with advanced sensor technologies to create comprehensive digital inspection platforms that can operate in environments where human presence would be dangerous or impractical. The ability to deploy these systems continuously, without the limitations of human work schedules or safety concerns, enables a level of operational monitoring that was previously impossible to achieve.

POSCO's journey toward becoming a fully autonomous manufacturing environment demonstrates the transformative potential of robotics and AI in steel production. The company's vision extends beyond traditional smart factory concepts to embrace what they term "Intelligent Factory" manufacturing, where people, AI, and robots collaborate to create self-optimizing production systems. This approach recognizes that the future of steel manufacturing lies not in replacing human workers entirely,

but in augmenting human capabilities with advanced robotic systems that can handle dangerous, repetitive, and precision-critical tasks while enabling human operators to focus on higher-value activities such as strategic planning, problem-solving, and process optimization.

Transforming Steel Manufacturing Safety Through Advanced Robotics

The integration of robotics and AI in steel manufacturing has fundamentally transformed the safety paradigm in one of the world's most dangerous industrial environments. Traditional steel production operations have historically exposed workers to extreme hazards including molten metal splashes, toxic gas exposure, heat-related injuries, and struck-by incidents from heavy machinery and falling objects. The implementation of advanced robotic systems like Boston Dynamics' Spot has enabled steel manufacturers to dramatically reduce these risks while maintaining the high levels of operational monitoring and maintenance required for safe, efficient production.

The hazardous nature of steel manufacturing environments creates unique challenges for both human workers and robotic systems. Blast furnace operations, in particular, involve extreme temperatures that can exceed 1,500°C, toxic gas concentrations that can be lethal, and confined spaces where emergency evacuation may be difficult or impossible. These conditions have traditionally required extensive safety protocols, specialized personal protective equipment, and emergency response procedures that add significant complexity and cost to manufacturing operations while still exposing workers to substantial risks.

Robotics technology has emerged as a transformative solution to these safety challenges by enabling remote monitoring and inspection capabilities that eliminate the need for human presence in hazardous areas. The deployment of robots like Spot in steel manufacturing facilities allows for continuous monitoring of critical equipment and systems without exposing workers to dangerous conditions. This capability is particularly valuable in applications such as blast furnace windbox inspections, where traditional methods required workers to enter confined spaces filled with toxic gases and extreme temperatures.

The multi-sensor capabilities of advanced inspection robots provide comprehensive monitoring that often exceeds the capabilities of human inspectors while operating in environments where human presence would be dangerous or impossible. Thermal imaging systems can detect temperature anomalies that might indicate equipment failures or safety hazards, while acoustic sensors can identify abnormal

sounds or vibrations that precede equipment failures. Visual inspection capabilities combined with AI-powered analysis can identify safety hazards such as spills, missing safety equipment, or structural damage that might pose risks to workers or equipment.

The continuous operation capability of robotic systems represents a significant advancement in safety monitoring compared to traditional inspection methods. While human inspectors are limited by shift schedules, fatigue, and safety protocols that restrict access to hazardous areas, robots can operate continuously to provide real-time monitoring of safety-critical systems. This continuous monitoring capability enables immediate detection of developing safety hazards and allows for rapid response to prevent accidents or equipment failures.

The implementation of robotics in steel manufacturing safety has also enabled the development of more sophisticated predictive safety systems that can identify potential hazards before they develop into serious problems. By analyzing data collected continuously from multiple sensors, AI-powered systems can identify patterns and trends that indicate developing safety risks, enabling proactive interventions that prevent accidents rather than simply responding to them after they occur. This predictive approach to safety management represents a fundamental shift from reactive to proactive safety strategies.

The integration of robotics with advanced communication and alert systems has created comprehensive safety monitoring networks that can provide real-time information to safety managers and emergency response teams. When safety hazards are detected, automated alert systems can immediately notify appropriate personnel and initiate emergency response procedures, reducing response times and minimizing the potential impact of safety incidents. These systems can also maintain detailed logs of safety-related events and inspections, providing valuable data for safety analysis and continuous improvement efforts.

The successful deployment of robotics in steel manufacturing safety has demonstrated that advanced technology can simultaneously improve both safety outcomes and operational efficiency. By eliminating the need for human workers to enter hazardous areas, robotics reduces both the direct risks to workers and the indirect costs associated with safety protocols, insurance, and potential accident-related downtime. The improved consistency and frequency of safety inspections enabled by robotics also contributes to better overall safety performance and compliance with regulatory requirements.

The transformation of steel manufacturing safety through robotics has broader implications for the industry's ability to attract and retain skilled workers. The perception of steel manufacturing as a dangerous occupation has historically made it difficult to recruit qualified personnel, particularly younger workers who may have alternative career options. The implementation of advanced robotics and AI systems that reduce safety risks while creating opportunities for workers to develop new technical skills has helped steel manufacturers improve their attractiveness as employers and build more sustainable workforce strategies.

Economic Impact and Return on Investment in Robotic Steel Manufacturing

The economic implications of implementing advanced robotics and AI systems in steel manufacturing extend far beyond the initial capital investment, creating comprehensive value propositions that include direct cost savings, operational efficiency improvements, risk reduction, and strategic competitive advantages. The financial benefits of robotic implementation in steel manufacturing are multifaceted and compound over time, making the technology increasingly attractive to manufacturers seeking to improve their long-term competitiveness and profitability.

The direct cost savings from robotic implementation in steel manufacturing are substantial and measurable across multiple operational areas. Labor cost reductions represent one of the most immediate benefits, as robots can perform dangerous inspection and monitoring tasks that would otherwise require human workers with specialized safety training and equipment. The elimination of human exposure to hazardous environments also reduces costs associated with safety equipment, medical monitoring, insurance premiums, and potential accident-related liabilities. These safety-related cost savings can be particularly significant in steel manufacturing, where the high-risk nature of operations creates substantial ongoing expenses for safety management and risk mitigation.

The operational efficiency improvements enabled by robotic systems create significant value through increased inspection frequency, improved data quality, and reduced downtime. POSCO's implementation of Spot robots has enabled them to double their inspection frequency from once daily to twice daily, with plans to increase to four times daily, providing more timely detection of developing problems and enabling more proactive maintenance scheduling. This increased monitoring frequency reduces the likelihood of catastrophic equipment failures that can result in extended production outages, with each day of unplanned downtime in steel manufacturing potentially costing millions of dollars in lost production and recovery expenses.

The enhanced data quality and consistency provided by robotic systems enables more sophisticated predictive maintenance strategies that can significantly reduce maintenance costs while improving equipment reliability. Traditional human-based inspections are subject to variability in quality and consistency, while robotic systems provide standardized, repeatable measurements that enable more accurate trend analysis and failure prediction. This improved data quality enables maintenance teams to optimize their activities, focusing resources on equipment that actually requires attention rather than following fixed schedules that may result in unnecessary maintenance or missed problems.

The risk reduction benefits of robotic implementation create substantial economic value through reduced insurance costs, improved regulatory compliance, and decreased liability exposure. Insurance companies increasingly recognize the risk reduction benefits of advanced robotics and AI systems, leading to reduced premiums for manufacturers that implement these technologies. The improved safety performance and regulatory compliance enabled by robotic systems also reduces the risk of costly fines, legal liabilities, and reputation damage that can result from safety incidents or regulatory violations.

The competitive advantages created by robotic implementation can provide long-term economic benefits that extend beyond direct cost savings. Manufacturers that successfully implement advanced robotics and AI systems can achieve superior operational performance, enabling them to compete more effectively in global markets where cost, quality, and reliability are critical success factors. The ability to attract and retain skilled workers by offering safer, more technologically advanced work environments also provides competitive advantages in tight labor markets where qualified personnel are increasingly difficult to find.

The scalability of robotic systems creates opportunities for manufacturers to achieve economies of scale that can significantly improve the return on investment over time. Once initial implementation challenges are overcome and operational processes are optimized, robotic systems can often be expanded to additional applications and locations with relatively modest incremental investments. This scalability enables manufacturers to amortize their initial technology investments across broader applications while achieving cumulative benefits that grow over time.

The integration of robotic systems with broader digital transformation initiatives creates synergistic value that exceeds the sum of individual technology implementations. Robotic systems generate vast amounts of operational data that can be integrated with other digital systems to create comprehensive digital twins, advanced analytics platforms, and AI-powered optimization systems. These

integrated digital systems can provide insights and capabilities that enable manufacturers to optimize their operations in ways that would not be impossible with traditional approaches.

The strategic value of robotic implementation extends to brand reputation and stakeholder relationships, as manufacturers that successfully implement advanced technologies are often viewed more favorably by customers, investors, and other stakeholders. The demonstration of technological leadership and commitment to innovation can create intangible value that supports premium pricing, improved customer relationships, and better access to capital for future investments. These strategic benefits can be particularly important for manufacturers competing in global markets where technological capability is increasingly important for long-term success.

Future Implications and Industry Transformation

The successful implementation of robotics and AI in steel manufacturing represents more than a technological advancement; it signals a fundamental transformation in how industrial operations will be conceived, implemented, and optimized in the coming decades. The convergence of autonomous robotics, artificial intelligence, and advanced manufacturing technologies is creating new paradigms for industrial production that will reshape the competitive landscape and redefine the capabilities of manufacturing enterprises worldwide.

The evolution toward fully autonomous manufacturing systems represents the next frontier in industrial automation, where interconnected robots, AI-powered decision-making systems, and advanced sensing technologies work together to create self-optimizing production environments. POSCO's vision of "Intelligent Factory" manufacturing, where people, AI, and robots collaborate to create adaptive production systems, provides a glimpse of this future where manufacturing operations can continuously optimize themselves based on real-time data and changing conditions. This transformation will enable manufacturers to achieve levels of efficiency, quality, and responsiveness that are impossible with traditional approaches.

The integration of robotics with emerging technologies such as 5G connectivity, edge computing, and advanced AI models will create new capabilities that extend far beyond current applications. High-speed, low-latency communication networks will enable real-time coordination between distributed robotic systems, creating seamless collaboration across entire manufacturing facilities. Edge computing capabilities will

allow complex AI algorithms to operate locally on robotic platforms, reducing dependence on cloud connectivity while enabling more sophisticated autonomous decision-making capabilities.

The development of digital twin technology integrated with robotic systems will create comprehensive virtual representations of manufacturing operations that can be used for optimization, testing, and training purposes. These digital twins will enable manufacturers to experiment with new processes, test equipment modifications, and train personnel in virtual environments before implementing changes in real-world operations. This capability will dramatically reduce the cost and risk associated with process improvements while accelerating the pace of innovation in manufacturing operations.

The transformation of workforce requirements represents one of the most significant implications of robotic implementation in steel manufacturing. As robots take over dangerous, repetitive, and precision-critical tasks, human workers will increasingly focus on higher-value activities such as system oversight, problem-solving, strategic planning, and innovation. This shift will require substantial investments in worker training and development, but will also create more engaging and rewarding career opportunities for manufacturing professionals.

The environmental implications of robotic implementation in steel manufacturing are substantial and align with global sustainability initiatives. Robotic systems can optimize energy consumption, reduce waste, and improve process efficiency in ways that contribute to reduce environmental impact. The ability to continuously monitor and optimize operations using AI-powered systems will enable manufacturers to achieve environmental performance improvements that would be impossible with traditional approaches.

The global competitive implications of robotic implementation in steel manufacturing will be profound, as manufacturers that successfully implement these technologies will gain significant advantages over those that do not. The ability to achieve superior safety performance, operational efficiency, and quality consistency will enable advanced manufacturers to compete more effectively in global markets while potentially reshoring production that has been moved to lower-cost countries. This technological transformation may lead to fundamental changes in global manufacturing patterns and supply chain structures.

The regulatory and standards implications of robotic implementation in steel manufacturing will require new approaches to safety, quality, and environmental compliance. As robotic systems become more sophisticated and autonomous,

regulatory frameworks will need to evolve to address new types of risks and opportunities. The development of international standards for robotic manufacturing systems will be crucial for enabling global deployment of these technologies while ensuring consistent safety and performance standards.

The innovation ecosystem surrounding robotic manufacturing will continue to expand, creating new opportunities for technology providers, system integrators, and manufacturing companies. The success of implementations like POSCO's Spot deployment will inspire similar projects across the industry, creating a virtuous cycle of innovation and improvement that accelerates the pace of technological advancement. This ecosystem development will be crucial for realizing the full potential of robotic manufacturing technologies.

Conclusions

The implementation of Boston Dynamics' Spot robot at POSCO represents a transformative milestone in the evolution of steel manufacturing, demonstrating how the strategic integration of advanced robotics and artificial intelligence can simultaneously address critical safety challenges, enhance operational efficiency, and create sustainable competitive advantages. This pioneering deployment has proven that autonomous robotic systems can successfully operate in the most demanding industrial environments while delivering measurable benefits that extend far beyond initial expectations.

The success for POSCO's robotic implementation provides a compelling blueprint for industrial transformation that other manufacturers can adapt and scale to their specific operational requirements. The company's journey from initial safety concerns about deploying robots in harsh steel manufacturing environments to operating multiple Spot robots conducting routine autonomous inspections illustrates the potential for similar transformations across the global manufacturing sector. The doubling of inspection frequency from once daily to twice daily, with plans to increase to four times daily, demonstrates the scalability of robotic solutions and their potential to fundamentally change how industrial operations are monitored and managed.

The comprehensive benefits achieved through POSCO's robotic implementation extend across multiple dimensions of manufacturing excellence. The elimination of human exposure to hazardous windbox environments has improved worker safety while enabling more frequent and consistent inspection activities. The real-time data collection and analysis capabilities provided by the Spot-Orbit system have enabled

more sophisticated predictive maintenance strategies that reduce unplanned downtime and extend equipment life. The improved worker satisfaction and attraction of new talent through demonstration of technological leadership has strengthened POSCO's human resource capabilities while positioning the company for continued innovation.

The technological implications of this implementation extend beyond the immediate benefits to signal broader transformations in manufacturing capabilities. The integration of autonomous robotics with AI-powered fleet management systems creates scalable platforms that can grow with manufacturing operations while adapting to changing requirements. The development of digital twin capabilities combined with robotic data collection creates comprehensive virtual representations of manufacturing operations that enable optimization and innovation at unprecedented scales. The emergence of predictive maintenance and autonomous process control capabilities represents a fundamental shift from reactive to proactive manufacturing management.

The economic impact of robotic implementation in steel manufacturing demonstrates that advanced technology investments can deliver substantial returns through multiple value creation mechanisms. Direct cost savings from reduced labor requirements, improved safety performance, and enhanced operational efficiency provide immediate financial benefits that justify initial investments. The strategic advantages created through technological leadership, improved competitiveness, and enhanced stakeholder relationships provide long-term value that extends beyond measurable cost savings. The scalability of robotic systems enables manufacturers to achieve cumulative benefits that grow over time as implementations expand across additional applications and locations.

The future implications of successful robotic implementation in steel manufacturing suggest that this technology will become increasingly critical for manufacturers seeking to remain competitive in global markets. The continued advancement of AI capabilities, sensor technologies, and autonomous systems will create new possibilities for manufacturing optimization that are currently impossible to achieve. The integration of robotics with emerging technologies such as 5G connectivity, edge computing, and advanced analytics will enable new levels of manufacturing intelligence and responsiveness.

The transformation of steel manufacturing through robotics and AI represents more than a technological advancement; it embodies a fundamental reimagining of how industrial operations can be designed to prioritize human safety while achieving

superior performance outcomes. POSCO's success with Spot robot deployment demonstrates that the apparent trade-off between safety and efficiency is false – advanced robotic systems can simultaneously improve both safety and operational performance while creating more engaging and rewarding work environments for human employees.

As the global manufacturing sector continues to evolve in response to technological capabilities, environmental requirements, and competitive pressures, the lessons learned from POSCO's robotic implementation will become increasingly valuable. The company's approach to careful planning, infrastructure development, and systematic scaling provides a proven methodology that other manufacturers can adapt to their specific circumstances. The success of this implementation proves that the future of manufacturing lies not in choosing between human workers and robotic systems, but in creating intelligent collaborations that leverage the unique strengths of both to achieve outcomes that neither could accomplish alone.

The continued expansion of robotic applications across POSCO's operations and the company's plans for even more sophisticated AI-powered manufacturing systems suggest that this implementation represents just the beginning of a broader transformation that will reshape the steel industry and manufacturing more broadly. As these technologies continue to mature and become more accessible, the competitive advantages enjoyed by early adopters like POSCO will become increasingly important for long-term success in global manufacturing markets.

The implementation of robotics and AI in steel manufacturing addresses multiple critical challenges simultaneously. First, it significantly reduces worker exposure to hazardous environment, as traditional inspection methods required personnel to enter dangerous areas such as blast furnace windboxes, where high-temperature gases and toxic fumes create life-threatening conditions. Second, it enhances operational efficiency by enabling continuous, automated monitoring and data collection that surpasses human capabilities in terms of consistency, accuracy, and frequency. Third, it supports predictive maintenance strategies that can prevent catastrophic equipment failures and reduce unplanned downtime, which in steel manufacturing can cost millions of dollars per day.

The integration of advanced robotics platforms like Boston Dynamics' Spot robot with sophisticated AI-powered fleet management systems represents a paradigm shift in how steel manufacturers approach facility management and quality control. These systems combine autonomous navigation capabilities with advanced sensor technologies to create comprehensive digital inspection platforms that can operate in

environments where human presence would be dangerous or impractical. The ability to deploy these systems continuously, without the limitations of human work schedules or safety concerns, enables a level of operational monitoring that was previously impossible to achieve.

POSCO's journey toward becoming a fully autonomous manufacturing environment demonstrates the transformative potential of robotics and AI in steel production. The company's vision extends beyond traditional smart factory concepts to embrace what they term "Intelligent Factory" manufacturing, where people, AI, and robots collaborate to create self-optimizing production systems. This approach recognizes that the future of steel manufacturing lies not in replacing human workers entirely, but in augmenting human capabilities with advanced robotic systems that can handle dangerous, repetitive, and precision-critical tasks while enabling human operators to focus on higher-value activities such as strategic planning, problem-solving, and process optimization.

Source: Steel Industry Newsletter, 11th July 2025

Coking Coal Export Import Projections

Country	Unit	2024	2025	2026	2027	2025 % Change	2026 % Change	2027 % Change
World trade	Mt	349	338	352	357	-3.0	4.1	1.4
Top Importers								
China	Mt	115	106	99	95	-8.0	-6.0	-4.0
India	Mt	77	81	85	89	5.0	5.0	5.0
Japan	Mt	36	35	34	33	-3.5	-2.2	-2.2
European Union 28	Mt	33	33	31	30	0.0	-6.1	-2.0
Southeast Asia	Mt	28	31	34	37	10.0	10.3	10.5
Metallurgical Coal Exports								
Australia	Mt	153	149	165	171	-2.9	11.0	3.7
United States	Mt	50	44	42	42	-12.0	-4.0	0.0
Canada	Mt	30	30	30	30	0.0	0.0	0.0
Russia	Mt	43	45	45	45	4.7	0.0	0.0
Mongolia	Mt	52	50	50	49	-3.0	0.0	-2.0
Mozambique	Mt	4	3	2	2	-25.0	-25.0	-25.0

Source: June 30 - Australian Government's resource quarterly

Carbon Clean Launches Global Innovation Centre in India

Carbon Clean, a global leader in revolutionising carbon capture solutions, announced the opening of its new Global Innovation Centre (GIC) in Navi

Mumbai. The GIC will be one of the world's largest dedicated carbon capture research facilities, spanning 77,121 square feet and housing two carbon capture plants alongside state-of-the-art laboratories for solvent development, analysis, and testing. It aims to serve as a hub for research, innovation, and technology demonstration.

Carbon Clean has invested in the development of the GIC, which will house its latest technologies and an expert workforce of over 100 people, with capacity to expand to 350 employees. The Centre will support Carbon Clean's continued global growth and provide world-leading capabilities in carbon capture, utilisation and storage (CCUS) research, accelerating the development activities and deployment of next-generation carbon capture technologies.

The facility will play a critical role in scaling up deployment of CycloneCC, the company's breakthrough modular, space-efficient carbon capture technology. CycloneCC offers a cost-effective and scalable decarbonisation pathway for hard-to-abate emitters.

The launch of the GIC reinforces its commitment to India, where Carbon Clean has pilot partnerships already underway with BHP and JSW, NTPC and Tata Steel. It also builds on the growing momentum behind CCUS in the country, where a national CCUS mission is expected to be announced in the coming months.

Carbon Clean is a leader in revolutionising carbon capture solutions for hard-to-abate industries including cement, steel, refineries, and energy from waste. The company's patented technology significantly reduces the costs of carbon capture when compared to conventional solutions.

Carbon Clean has over a decade of experience in designing, building, and operating industrial carbon capture systems and it has 50 technology references around the world. The company is an innovation leader in the CCUS market, with over 110 active patent assets across 18 patent families covering 30 countries, and has developed a modular technology, CycloneCC, that is vital for scaling industrial carbon capture deployment to achieve global net zero targets.

Headquartered in the UK and with offices in the US, Canada and India, the company has received funding and grant support from the British and US governments and has established partnerships with industry leaders including Chevron and Cemex. It is also an investor in the Swedish eFuel development company, Liquid Wind.

Source: Press Releases, Carbon Clean 3 July 2025

Cleaner Ironmaking Options - As US firms Retreat from Green Steel

Most steelmakers rely on iron from coal-fired blast furnaces. But emerging demand for “direct reduced iron” promises to slash the industry’s emissions.

Global demand for steel is rising, and with it, emissions from the coal-fired blast furnaces that churn out around 70% of the world’s supply. American steelmakers are less reliant on blast furnaces than other countries, but they are doubling down on plans to extend the lives of the handful still operating in the U.S.

As those same steelmakers plan new facilities, they are embracing a cleaner technology called “direct reduced iron”, or DRI, to purify iron ore, the first step in the production of primary steel.

The DRI process uses a high-temperature gas to remove oxygen from the ore. DRI can then be added to a traditional basic oxygen furnace or, more commonly in an electric furnace that can be powered by carbon-free electricity.

Most DRI plants operating today use natural gas, a fossil fuel primarily made up of planet-warming methane. But even those can produce 50% less carbon emissions than coal-fired blast furnaces — and if the technology can be paired with carbon capture or fueled instead by green hydrogen, carbon-free steel becomes a possibility.

While DRI facilities account for just 9% of global ironmaking capacity today, they comprise nearly 40% of what’s under development. The U.S., for its part, has only three DRI plants up and running — but every new ironmaking facility slated to be built in the country will use DRI. That includes South Korean automaker Hyundai’s planned DRI plant in Louisiana.

The technology for gas based DRI has existed for more than half a century, but it’s made exclusively by two firms: Midrex Technologies and Tenova.

Midrex Technologies dominates the DRI market. The North Carolina-based company built the first U.S. plant using the technology in Portland, Oregon, in 1969.

DRI has a bigger and bigger role to play in the energy transition. The long-term view for DRI is positive. Demand for DRI keeps increasing. It’s probably going to double, then triple, in the next 20 years.

The other major manufacturer, Tenova — owned by the Buenos Aires-based Techint, with technology jointly developed with Italy’s Danieli — started

making DRI technology at the turn of this century. With just a fraction of the market, the firm may be the underdog.

Tenova's technology can swap out natural gas for hydrogen without any modifications. While Midrex says its equipment needs only minor upgrades to optimize for hydrogen, Tenova said the innate flexibility of its system allows it to ride out whichever way the tides turn.

Lately those tides have been turning against green steel. In January 2025, the Swedish steelmaker SSAB bowed out of negotiations to put up a DRI plant powered entirely with green hydrogen in Mississippi.

Cleveland-Cliffs — considered the more progressive of the American steelmakers — has suggested it would abandon its plans to build a DRI facility and use hydrogen to produce steel at its Middletown, Ohio, plant.

Weeks after Cleveland-Cliffs started backing away from the project, Nippon Steel, the Japanese behemoth, the world's fourth-largest steel producer, has pledged to build a new electric arc furnace, a process that uses electricity to turn scrap metal into fresh steel, the company has also staked out plans to extend the operations of U.S. Steel's existing blast furnaces.

In the near term, most of the new DRI plants in the U.S. will likely run on gas. Natural gas is very accessible in the U.S.

Already, Tenova can capture some of the emissions from the gas it uses. Steelmaker Nucor deploys Tenova equipment at its plant in Louisiana, which last year set a world record for DRI production. In 2023, Nucor inked a deal with Exxon Mobil Corp. to capture and store the carbon from the steelmaker's DRI process.

In Mexico, the Latin American steelmaker Ternium funnels CO₂ captured from Tenova's DRI equipment to Coca-Cola. Tenova puts the gas through two rounds of cleaning until it's safe for use in beverages, and sells it to another company that in turn supplies the CO₂ to Coca-Cola. All of the soda produced in Mexico by Coca-Cola is using CO₂ recycled from an ironmaking plant.

While the CO₂ emitted by the DRI process is captured in the Tenova system, the carbon dioxide produced from heating the gas to 1,000 degrees Celsius remains a source of pollution. The company is planning to roll out new features in the next few years to capture even that "residual" CO₂.

Elsewhere, the company's equipment is already running on hydrogen, or will be soon.

Last year, a major Swedish green metal project selected Tenova's technology to generate iron with 100% hydrogen for the steelmaking giant SSAB. The fuel is gaining ground in China, too, which lacks domestic gas resources. Tenova-equipped plants in the world's second-largest economy are already churning out 700,000 tons of iron per year using anywhere from 30% to 70% hydrogen, though only some of that hydrogen is green.

Despite the headwinds for hydrogen-based steelmaking in the U.S., the industry could still move away from traditional steel plants (also called integrated plants because of their use of blast furnaces and basic oxygen furnaces) in the coming years. Industry analysts say DRI is the technology that will enable this shift — one that some say is critical both economically and for the climate.

Blast furnace technology is considered outdated — it's too energy and emission intensive. Overhauling the integrated mill fleet will be expensive, but it's an investment that will pay off in the long term.

Already, mini mills across the U.S. make use of the large volumes of scrap metal in the U.S. to produce lower-carbon steel than what coal-fired plants make.

Because of the switch of energy from coal, DRI technology offers the possibility of decoupling ironmaking from steelmaking. Ironmaking facility can be installed where the energy is cheap, and steelmaking facility can be maintained at the location where the customers are and scrap is available.

That could also create an opening for some of the startups looking to popularize next-generation ironmaking techniques. The Colorado-based company *Electra*, which aims to use a process called "electrowinning" to purify iron without a blast furnace, raised \$186 million in April to support its scale-up. The Massachusetts Institute of Technology green steel spin-off Boston Metal, meanwhile, is inching toward its first commercial revenue.

Tenova's own research and development teams are working on similar technology. But it's unlikely to be able to scaled up fast enough in the near term to compete with DRI or blast furnaces.

A medium-sized blast furnace can churn out enough iron for 3 million tons of steel per year. A DRI plant can reach about 2.5 million tons. It'll be decades before any of

these newer electricity-based technologies reach that scale. The level of development of those technologies is still at a very early stage. It can be about 20 years, or 30 years from now.

Source: Canary Media, 24 June 2025

Press Hardening Steel Grades: Unlocking Strength Through Innovation

What Are Press Hardening Steel Grades and How Are They Made?

Press hardening is a special hot forming process, where the part is quenched in a forming die to receive its high hardness. It has been used in the automotive industry for over 40 years now.

The most common press hardening steel (PHS) is 22MnB5, a low carbon steel with Manganese-Boron alloying. Since it achieves a typical tensile strength of 1500 MPa after heat treatment, this material is mostly named as PHS1500 or CR1500T-MB (Cold Rolled, 1500 MPa typical Tensile strength, Manganese-Boron alloyed).

The Direct Press Hardening Steel Process

The direct press hardening process involves heating the blanks over 900°C (1650°F) in an industrial furnace. The blanks are then removed from the furnace and quickly transferred to a forming die. The formed parts are not removed immediately. Instead, they are kept under force in a water-cooled tool set for quenching. With a 22MnB5 steel, the quenched part typically reaches 1500 MPa tensile strength.

Coatings and Early Process Enhancements

Over the years, the first improvement on the 22MnB5 material was the application of an aluminum-silicon coating around early 2000's. The addition of the coating did not affect its strength or elongation but improved the process as it eliminated scale formation during forming and quenching. AlSi coating however limited the process to the aforementioned direct process.

Zinc Coatings and the Indirect Process

Some OEMs, especially in Europe, wanted to use Zn-based coatings for corrosion protection. The typical 22MnB5 is available with hot-dip galvanized (GI) and galvanized (GA) coatings. Liquid metal embrittlement (LME) with Zn-based coatings is avoided with an indirect press hardening process. Forming is done at

ambient temperatures, with the part subsequently heated and quenched in a press tool. These materials and techniques have been available since 2008.

Figure 1 summarizes the most common 22MnB5 grades and coatings before and after the press hardening process.

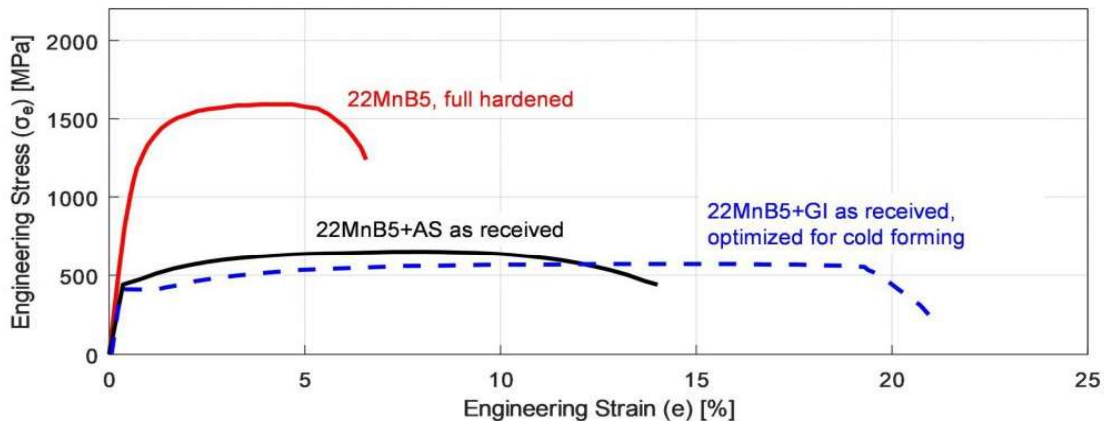


Figure 1: 22MnB5 before and after the hot stamping and quenching cycle. The incoming material is similar to HSLA 380 or DP600 and can be cold formed if needed. After hot stamping, typical tensile strength is around 1500 MPa (re-created after).

Measuring Performance: VDA Standards

In 2010, German Association of the Automotive Industry (VDA) developed a new bending test to evaluate energy absorbing capacity of PHS and PQS grades. This test gave a “bending angle” measurement, which replaced – to some extent – the use of “total elongation” value for energy absorbing calculations.

PHS1800 and Beyond

In 2011, a Japanese steel maker developed the first 1800 MPa (typical) tensile strength material. The material was AlSi coated with a modified, higher carbon, 30MnB5 chemistry and Nb alloying. One Japanese OEM applied the material in their bumper beams. The higher strength allowed using 1.4 mm thick PHS1800 material, instead of 1.6 mm PHS1500.

Tailored Solutions for Specific Applications

A German OEM designed a B-pillar with a PHS1500 upper section, laser welded to a lower section formed from HSLA 340LA (340 MPa yield strength) steel for improved energy absorption. It was later found that typical HSLA steels not designed for hot

stamping process may show significant variation in mechanical properties depending on the cooling rate.

The Rise of Press Quenched Steels (PQS)

Steel companies subsequently developed “Press Quenched Steels” (PQS) which are also HSLA but have been specifically modified to achieve consistent material properties at varying cooling rates. PQS grades are not hardenable, even after hot stamping and quenching cycle.

These steels were not used in the automotive industry until 2014, and have been commercially available since that time. These can be named as PQS450 and PQS550 (named after minimum tensile strength) or CR500T-LA and CR600T-LA (named after typical tensile strength, LA stands for Low Alloy).

Expanding Options: Pre-Cooled Steels

In 2015, a steel company in Europe developed 20MnB8 with GI coating. Chemistry with slightly lower carbon and higher manganese allowed forming to be done at lower temperatures. The company developed a new process route where the heated blank is first pre-cooled to around 500°C (930°F) and then formed and quenched – solving any LME concerns. The grade’s mechanical properties are nearly identical to 22MnB5 after quenching. Thus, it may be called PHS1500, but to differentiate the material, they are typically named CR1500T-MB-PS (PS stands for Pre-cooled Stamping).

Expanding Options: Composite Steels

In 2016, two different composite steels were developed for hot stamping. These are 3-layers, hot rolled clad grades with PQS on the outer skin and PHS1500 in the core. These were 1200 and 1400 MPa tensile strength level grades, with significantly improved bendability. There is only a commercial name for this material. To avoid using those names, the grades may be referred to as PHS1200 Sandwich and PHS1400 Sandwich.

Improving Formability and Weldability

Around 2016, steel makers started developing another PHS grade which has 1000-1200 MPa tensile strength after quenching. The grade had almost similar elongation with PHS1500 (almost 5%), but higher bendability (75° vs. 50°). These grades also have lower metallurgical notch effects when spot welded. The material may be named CR1100T-MB.

Multi-Step and Air-Hardening Innovations

In 2019, a Japanese steel company developed “air-hardening” 22MnSiB9-5 alloy with GA coating. After hot forming and quenching, the material had mechanical properties almost equivalent to 22MnB5. Thus, this material can also be named as PHS1500. Since the material is air-hardenable, meaning that it hardens even at very low cooling rates, it can be hot formed in a multi-station servo-mechanical-transfer press. The technique is then named as “multi-step hot forming”, with the grade referred to as CR1500T-MB-MS (the last MS stands for Multi-Step).

Ultra High Strength and the VDA Naming System

Since 2020, steel companies rolled out 1900 or 2000 MPa (typical) tensile strength materials. These grades are now commonly referred to as CR1900T-MB. These grades are already available uncoated, AlSi coated or GA coated.

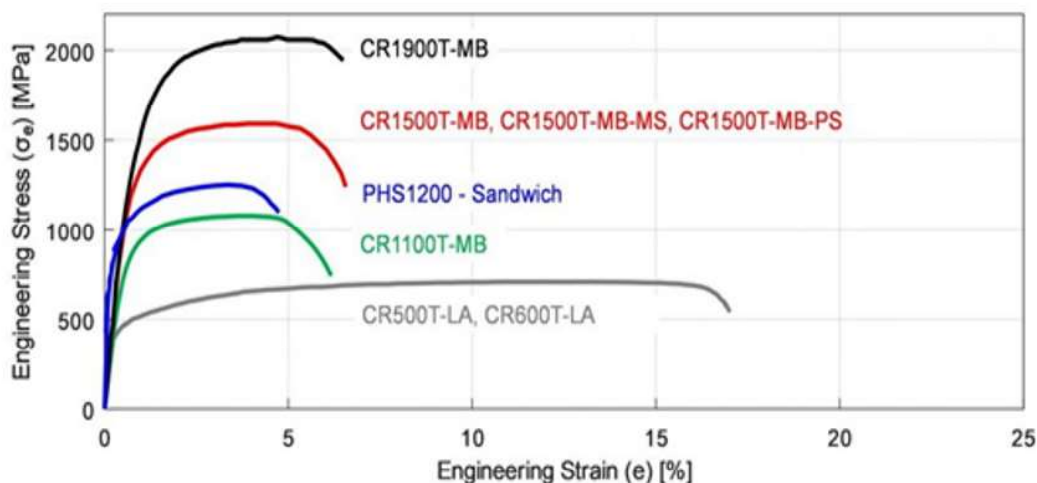


Figure 2: Stress-strain curves of commercially available PHS and PQS grades after quenching

In 2021, VDA published a new standard, which standardizes the naming, chemistry and mechanical properties of PHS and PQS grades. All the grades shown in Figure 2 (excluding the sandwich) are named based on this VDA standard.

The UniSteel Concept: One Alloy, Many Properties

In late 2021, researchers from China came up with a concept of using one chemistry (a modified 22MnB5) combined with different thermal processes to tailor the production of differing mechanical properties. Thus, it became possible to make a whole car from the same alloy, named as “UniSteel”. The different properties and

their use areas are shown in Figure 3. The research was published in Science magazine.

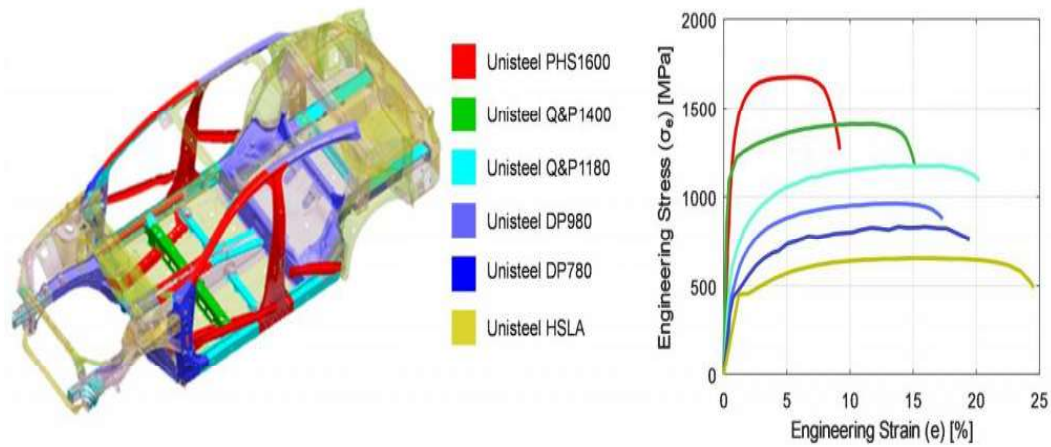


Figure 3: UniSteel concept: (a) material usage in a car body, (2) mechanical properties after heat treatments

The Future: BQP and SIBORA Development

In 2025, a German consortium developed a new grade 37SiB6 and a new process route called Bainitizing, Quenching and Partitioning (BQP). Similar to the Chinese UniSteel concept, the new SIBORA (Silicon Boron with Retained Austenite) material can have various strength and elongation levels. Both the process and resulting mechanical properties are given in Figure 4. Different strength levels can be achieved by changing the bainitizing temperature between 360 and 460°C (680 and 860°F).

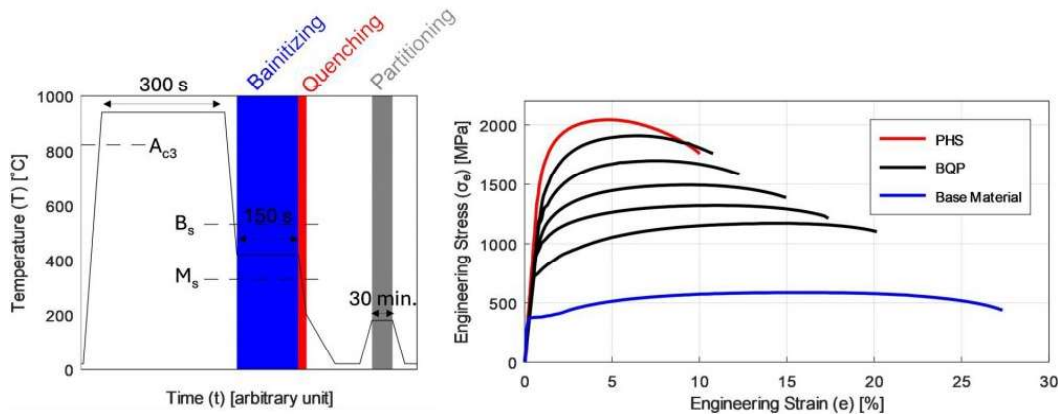
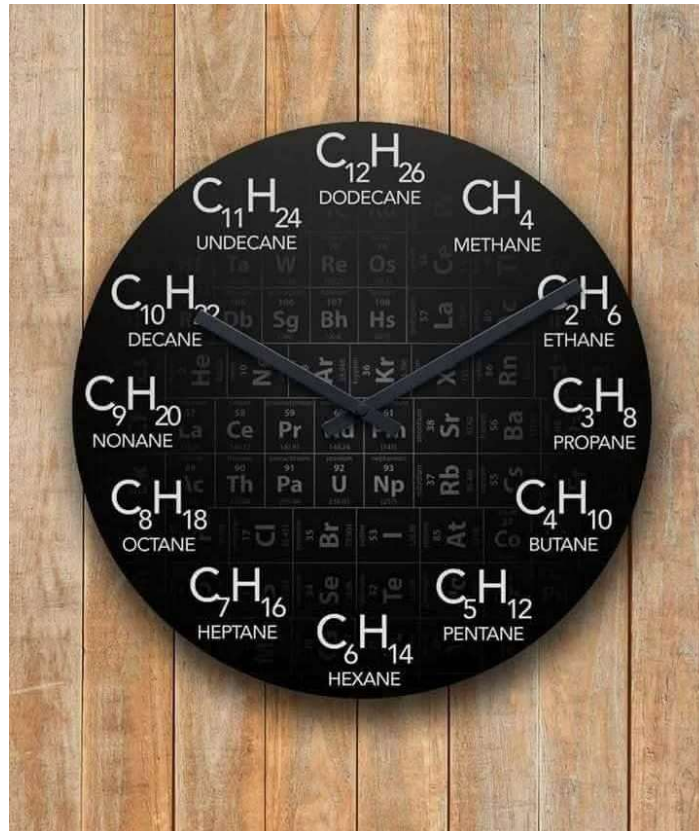


Figure 4: (a) the BQP process (shown here is 360°C bainitizing temperature), (b) the mechanical properties after PHS or BQP processes.

WorldAutoSteel Update: 26 June 2025

Chemistry Wall Clock



Tensile Testing: Engineering Stress-Strain Curves vs. True Stress-Strain Curves

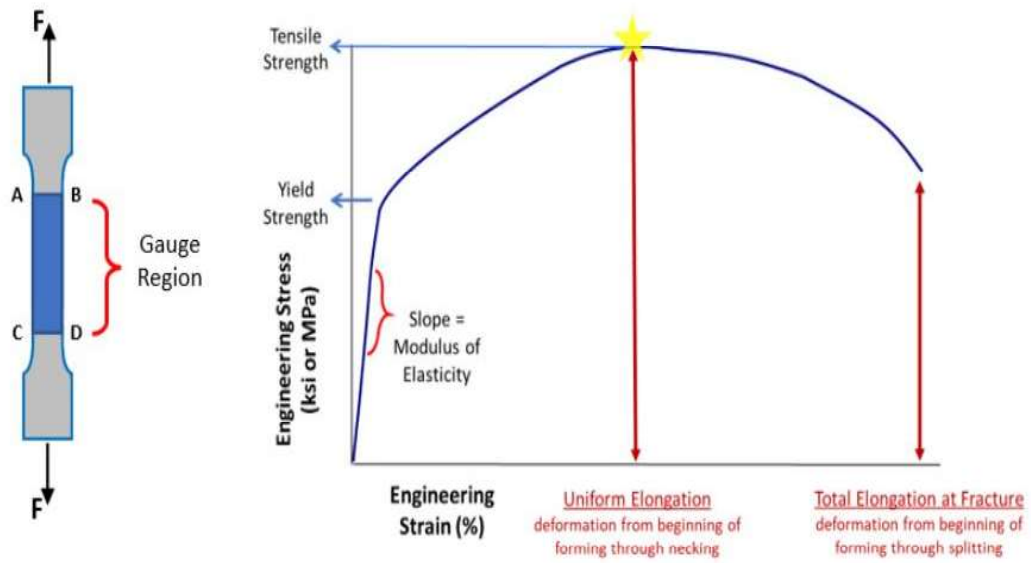
Tensile testing is one of the most basic formability characterization method available. Results from tensile testing are a key input into metal forming simulations, but if the right information isn't included, the simulation will not accurately reflect material behaviour.

Understanding Tensile Testing for Better Metal Forming Simulations

Tensile testing provides essential data for metal forming simulations, but using the wrong stress-strain model can lead to inaccurate results. Engineering stress-strain curves, based on initial measurements, don't account for how a material changes during deformation.

For advanced high-strength steels (AHSS), precise simulations help optimize production, reduce waste, and minimize costly recuts. Converting engineering data to true stress-strain curves—or using tests like biaxial bulge testing—improves

Tensile Testing



accuracy.

Tensile Testing: Engineering Stress-Strain Curves vs. True Stress-Strain Curves

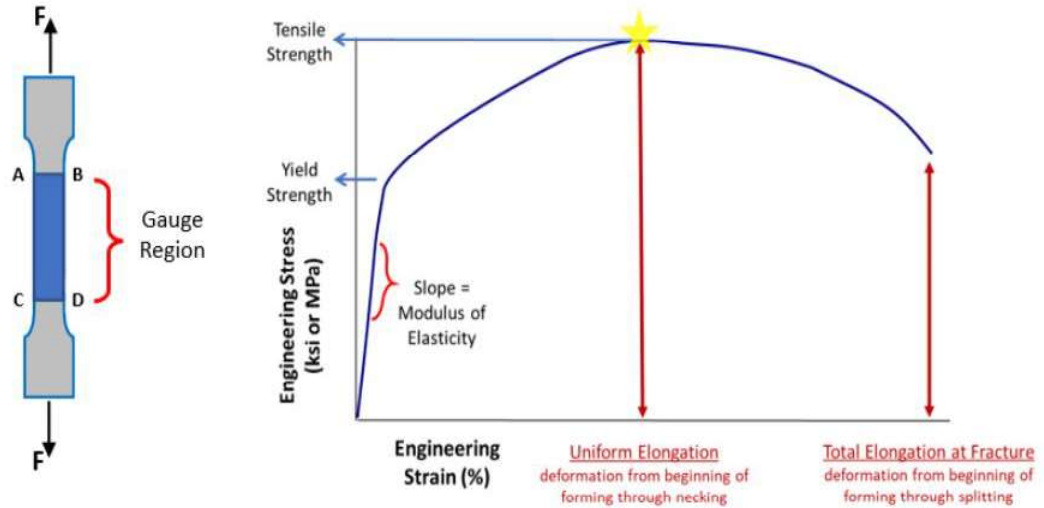
Metal forming simulation is particularly beneficial on the value-added parts made from advanced high strength steels, since accurate simulations allow for optimal processing with minimal recuts ... at least when the right information is used as inputs.

Tensile Testing

During tensile testing, a standard sample shape called a dogbone is pulled in tension. Load and displacement are recorded, which are then converted to a stress-strain curve. Strength is defined as load divided by cross-sectional area. Exactly when the cross-sectional area is measured during the test influences the results?

Before starting the pull, it's easiest to measure the width and thickness of the test sample.

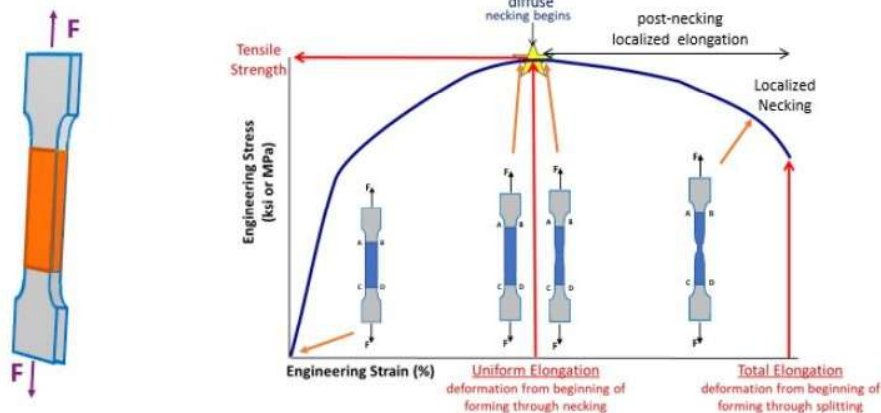
Tensile Testing



Engineering Stress-Strain Curve

Engineering Stress-Strain Curve

Engineering Stress: Applied load divided by initial cross-section area
 Engineering Strain: Increase in length relative to the initial length



At any load, the engineering stress is the load divided by this initial cross-sectional

area. Engineering stress reaches a maximum at the Tensile Strength, which occurs at an engineering strain equal to Uniform Elongation. After that point, engineering stress decreases with increasing strain, progressing until the sample fractures.

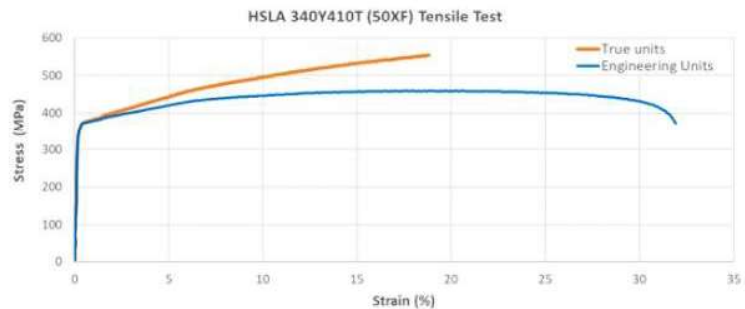
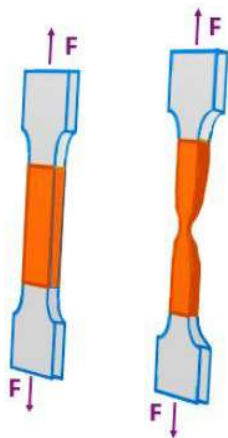
However, metals get stronger with deformation through a process known as strain hardening or work hardening. As a tensile test progresses, additional load must be applied to achieve further deformation, even after the “ultimate” tensile strength is reached. Understanding true stress and true strain helps to address the need for additional load after the peak strength is reached.

During the tensile test, the width and thickness shrink as the length of the test sample increases. Although these dimensional changes are not considered when determining the engineering stress, they are of primary importance when determining true stress. At any load, the true stress is the load divided by the cross-sectional area at that instant.

True Stress-Strain Curve

True Stress: Applied load divided by instantaneous cross-section area

True Strain: \ln (instantaneous change in length relative to the initial length)



True Stress-Strain Curve

The true stress – true strain curve gives an accurate view of the stress-strain relationship, one where the stress is not dropping after exceeding the tensile strength stress level.

True stress is determined by dividing the tensile load by the instantaneous area.

True stress-strain curves obtained from tensile bars are valid only through uniform elongation due to the effects of necking and the associated strain state on the calculations. Inaccuracies are introduced if the true stress-true strain curve is extrapolated beyond uniform strain, and as such a different test is needed. Biaxial bulge testing has been used to determine stress-strain curves beyond uniform elongation. Optical measuring systems based on the principles of Digital Image Correlation (DIC) are used to measure strains. The method by which this test is performed is covered in ISO 16808.

Stress-strain curves and associated parameters historically were based on engineering units, since starting dimensions are easily measured and incorporated into the calculations. These are the values you see on certified metal properties, also called metal cert sheets that you get with your steel shipments.

Engineering Stress-Strain and True Stress-Strain

$$\text{Engineering Stress} = s = \frac{F}{A_0} = \frac{\text{Force}}{\text{Initial Cross Sectional Area}}$$

$$\text{True Stress} = \sigma = \frac{F}{A_i} = \frac{\text{Force}}{\text{Instantaneous Cross Sectional Area}}$$

$$\text{Engineering Strain} = e = \frac{L_f - L_0}{L_0} = \frac{\Delta L}{L_0} = \frac{\text{Change in Length}}{\text{Initial Gauge Length}}$$

$$\text{True Strain} = \epsilon = \ln \left(\frac{L_i}{L_0} \right) = \frac{\text{Instantaneous Change in Length}}{\text{Initial Gauge Length}}$$

$$\sigma = s(1+e) \quad \epsilon = \ln(1+e)$$

True stress and true strain provide a much better representation of how the material behaves as it is being deformed, which explains its use in computer forming and

crash simulations. It's much more challenging to get accurate dimensional measurements once the test has started unless there are multiple loops of the operator stopping the test, remeasuring, then restarting the pull. This is not a practical approach.

Fortunately, there are equations that relate engineering units to true units. Conventional stress-strain curves generated in engineering units can be converted to true units for inclusion in simulation software packages.

As the industry moves to more value-added stampings, metal forming simulation is done on nearly every part. The value-added nature of parts made from advanced high strength steels requires best practices be used throughout – otherwise the results from simulation drift further away from matching reality, leading to longer development times and costly recuts.

Source: WorldAutoSteel Update - March 2025

Recycling Critical to Self-reliance

With China's step back from providing critical minerals, including rare earth alloys, mixtures and magnets, to India and other countries, manufacturers of electric vehicles, defence products and solar panels are worried about the future of their businesses.

Chinese imports power the manufacture of products like cell phones, laptops, compressors, solar panels, EV parts, defence equipment, headphones and many other devices.

Though the Chinese move is understood to be in retaliation to the US' tariff threats and limited to a few critical substances, the fear is that any further ban on other critical minerals, such as lithium and cobalt, could potentially stall production in the companies and countries that depend on these imports.

This, in turn, has triggered efforts in India to achieve self-reliance vis-à-vis critical minerals. Apart from exploring and mining for minerals, a key resource in focus is 'urban mining', which involves reclaiming minerals from end-of-life devices.

Recyclers in Focus

Some of the large recyclers have expressed their intent and ability to help the country plug the demand-supply gap and bolster the recently announced National

Critical Mineral Mission. Several of them have announced a ramping up of capacity. Attero Recycling, for instance, has announced an investment of ₹100 crore to scale up its rare earth element (REE) recycling capacity to 30,000 tonnes over the next 12 to 24 months. It also extracts rare earth material like germanium and selenium from solar panels, and expects to expand capacity to 20,000 tonnes per annum within two years.

A range of measures has been suggested to bring long-term gains to the country, as also to tide over the crisis in the short term. These include appealing to China to continue supplying critical minerals to some sectors, production-linked incentive for the recycling industry, and import of end-of-life rare earth products from the US and Europe to turn India into a global recycling hub. It is opined that if we manage to recycle 90 per cent of available magnets - recovering 95 per cent of material — we could meet 75-80 per cent of India's magnet demand.

Source: The Hindu Businessline, 21st July 2025

Institution of AC Wadhawan Memorial Lecture by IIM Delhi Chapter

IIM Delhi Chapter proposed institution of **AC Wadhawan Memorial Lecture** and sought approval of IIM Council.

Late Shri Avinash Chandra Wadhawan was born on January 27th Jan. 1938 and passed away on 31st May 2015. He was the President of The Indian Institute of Metals in 1992-93, and held many distinctive positions such as Chairman, Hindustan Zinc Limited (HZL), Chairman of Public Sector Enterprises Selection Board (PESB) and Chairman, Standing Conference on Public Enterprises (SCOPE).

The Memorial Lecture is proposed to be organized as a part of the Chapter Annual event of **IMMS – International Metals and Materials Summit**, first edition of which was held on 28th Feb. 2025 in New Delhi.

AC Wadhawan Memorial Lecture Fund shall be set up with a contribution estimate of Rs.10 Lakhs. Selection Committee for the Lecture shall be instituted by the Delhi Chapter.

IIM Council in its meeting held on 8th July 2025 has accorded **In-Principal** Approval in this regard and congratulated IIM Delhi Chapter to bring up this initiative for a righteous cause, being already practiced by many other Chapters of IIM.

India Steel Conclave 2025 – Enhancing Steel Demand to 500 MT for Viksit Bharat

ASSOCHAM organized ‘India Steel Conclave 2025 – Enhancing Steel Demand to 500 MT for Viksit Bharat-’ on 25th July 2025 in New Delhi. IIM Delhi Chapter was requested to be a “Supporting Association” for this Conclave.

Shri RK Singhal Executive Committee Member, participated in one of the Panel Discussion Session during the Conclave.

Chapter Relations Committee Meeting and Annual General Meeting of IIM

Chapter Relations Committee Meeting and Annual General Meeting of IIM were held at Kolkata on 25th and 26th July 2025. Shri K Krishnakumar, Hon. Secretary IIM Delhi Chapter represented IIM Delhi Chapter in these meetings.

India's Macroeconomic Indicators (Jun'24-May'25)

Key Parameters	2024						2025					
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Crude steel production (in million tonnes)	12.1	12.3	12.3	11.7	12.5	12.4	13.6	13.6	12.7	13.8	12.9	13.5
Pig iron production (in million tonnes)	0.64	0.70	0.67	0.71	0.77	0.78	0.73	0.67	0.61	0.73	0.74	0.73
Steel Exports (in million tonnes)	0.40	0.36	0.46	0.47	0.54	0.59	0.42	0.52	0.52	0.55	0.51	0.52
Steel Imports (in million tonnes)	0.67	0.79	0.97	1.08	0.82	0.63	0.61	0.75	0.5	0.62	0.41	0.63
Iron ore Imports (in million tonnes)	0.16	0.31	0.32	0.05	0.47	1.19	1.04	1.17	0.53	0.7	0.48	0.43
Coal Production (in million tonnes)	85	74	63	69	84	91	98	104	98	119	82	86
Coal Imports (in million tonnes)	24.5	23.4	21.5	20.8	21.5	20.2	20.4	21.7	19.3	23.2	24.7	27.2
Automobile Production (in million units)	2.33	2.43	2.49	2.77	2.88	2.40	1.92	2.54	2.34	2.47	2.31	2.58
Automobile Sales (in million units)	2.08	1.91	2.21	2.53	2.71	2.09	1.55	2.06	1.9	2.19	1.93	2.12
Daily Average Power Consumption ('000 MUs)	5.08	4.85	4.66	4.71	4.53	4.15	4.20	4.44	4.70	4.80	4.90	4.80
Merchandise exports (in Billion USD (\$))	35.2	34.0	34.7	34.6	39.2	32.1	38.0	36.4	36.9	42.0	38.5	38.7
EV Registrations ('000 Units)	97	129	106	111	169	146	95	125	147	100	121	131
GST Collections (in Trillion INR (₹))	1.74	1.82	1.75	1.73	1.87	1.82	1.77	1.96	1.84	1.96	2.37	2.01
Manufacturing PMI Index	58.3	58.1	57.5	56.5	57.5	56.5	56.4	57.7	56.3	58.1	58.2	57.6

Source: Various Ministries (Government of India) | SIAM | BigMint

Know Your Members



Shri Ashok Kumar

Ex General Manager, Corporate Materials Management Group, SAIL

Metallurgical Engineering Graduate (1989)
from Punjab Engineering College (now PEC University)

Master of Business Administration (MBA)
from the Faculty of Management Studies (FMS), Delhi University.

Shri Ashok Kumar started his career with DGS&D (now GeM) and then RDSO (Ministry of Railways), Lucknow, before joining Steel Authority of India Ltd. (SAIL) in 1991 at Durgapur Steel Plant as (DSP) Management Trainee. At DSP, he worked as Technical Officer of Head of Steel Melting Shop, Production Planning & Control, Sales and Coordination and in Raw Materials before moving to SAIL Corporate Office at New Delhi in 2005.

At SAIL Corporate Office, Shri Ashok Kumar worked in Personnel Directorate and gained varied exposure across personnel functions (Estate, Recruitment, CSR, Ministry matters etc.). He was pioneer in implementing CSR initiatives in SAIL post-enactment of the Companies Act in 2013. He worked very closely with the Department of Public Enterprises and other Govt./Non-Govt. agencies for execution of projects of the National Mission. He drafted CSR Policy and Sustainability Reports for SAIL conforming to the UNDP's GRI G3 Guidelines. He was Nodal Officer of CPGRAMS and Steel Ministry matters. On behalf of SAIL HQ, he also worked in close association with Impact India Foundation and TISS for various projects of GoI. He was part of the Coordinating Committees on Parliamentary Matters and dealt with several standing committees.

During his professional journey at SAIL, he rose progressively before moving to Corporate Materials Management Group as General Manager, where he took the responsibility for procurement of Goods & Services through GeM in 2019.

Shri Asok Kumar has had the opportunity to work with multi-oriented task groups and cross-functional hierarchies for more than three decades, which has shaped him into a seasoned professional with a technical and management working style. Being an alumnus of FMS, DU, he also served as a core committee member for Corpus Fund Management of FMS.

Shri Ashok Kumar superannuated from SAIL in December, 2024 as General Manager, Corporate Materials Management Group.

Shri Ashok Kumar is blessed with melodious singing voice.

Contact Details E-mail: akdel12@gmail.com; Mob: 8076904331