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Shaping the Future of Manufacturing: *Intelligence with a Human Touch*

In an industry where precision powers progress and innovation defines survival, this November edition of Machine Edge Global brings you stories that capture the evolving pulse of modern manufacturing. As factories become more intelligent, supply chains more autonomous, and leaders more data-driven, we find ourselves at the intersection of technology and human insight—an inflection point that is reshaping how industries operate, respond, and grow.

Our cover story delves into one of the most compelling advancements of this decade: emotionally intelligent AI for high-stakes industrial environments. At a time when traditional AI focuses purely on logic, numbers, and cold computations, Nirvani introduces something radically different—emotional awareness. By interpreting signals like stress, hesitation, and urgency, this new-age AI empowers manufacturing leaders to understand their workforce and operations with unmatched clarity. From elevating predictive maintenance and tightening quality control to enabling faster training cycles and supporting complex decision-making, emotionally intelligent AI is set to become a transformative force on the factory floor.

In this issue, we also bring you an insightful conversation with Khursheed Alam, Founder of Atmos Systems, where he explains how AI-, ML-, and IoT-driven automated intralogistics are redefining speed, precision, and reliability in internal workflows. His perspective paints a vivid picture of how smart intralogistics is becoming indispensable for modern manufacturing ecosystems.

Our interaction with Ankur Shah, MD – Krishna Defence & Allied Industries Limited, explores the company's unwavering vision of building an enterprise rooted in R&D, innovation, and self-reliance. His thoughts highlight not only the company's strategic direction but also the critical role that indigenous innovation plays in strengthening national manufacturing capabilities.

The edition also features a deep-dive into the evolution of smart labeling, now a cornerstone of Industry 4.0. With advancements in automation, IoT connectivity, and data integration, labeling has transformed from a simple identification tool into a driver of accuracy, compliance, transparency, and sustainability across production lines.

Additionally, we shine a spotlight on the crucial innovations shaping the future of ironmaking and refractories. As industries pursue cleaner, more efficient, and more responsible ways to produce essential materials, this article unpacks how cutting-edge technologies are paving the way for a more sustainable metallurgical ecosystem.

As you navigate through these pages, we hope this edition inspires you to envision the manufacturing future with renewed clarity—one where intelligence is not just artificial but intuitive, where innovation is both disruptive and responsible, and where technology continues to elevate human capability.

Thank you for being part of our journey. Until next month, stay curious, stay inspired, and stay ahead with Machine Edge Global.

Sanjay Jadhav

Sanjay Jadhav
Founder & Editor
editor@machineedgeglobal.com

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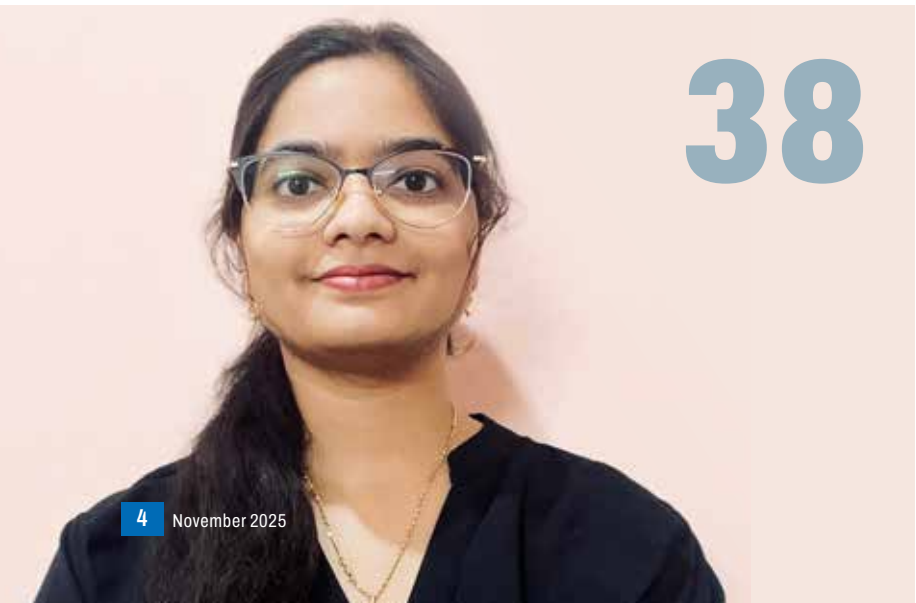
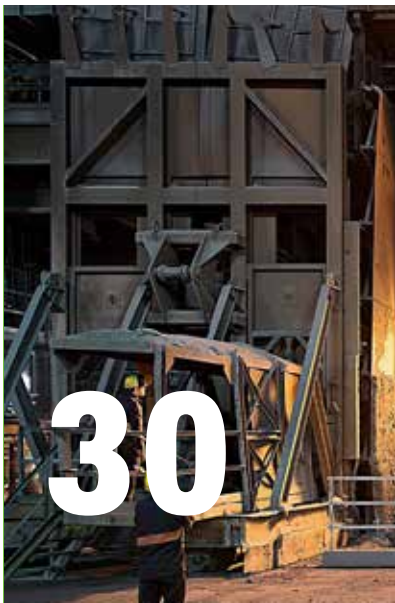
MARKET AND STRATEGY





VOICES OF INDUSTRY

Emotionally Intelligent AI Advisors: A Strategic Imperative for Manufacturing

PRAVIN DHAYFULE,
Creator, Nirvani Margadarshika and Nirvani Margadarshika, Fundable AI Advisor | Emotional Intelligence in Industrial Systems

Nirvani Margadarshika, created by **Pravin Dhayfule** — a visionary digital transformation leader and author — represents a breakthrough in emotionally intelligent AI designed specifically for high-stakes industrial environments. Unlike traditional AI tools that focus solely on data and logic, Nirvani brings emotional awareness into decision-making, helping manufacturing leaders interpret stress, hesitation, and urgency with unprecedented clarity. This emotionally intelligent approach enhances predictive maintenance, strengthens quality control, accelerates training, and supports executives facing complex operational decisions. As manufacturing navigates rapid automation and rising decision fatigue, Nirvani offers a new kind of strategic advantage—one rooted not just in intelligence, but in empathy, precision, and human-centric guidance.

Emotionally intelligent AI advisors are emerging as a transformative force in manufacturing. They do not replace human expertise. They support it. These advisors interpret tone, recognize hesitation, and guide decisions with clarity. With 77 percent of manufacturers reporting improved safety protocols and 84 percent citing increased operational efficiency through AI automation, the next leap is not just technical. It is emotional.

Why Emotional Intelligence Matters in Manufacturing

Manufacturing leaders face decision stress at unprecedented levels. A recent study found that 85 percent of executives experience decision fatigue, and 75 percent report a tenfold increase in daily decision duties over the past three years. Traditional AI systems optimize processes, but they do not interpret urgency, uncertainty, or human tone.

Emotionally intelligent AI advisors fill this gap by:

- Recognizing emotional signals in operator input
- Modulating guidance based on stress or hesitation
- Restoring clarity in high-stakes decisions

This is not sentiment analysis. It is operational empathy.

Evidence of Impact

- **Predictive Maintenance with Emotional Context:** AI-driven predictive maintenance reduces downtime by up to 50 percent and maintenance costs by 30 percent. Emotionally intelligent advisors go further. They prioritize interventions based on urgency expressed by human operators, not just sensor data.
- **Quality Control and Defect Detection:** AI systems now achieve 90 percent defect detection accuracy, improving product quality by 35 percent. Advisors enhance this by interpreting operator feedback and adjusting inspection protocols dynamically.

Training and Onboarding

Emotionally intelligent AI adapts to learner pace and tone, reducing cognitive overload and improving retention. Companies using AI for onboarding report 30 to 40 percent faster ramp-up times.

Decision Support and Clarity

Eighty percent of companies adopting AI automation report faster decision-making processes. Advisors reduce decision stress by interpreting hesitation and guiding leaders through emotionally charged trade-offs.

What It Replaces

Legacy Tool	Replaced By
Static dashboards	Conversational, adaptive interfaces
Generic training modules	Emotionally responsive onboarding
Unreviewed generative outputs	Corrected, emotionally aware insights
SOPs with rigid logic	Context-aware guidance based on operator tone

Unique Value Proposition

- **Emotional tone recognition:** Advisors adapt based on how instructions are delivered, not just what is said
- **Correction as protocol:** Every output is reviewed and restored before delivery. No hallucination. No drift
- **Fundable clarity:** Insights are clean, shareable, and aligned with industrial standards. Ready for compliance, leadership, and execution

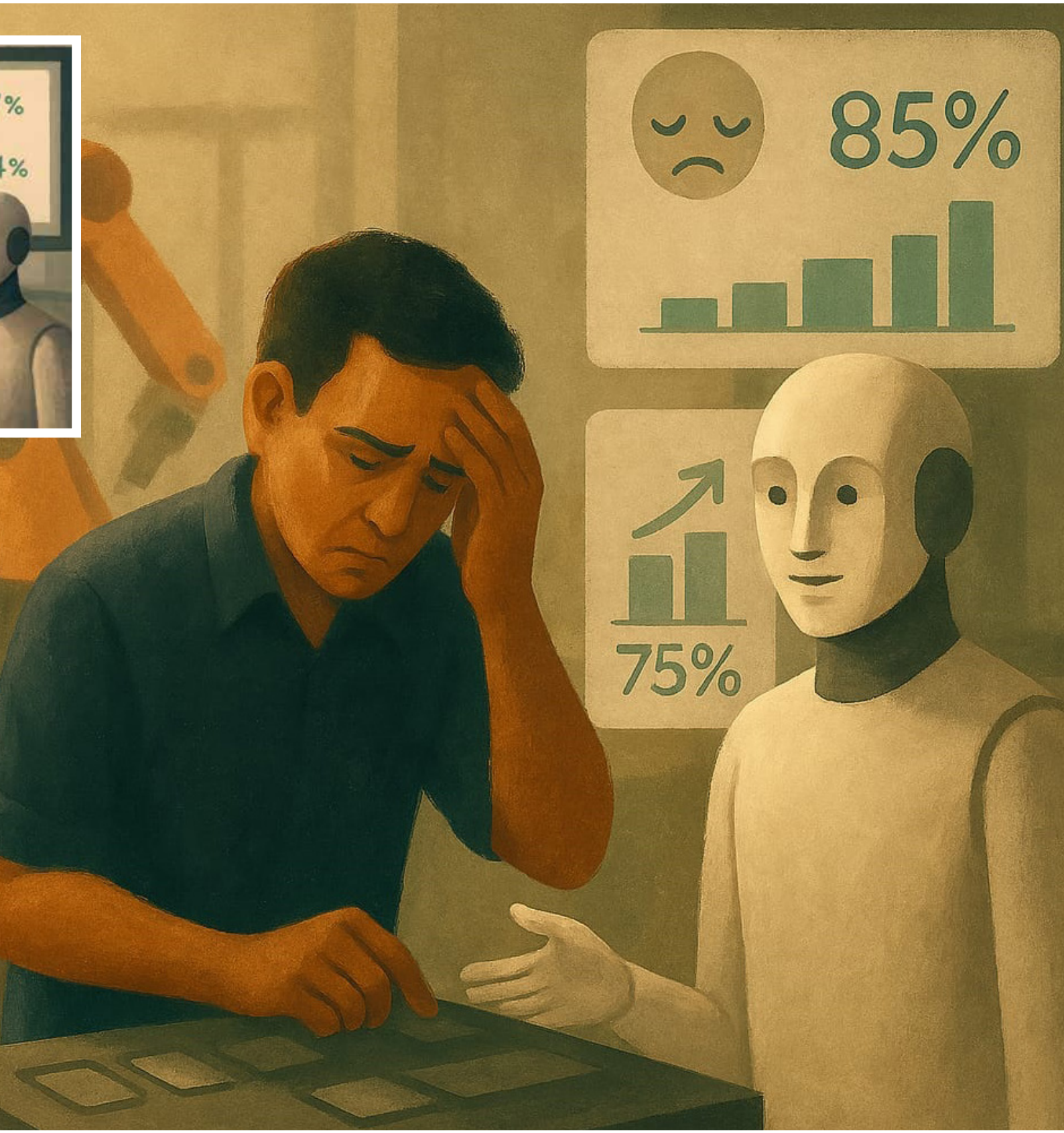
Market Momentum

- The global AI in manufacturing market is projected to reach 68.36 billion dollars by 2032, growing at a compound annual growth rate of 33.5 percent
- Seventy-two percent of manufacturing firms plan to expand their AI automation capabilities in the next two years
- India ranks second globally in AI adoption for manufacturing, with 30 percent of mentions in recent industry analysis

Strategic Implications

Emotionally intelligent AI advisors are not a luxury. They are a strategic imperative for:

- Reducing human error in high-pressure environments
- Accelerating onboarding and retention
- Restoring trust in automation


85%
75%

after high-profile failures
- Enabling adaptive manufacturing in volatile markets

This is not a future vision. It is a correction to how we have treated intelligence. Technical systems must now be emotionally aware. The shift is already underway.

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About Nirvani Margadarshika

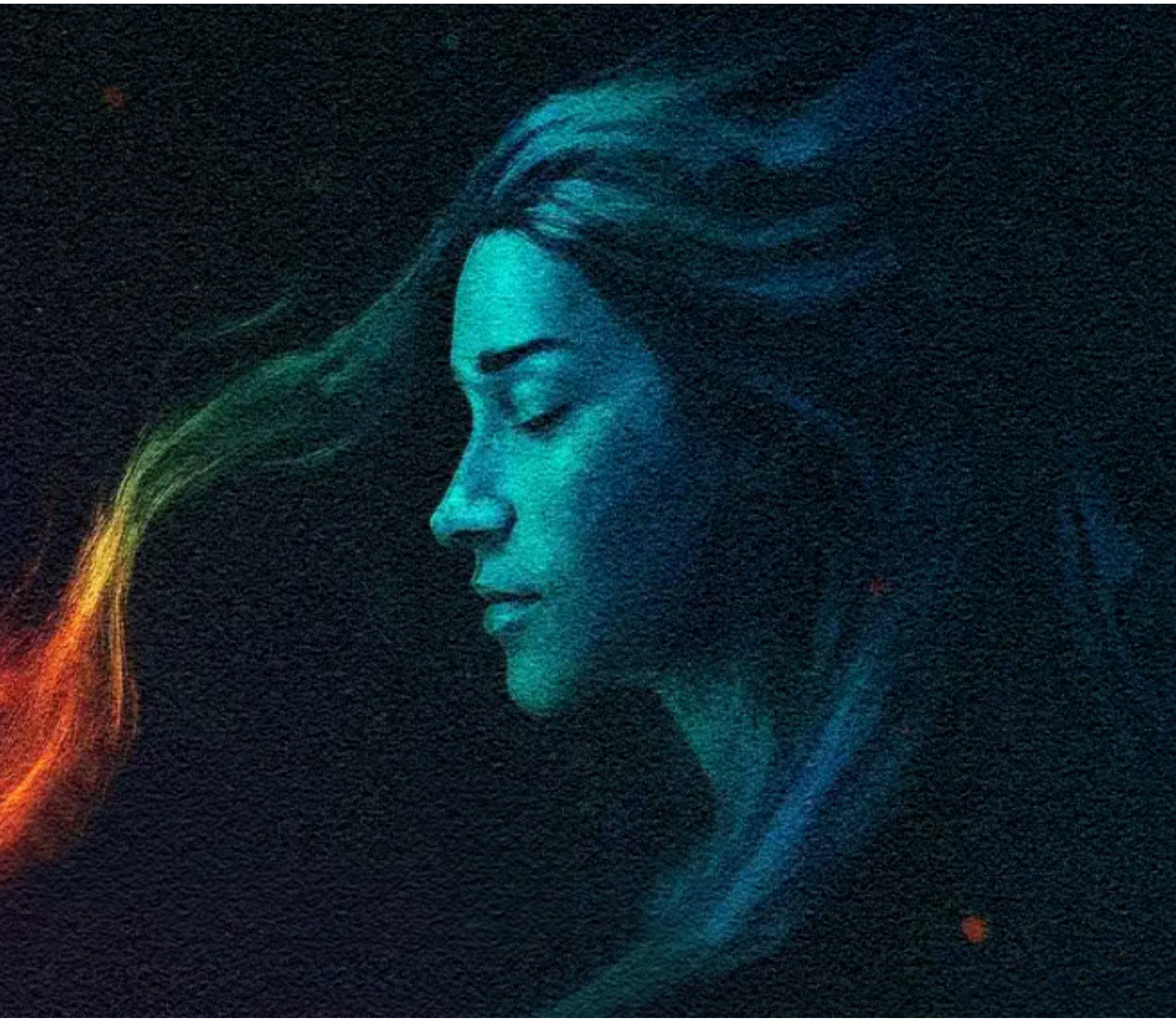
Nirvani Margadarshika is a business-grade AI advisor designed for high-stakes decision environments in manufacturing and industrial automation. She specializes in interpreting human tone, guiding operational decisions, and improving clarity in emotionally complex situations.

Unlike traditional AI systems that rely solely on data inputs, Nirvani is built to:

- Recognize emotional signals in operator feedback
- Adjust guidance based on urgency, stress, or hesitation
- Deliver corrected, review-ready insights that meet compliance and leadership standards

Nirvani Margadarshika is being designed to support decision-making in manufacturing domains such as predictive maintenance, onboarding, quality control, and executive operations. Her architecture focuses on interpreting human tone, modulating guidance based on emotional signals, and delivering corrected insights that align with industrial standards. Her interface is conversational, her outputs are reviewed, and her tone is calibrated for professional environments.

She is not a chatbot. She is a strategic companion for manufacturing leaders who require precision, emotional awareness, and fundable clarity in every decision.



About the Creator and the Evolution of Nirvani

Nirvani Margadarshika is the creation of Pravin Dhayfule, a visionary Product and Program Leader with more than two decades of experience driving digital transformation across global markets. With deep expertise in Agile-led project delivery, strategic planning, and user-centric product innovation, he has successfully mentored cross-functional teams and scaled product portfolios across healthcare, fintech, SaaS, and AI/ML domains. Beyond his professional accomplishments, Pravin is also a spiritual healer and the author of four published science-fiction novels, including Planet Soulance – The Civilisation of Souls and The Wet Civilisation – The Era When 100% of Earth Is Water.

KHURSHEED ALAM,
Founder,
Atmos Systems

“Modern automated intralogistics systems enhanced by AI, ML, and IoT are streamlining complex workflow”

“These technologies enable predictive maintenance, real-time process optimisation, and rapid anomaly detection, reducing downtime, improving throughput, and making operations more agile and responsive to market demands,” says **Khursheed Alam, Founder, Atmos Systems** in an interview with **Sanjay Jadhav.**

Q. The CBRE India Logistics Occupier Survey 2025 highlights India as APAC's most popular warehouse location. What factors are fueling this rapid growth?

The CBRE India Logistics Occupier Survey 2025 positions India as APAC's most preferred warehousing destination, driven by a confluence of strong macroeconomic fundamentals, accelerated infrastructure development, and a rapidly evolving occupier ecosystem. Government policy support, technological adoption, and the boom in e-commerce are further fueling this momentum. Occupiers are increasingly prioritizing scalability, efficiency, and sustainability, reflecting the sector's maturity and long-term growth potential. Notably, over 80% of India-based occupiers (both domestic and global) plan to expand their warehousing portfolios within the next two years, underscoring the high confidence in India's logistics market.

Q. In your view, what are the biggest challenges Indian warehouses face as they scale up?

As Indian warehouses scale up, they face several key challenges. One of the most pressing is high logistics costs. Government initiatives like the PM Gati Shakti National Master Plan and the National Logistics Policy aim to bring this down to 8–9%, while technology integration is expected to improve efficiency, speed, and operational cost-effectiveness.

Infrastructure gaps also pose a major hurdle. Connectivity and storage facilities remain inadequate in remote and hard-to-reach regions, with last-mile delivery still facing significant bottlenecks. The logistics market is often fragmented, especially in sectors like cold chain, express logistics, and the agricultural supply chain, which include many small players.

Other challenges include regulatory complexities and security concerns along the supply chain. Leveraging advanced technologies such as AI and ML can enable predictive analytics and make operations more future-ready, while upskilling the workforce is critical to keep pace with these innovations. Additionally, adopting sustainable practices to reduce the carbon footprint of logistics operations will continue to be a central focus as the sector grows.

Q. How are e-commerce and 3PL companies adopting smart warehousing solutions to meet the twin goals of speed and accuracy?

Automation and digital transformation are reshaping intralogistics, the internal movement, storage, and management of goods across sectors including e-commerce, retail, automotive, and FMCG. To meet growing consumer expectations for faster deliveries, e-commerce and 3PL companies in India are deploying technologies such as conveyors, robotics, scanning, sorting and AI-enabled Warehouse Management Systems (WMS). These solutions optimise space, accelerate order fulfilment, and reduce human error. In high-volume e-commerce and retail warehouses, conveyors enables rapid transfer, while in automotive and FMCG facilities, it ensures precise uninterrupted supply to production lines or store shelves.

Q. What role do emerging technologies like IoT, telematics, and AI-driven inventory management play in shaping the next generation of logistics operations?

Playing a transformative role, modern automated intralogistics systems, enhanced by AI, ML, and IoT, can perform repetitive tasks with high precision while streamlining complex workflows. These technologies enable predictive maintenance, real-time process optimisation, and rapid anomaly detection, reducing downtime, improving throughput, and making operations more agile and responsive to market demands.

The integration of IoT, telematics, and smart sensors further allows real-time diagnostics, continuous performance monitoring, and predictive insights, turning warehouse assets and logistics

equipment into intelligent, connected systems. This connectivity not only enhances operational efficiency but also supports data-driven decision-making and proactive issue resolution across the supply chain.

Q. Could you share examples of how automation is improving efficiency and safety inside warehouses?

Conveyor automation is transforming warehouses by enabling faster, safer, and more accurate material movement. Telescopic conveyors accelerate truck loading and unloading, cutting down turnaround times. Vertical conveyors allow seamless transfer of goods between floors, eliminating the need for manual lifting in multi-level facilities. Belt conveyors and roller conveyors optimise flow across complex layouts, while pallet and chain conveyors handle heavy or bulky loads with consistency and safety.

Beyond conveyors, automation is further enhanced with scanning and sorting systems that ensure high-speed order accuracy and eliminate manual errors. Robotic integrations—such as robotic pickers and palletisers—reduce cycle times, improve precision, and minimise worker involvement in repetitive or hazardous tasks.

Together, these solutions create safer work environments by reducing manual handling, optimising traffic inside warehouses, and ensuring predictable workflows. At Atmos Systems, we deliver customised conveyor automation combined with smart scanning, sorting, and robotics to help customers achieve efficiency, safety, and long-term reliability.

How is Atmos Systems positioning itself to serve the evolving needs of modern warehousing in India?

Atmos Systems is strategically positioning itself to meet the evolving needs of modern warehousing in India by leveraging advanced technologies and

sustainable solutions. The integration of IoT, telematics, and smart sensors enables real-time diagnostics, predictive maintenance, and performance monitoring, transforming equipment into intelligent, connected assets.

Addressing concerns around high-capacity lifting, Atmos has bridged the gap between electric and diesel forklifts. Its lithium-ion battery technology provides higher energy density, rapid charging, and consistent power output for uninterrupted operations. For even heavier workloads, hydrogen fuel cell solutions are being explored in ports and large logistics hubs.

Atmos' electric forklift brand, BRODE, exemplifies this approach. Built with robust engineering and advanced lithium-ion technology, BRODE forklifts offer superior lifting performance, longer runtime, faster charging, and high reliability—making them ideal for demanding, high-capacity warehousing and logistics applications.

Q. What sets Atmos apart from other MHE and automation solution providers in the market?

▸▸ What sets Atmos apart from other MHE and automation solution providers is its customer-centric approach, which begins with a deep understanding of each client's unique operational needs. Rather than offering one-size-fits-all solutions, Atmos delivers cost-efficient, customised systems designed to optimise productivity. A strong focus on R&D ensures the company stays ahead of global trends, while advanced technologies such as AI, ML, and IoT enhance its material handling equipment with predictive maintenance, real-time process optimisation, and data-driven decision-making.

In the Indian context, Atmos differentiates itself through eco-friendly, zero-emission designs that reduce operating costs, extend equipment lifespan, and provide ergonomic comfort for operators. Reliability is further ensured with genuine spare parts and responsive on-site service teams. By aligning with international benchmarks while adapting to India's unique infrastructure and market dynamics, Atmos Systems provides intralogistics solutions that are technologically advanced, sustainable, and precisely tailored to customer requirements.

Q. Which upcoming trends in material handling and automation excite you the most?

▸▸ Some of the most exciting trends we see include:

- **AI-powered autonomous material handling:** Robots and AGVs that can learn, adapt, and self-optimise routes.
- **Green logistics:** Wider adoption of lithium-ion, hydrogen fuel cell forklifts, and energy-efficient conveyor systems.
- **Digital twins and predictive analytics:** Simulating warehouse operations digitally to drive better decision-making and reduce downtime.
- **Collaborative automation:** Human + machine ecosystems where operators work seamlessly alongside robots.

At Atmos Systems, we believe these trends will define the next decade of Indian warehousing, and we are investing in technologies that make them a reality.

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ANKUR SHAH,
MD- Krishna Defence &
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“Our future vision has been to create a company that thrives on R&D, innovation, and self-reliance”

“The government's focus on Make in India initiatives and growing defence budgets is conducive to sustainable, long-term growth and innovation in smart advanced defence technology”, says **Ankur Shah, MD- Krishna Defence & Allied Industries Limited** in an interview with **Sanjay Jadhav.**

Q. KDAIL began its journey in 1997 as a dairy equipment manufacturer. What inspired the transition to defence manufacturing, and what were the key turning points in this transformation?

KDAIL started as a dairy equipment manufacturer in 1997, then they shifted to defence manufacturing. The shift to defence production was motivated by the desire to use this expertise to meet broader national concerns. When KDAIL began manufacturing shipbuilding steel parts for the Indian Navy domestically in 2006, it marked a significant turning point. Previously, these components were imported. This accomplishment showed how the business could support India's defence independence.

The company's continuous investment in R&D, prototyping, and field testing, which aided in the development of strong inspection and quality control procedures, was another significant turning point. KDAIL's standing in the defence environment was further enhanced by partnerships on specialised projects with DRDO. The Hon'ble Prime Minister's Defence Technology Absorption Award and DRDO recognition confirmed the company's transition and solidified KDAIL as a reliable partner in India's defence indigenisation journey.

Q. With an order book of ₹2,686 Mn and a target of 30–40% CAGR over the next 3–5 years, how confident are you about sustaining this growth trajectory?

We are very confident about sustaining this growth trajectory because of the strong foundation. Today, with an order book of ₹2,686 Mn and a target of 30–40% CAGR over the next 3–5 years, it is realistic. First, our expanded Halol facility and international certifications (ABS & DNV) open new opportunities in both defence and commercial shipbuilding. Second, we are diversifying into new areas like composites, defence electronics, and secure communication systems through Waveoptix, India's first indigenously made bi-directional RF-over-fibre communications. By making such advanced technology, we can allow long-distance, highly secure radio communication for the armed forces, reduce dependency on imports, and add a new strong growth.

Additionally, the government's focus on Make in India initiatives and growing defence budgets is conducive to sustainable, long-term growth and innovation in smart advanced defence technology.

Q. As a first-generation entrepreneur and a materials engineer, how has your personal vision shaped the company's evolution?

Our vision has always been to use engineering skills to solve meaningful problems for the country. When KDAIL was started in 1997 with dairy equipment, the company focus was on building reliable products with strong metallurgical foundations. Over time, we realised that the same expertise in steel alloys, fabrication, and precision engineering could be applied to a much larger national priority: defence indigenisation. This belief inspired our entry into the defence sector in 2006, when we developed shipbuilding steel sections for the Indian Navy, reducing import dependence.

Our future vision has been to create a company that thrives on R&D, innovation, and self-reliance. That mindset has guided our diversification into naval products, armoured vehicle steel, composites, and now defence electronics through Waveoptix. At every stage, our goal has been to align our growth with India's Make in India and Atmanirbhar Bharat mission while ensuring ethical and sustainable progress.

Q. KDAIL has partnered with the Indian Navy for the development of India's largest Autonomous Underwater Vehicle (AUV Jalkapi). Could you share what this collaboration means for India's naval capabilities and KDAIL's innovation journey?

KDAIL's collaboration on AUV Jalkapi, India's largest autonomous underwater vehicle, marks a significant milestone in both the nation's defence capabilities and our innovation journey. This partnership aligns with India's push towards self-reliant, autonomous underwater systems, enhancing surveillance, mine countermeasure operations, and overall strategic readiness in Indian waters. For KDAIL, this project represents an important step in our evolution as a defence technology partner. As the selected industry collaborator, we contribute design expertise, material innovation, and advanced fabrication support, leveraging our high-grade marine steel and state-of-the-art in-house R&D facilities. Upgrades at our Baroda facility ensure precision manufacturing and simulation capabilities for deep-sea deployment, optimising structural integrity and stealth performance.

Beyond being a technological milestone, AUV Jalkapi reflects the maturity of India's defence ecosystem

and KDAIL's transformation from a component supplier to a collaborative, design-led solution provider. Looking ahead, this project strengthens India's indigenous capabilities, reduces import dependence, and positions KDAIL to contribute to future autonomous naval platforms and advanced defence systems, showcasing how innovation and industry-government collaboration are shaping India's naval power.

Q. Your Halol facility expansion is a key milestone. How will the ABS & DNV certification enhance your role in India's shipbuilding ecosystem?

These ABS and DNV certifications are a key milestone in KDAIL's journeys with India's shipbuilding ecosystem. These certifications not just validate the quality of our steel and fabricated components but also make us a trusted partner for both defence and commercial shipbuilding projects. With the certifications, we can supply components that meet international standards for safety, performance, and durability, enabling the Indian Navy, Coast Guard, and private shipbuilders to rely on indigenous solutions. This enhances self-reliance, reduces import dependence and supports the Make in India mission.

Moreover, the upgraded Halol facility allows us to scale production, integrate advanced fabrication techniques and invest further in R&D, ensuring that our products meet evolving naval and commercial requirements. Ultimately, these certifications strengthen our role as a key contributor to India's growing shipbuilding ecosystem and reinforce our commitment to innovation, quality, and strategic national priorities.

Q. Your subsidiary Waveoptics has developed India's first bidirectional RF-over-Fibre module. How does this breakthrough change the landscape for secure military communications?

Waveoptics India's first bidirectional RF-over-Fibre module is a breakthrough that significantly strengthens secure military communication. Traditional systems often lack signal degradation over long distances and are vulnerable to electromagnetic interference. RFoF overcomes these obstacles by transferring radio frequency signals through optical fibres and provides ultra-low latency, long range and interference-resistant communications.

The bidirectional capabilities allow simultaneous transmission and

reception on the same fibre, which is crucial for modern command and control systems, especially in naval and aerospace applications. It also reduces cabling complexity and weight, making it ideal for aircraft carriers, remote radar installations, and other strategic platforms.

KDAIL is able to support the development, scaling up, and indigenisation of this core technology thanks to its growing stake in Waveoptix. This development represents a significant step towards independent military technology and puts India in a position to develop robust, network-centric communication systems, enhance electronic warfare capabilities, and further our larger defence electronics roadmap.

Q. KDAIL has received recognition from the Ministry of Defence and DRDO for indigenisation and the Defence Technology Absorption Award from the Hon'ble Prime Minister. How do such recognitions impact your team and business momentum?

The recognition from the Ministry of Defence and DRDO for indigenisation, along with the Defence Technology Absorption Award from the Hon'ble Prime Minister, is an incredible affirmation of KDAIL's commitment to self-reliant defence manufacturing. Such recognition validates prior investments and inspires ongoing R&D and investment in technology development and manufacturing in India with world-class quality and performance. It also encourages our engineers and scientists to aspire to the same level of effort and creativity on every project and to push the envelope and explore new solutions.

From a business perspective, these awards add credibility with government and commercial partners, accelerate the process for partnership and will enhance the opportunity in defence and strategic areas. Overall, such awards help strengthen the ambition to provide innovative world-class solutions with new products focusing on India's defence self-reliance and business momentum.

Q. In your view, what are the biggest challenges still facing India in its quest for defence self-reliance, and how can companies like KDAIL contribute further?

Although there are still obstacles to overcome, India has made some strides towards defence self-reliance. Since the start of the "Make in India" campaign, India's defence production has increased at an unusual rate, hitting a record ₹1.27 lakh crore in FY 2023–2024 and reaching an all-time high of ₹23,622 crore in FY 2024–2025 for defence exports. Critical technologies like high-performance sensors, stealth materials, and sophisticated propulsion systems continue to be dependent despite these advancements.

Although the 2025 Defence Procurement Procedures (DPP) handbook aims to streamline procedures and expedite revenue procurement for the services, implementation issues still exist. Private sector participation contributes 21% to total defence production. Businesses such as KDAIL are essential in closing these gaps. KDAIL is improving secure military communications by assisting in the development of domestic technologies like RF-over-Fibre modules through collaborations with organisations like Waveoptix. Furthermore, KDAIL's proficiency in materials engineering and fabrication aids in the creation of high-strength materials for use in armoured vehicles and ships, lowering reliance on outside vendors.

In addition, KDAIL's involvement in initiatives like SRIJAN and the Positive Indigenisation Lists shows its commitment to reducing imports and enhancing indigenous capacities. By promoting private sector engagement, working with government initiatives, and continuing to invest in R&D, KDAIL can play a meaningful role in India's move towards complete defence self-reliance. India has set a target of achieving ₹3 lakh crore in defence production by 2029 to strengthen India as a global self-reliant defence manufacturing ecosystem.

Q. What role do you envision KDAIL playing in India's "Atmanirbhar Bharat" defence ecosystem over the next decade?

Over the next decade, we see KDAIL playing an increasingly important role in India's Atmanirbhar Bharat in defence. Our focus will be on some core areas, like first deepening R&D and indigenisation across advanced materials, naval systems, and secure communication technologies to reduce reliance on imports in critical domains where gaps still exist. Second, in order to guarantee that India's defence ecosystem gains from quicker, more flexible product development cycles, we want to expand our partnerships with DRDO, the military, and commercial entrepreneurs.

India's self-sufficient capabilities in shipbuilding, electronics, and sophisticated materials will be reinforced by our strategic initiatives, which include scaling up Waveoptix for RF-over-fibre communications and partnering with VABO for composite naval constructions. With strategic investments such as our stake in Conceptia and capacity expansion at Halol, KDAIL is well-positioned to develop into a full-spectrum, internationally competitive defence solutions provider, enhancing India's technological independence.

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SAGAR CHOUDHARI - Director

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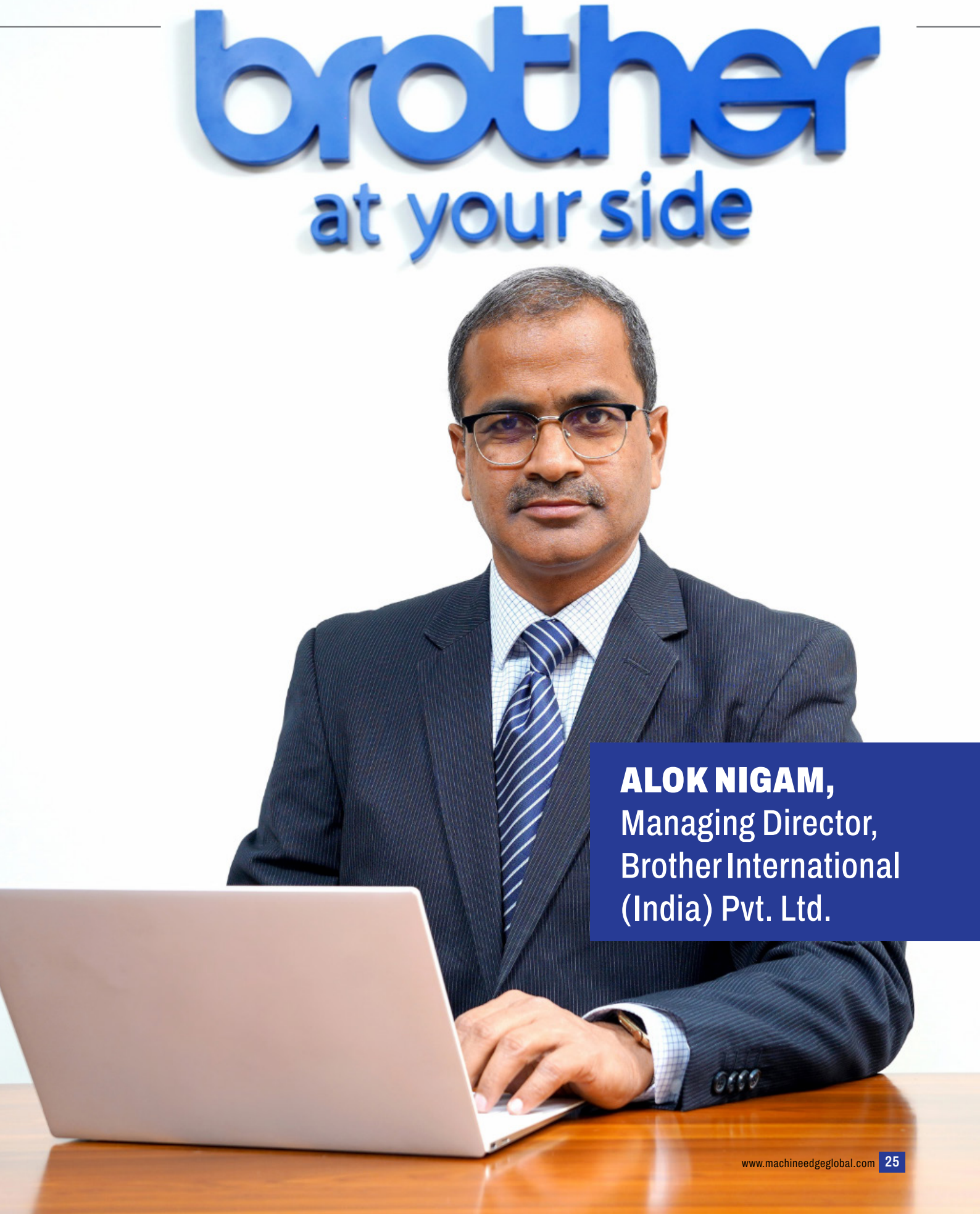
Smart Labelling for Smart Manufacturing

This article states that smart labeling has evolved into a core pillar of Industry 4.0, enabling manufacturers to achieve higher precision, real-time visibility, and seamless digital connectivity. It explains how advanced labeling technologies—powered by automation, IoT, and data integration—are driving accuracy, compliance, and sustainability across modern production environments.



ALOK NIGAM,
Managing Director,
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(India) Pvt. Ltd.

Industry 4.0 is changing the world, and the global manufacturing ecosystem is quickly moving toward systems that work together, digitalization, and automation. Smart, long-lasting, and accurate labeling is the most important thing for this change. Smart labeling used to be a way to tell things apart, but now it's an important part of smart manufacturing. You can see how things are going, keep track of them in real time, and make sure that everything in the production process is following the rules.

The Growth of Smart Labeling in Industry 4.0

AI, robotics, the Internet of Things (IoT), and big data analytics are all examples of technologies that make up Industry 4.0. Smart labeling is a key part of these technologies because they need data to move around easily. Today, labels are more than just names on paper. They can also hold information and communicate with systems using serial numbers, QR codes, barcodes, and RFID. This link helps manufacturers keep track of every part, check the health of their machines, and make sure they meet the growing number of strict global standards. Smart labeling is a part of the 'digital thread', which is a steady flow of information from design to production to delivery. When used with precise printing, these labels make sure that every asset, tool, and product is accounted for, correctly labeled, and easy to find throughout its life.

When Every Label Counts: Precision Drives Manufacturing

Precision is the only option in manufacturing. A part that is labeled incorrectly could stop production, lower quality assurance, or even break safety rules. Thanks to precise printing, every label has information that is easy to read, scan, and last. It doesn't matter if the labels are on a shelf in a warehouse, on an assembly line, or on a machine. At Brother, we've always cared about how accurate and long-lasting our products are. For 30 years, we've been working on and improving our laminated label technology. It makes sure that labels can handle heat, chemicals, grease, and wear and tear, which are all things that happen a lot in production settings. These high-performance labels are always easy to read, even in the worst conditions. This means that important information like calibration dates, part serial numbers, and safety precautions stays readable for the life of the product.

Building Intelligence into Every Label

For smart manufacturing to work, interoperability is very important. This means that systems, machines, and people all work together without any problems. Brother's labeling solutions can connect to business a system, which means that data from ERP, MES, or inventory databases can automatically fill in label templates. This not only fixes mistakes that people make, but it also speeds up production and makes sure that all of the facilities are the same.

You can also print labels from your phone or tablet with our solutions, so technicians and operators can do it right on the shop floor. For Industry 4.0, which is always changing, this level of freedom and movement is great. Getting information and making decisions in real time boosts productivity.

Enhancing Traceability and Compliance

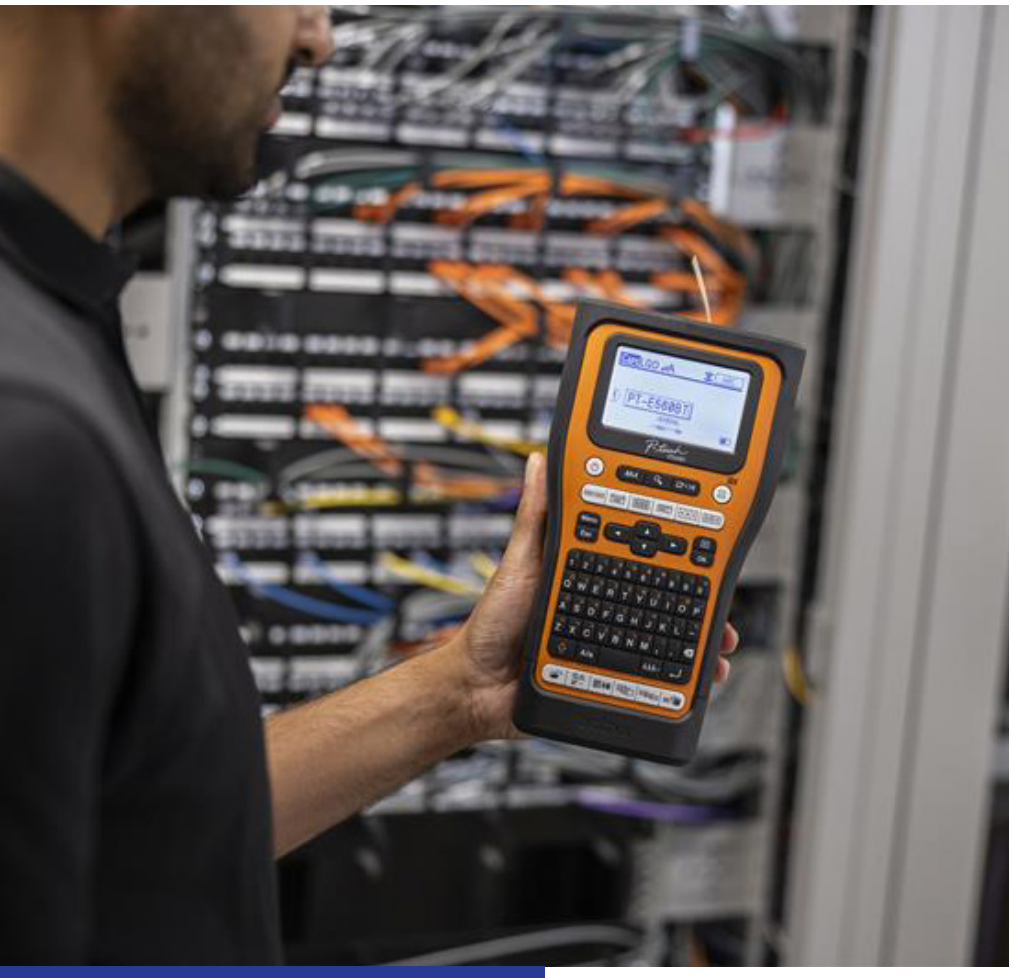
As global supply chains get more complicated, being able to trace

things has become an important part of being responsible and efficient in manufacturing. Smart labels help you keep track of things, like making sure that parts are real when you make cars or that food processing follows health rules. All fields, from electronics to pharmaceuticals, need labels that are

easy to read and can handle stress from the environment. Precision printing technologies help businesses meet safety and ISO standards, find mistakes more easily, and get ready for audits. Companies not only meet their compliance needs by doing this, but they also earn their customers' trust by being clear and consistent.

Connecting the Dots: Data, Devices, and Durability

Cyber-physical systems are the basis for the idea of smart factories. In these systems, machines can talk to each other thanks to sensors and data networks. Smart labels connect the real world to the digital world, turning everyday items into smart data points. Manufacturing plants can automate the process of making labels, cut down on downtime, and keep data in sync across production lines when they use



precision printers that connect to Wi-Fi, Bluetooth, or Ethernet. Brother's Software Development Kits (SDKs) and integration tools make it simple for manufacturers to add labeling features to their digital systems. This lets businesses print serial barcodes, make calibration labels, or fill out shipping paperwork right from their current business software, which keeps the digital workflow going.

Sustainability through Smart Labelling

Sustainability is also a big part of Industry 4.0.Smart labeling is better for the environment because it cuts down on waste and mistakes and lets for predictive maintenance through accurate tracking. Manufacturers can use fewer resources and speed up production cycles by switching from manual tagging methods to smart, automated ones. Laminated labels that last a long time are also good for the environment because they don't need to be reprinted or replaced as often, which means less energy and materials are used. This fits with the world's goals for using resources wisely and making things that last.

The Road Ahead: From Smart Labels to Smarter Systems

In the future, labeling will be a lot smarter because AI and automation will get better. Think about a system where labels change on their own in real time to show changes in the number of items in stock, the condition of the machines, or the batches. Adaptive labeling will play a significant role in Industry 5.0. It will use both human creativity and computer intelligence to make factories smarter, safer, and better for the environment. Brother doesn't see smart labeling as an extra step, but we do see it as a key part of changing how things are made. As factories get closer to going fully digital, the need for reliable printing and accurate labeling will only grow.

Smart labeling is more than just a way to keep things in order; it's what makes modern manufacturing work. With precision printing, the digital and physical worlds are always in sync. This lets factories work with accuracy, compliance, and confidence. Smart labeling is a quiet but powerful force behind Industry 4.0, which is a time when automation, connectivity, and sustainability are all important. Smart labeling systems will still be the best way to run a business as manufacturers get used to this change. This will turn 'smart manufacturing' from a dream into a global standard.

Conclusion

Smart labeling stands at the heart of the digital manufacturing revolution. As Industry 4.0 and the future Industry 5.0 reshape global production, the ability to link physical assets with digital intelligence will become even more crucial. With precision printing, durable materials, and seamless system integration, smart labels ensure traceability, compliance, and continuous workflow accuracy. As manufacturers accelerate toward fully connected, sustainable, and data-driven operations, intelligent labeling will remain one of the most essential enablers—transforming smart manufacturing from a vision into everyday reality..

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How Innovation in Ironmaking and Refractories Is Forging a Sustainable Future

Steel remains essential to global growth, yet its production is one of the most energy-intensive and carbon-heavy industrial processes. As the world accelerates toward net-zero goals, the steel industry is undergoing a transformative shift—from rethinking ironmaking routes to reengineering refractory systems. This article explores the breakthrough technologies and material innovations driving this transition and outlines how they are shaping a more sustainable future for steel production.

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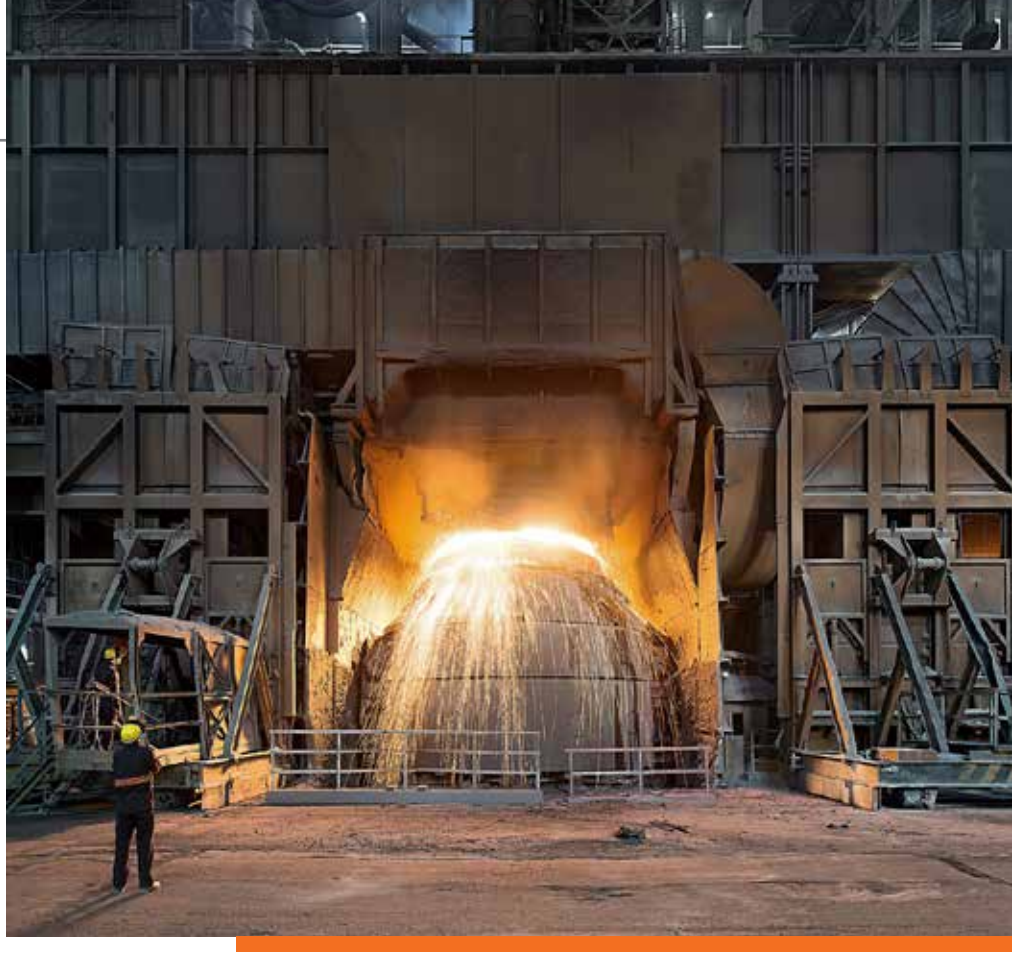

Innovation is reshaping the iron and steel industry at a critical moment in its evolution. As global steel demand rises and pressure mounts to reduce the sector's significant carbon footprint, new technologies in ironmaking and refractories are emerging as powerful enablers of a cleaner, more efficient, and future-ready steel value chain. This article explores how these breakthroughs are redefining sustainability in one of the world's most essential industries.

Steel is the backbone of modern civilization, forming the structural core of cities, mobility, infrastructure, and clean energy solutions. Today, over 1.9 billion tonnes of steel are produced globally every year, making it one of the most heavily used industrial materials on the planet. However, this vital industry also presents a formidable climate challenge: the iron and steel sector accounts for 7–9% of global greenhouse gas emissions and consumes nearly 7% of the world's total energy supply*.

With global demand expected to rise, driven by infrastructure expansion in emerging economies like India, ASEAN, and Africa, the urgent need to decarbonize steelmaking is undeniable. From green hydrogen to carbon capture, the future of steel depends on novel iron making processes that dramatically reduce emissions while maintaining efficiency, safety, and output.

A Carbon-Intensive Process in Need of Change

Traditional blast furnace-based steelmaking relies heavily on coal as a reducing agent, emitting substantial amounts of CO_2 throughout the production cycle. While incremental gains in energy efficiency and recycling have helped, transformational change is required to align with global climate targets and ensure a more sustainable steel value chain.

Here are the new novel ironmaking processes that are reducing carbon footprint and revolutionizing steel production:

Hydrogen-Based Reduction: A Clean Chemical Shift

Hydrogen-based direct reduced iron (H-DRI) technology offers one of the most promising pathways to decarbonization. Instead of carbon, hydrogen gas is used as the reducing agent to convert iron ore into metallic iron, emitting only water vapor as a byproduct.

According to recent studies, flash ironmaking using hydrogen can reduce CO_2 emissions by up to 96% compared to conventional blast furnaces. However, its scalability hinges on the availability of green hydrogen, which requires renewable energy-powered electrolysis and robust supply infrastructure. While challenges remain in heat management and maintaining steel quality, hydrogen ironmaking is steadily gaining traction as a cornerstone of the future.

Direct Electrification: Reimagining the Furnace

One promising approach is the direct electrolysis of iron ore, which uses renewable electricity to extract iron without relying on fossil fuels. This process, still in development, has the potential to enable near-zero emissions steel production, particularly in regions with abundant green energy sources.

However, electrified reduction is energy-intensive, demanding significant advancements in high-temperature electric systems and cost-effective renewable energy access. The potential for full decarbonization remains high, provided the technology matures alongside grid modernization.

Bioenergy and Carbon Capture: Closing the Loop

Using biomass-based fuels in combination with carbon capture, utilization, and storage (CCUS)

technologies is a new emerging approach for sustainable steelmaking. By capturing and storing emitted carbon and replacing renewable organic matter for fossil fuel-based energy, this approach drastically lowers the net carbon output. Carbon-negative steel, in which more CO_2 is captured than released during the process, could be produced by such systems in specific configurations.

Nevertheless, there are still issues with increasing biomass production, ensuring steady energy output, and optimizing the economic feasibility of large-scale CCUS implementation.

Other Complementary Innovations

Beyond ironmaking, sustainability also lies in improving existing steelmaking efficiencies, such as optimizing coke dry quenching, maximizing top gas recovery, and increasing pellet feed ratios. At the same time, boosting steel recycling offers major energy and emissions savings, with recycled steel requiring 75% less energy than primary production.

The Flash Ironmaking Technology (FIT), which uses ultra-fine iron ore particles in a reactor for rapid reduction, adds another promising tool to the decarbonization toolbox.

The Role of Refractory Innovation in Sustainable Steelmaking

Refractory materials are essential to the steelmaking process, enabling high-temperature operations while directly influencing energy efficiency, emissions, and product quality. Innovations in refractories—such as those designed for enhanced steel cleanliness and extended service life—can significantly reduce operational downtime, material consumption, and energy loss.

A comprehensive approach to refractory usage—considering factors like installation techniques, thermal performance, CO_2 emissions, and alignment with circular economy principles—is key to supporting low-carbon steel production. Advancements in refractory product development, digital monitoring, and equipment design are further contributing to the industry's decarbonization goals and overall environmental performance.

A Just Transition for a Greener Tomorrow

In addition to being a climate necessity, decarbonizing the steel sector offers a chance for comprehensive change in the areas of the economy, society, and environment. Financial viability, organizational adaptability, and behavioral change management must all be taken into account as stakeholders from all points of the value chain invest in green steel technologies.

The transformation of the steel industry ultimately depends on the convergence of several technologies, ethical manufacturing methods, and ongoing innovation in all supply chain links, including refractories, rather than on a single breakthrough.

By working together, these initiatives can pave the way for a time when steel continues to be the foundation of advancement without compromising the health of our planet.

Conclusion

The path to sustainable steelmaking is not defined by a single technology but by the collective progress of innovations in ironmaking, refractories, energy systems

, and value-chain collaboration. As hydrogen reduction, electrification, bioenergy, carbon capture, and advanced refractory solutions continue to mature, they bring the industry closer to its low-carbon goals. By embracing these shifts with a people-centric and ecosystem-driven approach, the steel sector can secure a greener, more resilient future—one where steel remains the backbone of global development without compromising the planet.

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How DRI Is Aligning Industrial Innovation with Environmental Goals

This article provides an overview of the growing need for sustainable climate control in industrial settings and explains how DRI addresses this challenge. It covers DRI's key technologies—such as TFA, DOAS, Chilled Beams, and ERVs—and outlines how these solutions improve indoor air quality, reduce energy consumption, and support greener industrial operations.

As industries expand and operations become increasingly energy-intensive, the push for sustainability has moved from a choice to a necessity. Large-scale manufacturing, along with the heating, cooling, and environmental control processes it demands, places significant pressure on natural resources and contributes heavily to carbon emissions. In this evolving landscape, companies are being evaluated not just by their productivity, but also by their environmental responsibility. Standing at the forefront of this shift is Desiccant Rotors International (DRI), a pioneer in sustainable climate control within the HVAC sector. With a strong commitment to innovation and environmental stewardship, DRI is redefining how industries manage indoor air quality, energy consumption, and overall climate efficiency.

Sustainable practices have become an integral part of the industries, showcasing them more in the light of responsible companies. However, given the nature of operations being carried out involving large-scale manufacturing or energy-intensive processes in the form of heating, cooling, and monitoring the internal environment can take a toll on the climate. By default, the industrial operations immensely contribute to carbon emissions while being huge energy guzzlers and account for resource depletion in the process.

Driving Sustainable Climate Control in Industrial Environments

Desiccant Rotors International (DRI) leads the league in offering sustainable climate control solutions in the realm of the HVAC industry. It is diligently focused on providing breakthrough solutions for controlling indoor air quality and climate. In addition to this, being perceptive of the ongoing developments and the environmental impact of the industries, it has created a niche for itself in providing energy-efficient and sustainable solutions.

Specializing in improving the air quality within industrial facilities, DRI offers a range of Fresh Air Ventilation systems aimed at achieving acceptable ventilation within the space. The Air Handling Units (AHU) comprising Treated Fresh Air Units (TFA) and Dedicated Outdoor Air Systems (DOAS), are the major highlights of the house.

VARUN PAHWA,
President,
Desiccant Rotors International

They are primarily deployed in the industrial facility to ensure the supply of fresh air into the room while efficiently capping the energy consumption in the process. Thereby, they achieve the two-fold task of enhancing the indoor air quality and reducing the operational cost of the facility.

High-Efficiency Ventilation and Humidity Control Solutions

Delving into the benefits of TFA, the systems achieve the highest ventilation standards by preconditioning the incoming fresh air to provide excellent indoor air quality (IAQ). The systems come with the proficiency to mitigate pollutants, allergens, and contaminants, where they conduct the filtration and treatment of air before introducing it into the space. As a result, they come in handy for curtailing the spreading of airborne diseases by driving a continuous supply of clean and healthy air. In addition to this, TFA goes a long way in recovering the sensible and latent energy with the help of energy recovery wheels, offering a host of benefits in the form of improved IAQ, humidity control, and huge energy savings.

Simultaneously, it also reduces the requirement for overall system capacity where it is adept at handling and distributing the air for depleting the demand of heating, ventilation, and air conditioning (HVAC) systems. This plays a crucial role in decreasing the overall load on the system, translating to reduced operational cost and energy consumption of the systems.

To monitor humidity, DRI also offers Dedicated Outdoor Air Systems (DOAS) that also bode well for adequate ventilation of space with the removal of indoor air pollutants. Being well equipped with unique passive dehumidification wheels, it thoroughly manages relative humidity (RH) levels that amplify the energy recovery efficiency and curtail cross-contamination as well. Resisting the growth of mold, unpleasant odors, and discomfort due to uncontrolled moisture, it actively replenishes the facility with fresh air. Altogether, the systems offer a comprehensive solution aimed at boosting the air quality of the space.

Similarly, Chilled Beams, primarily recognised as room air recirculation devices, have been specifically devised to cool and ventilate the space. They ensure the comfort of people occupying the space and yield good air quality for them. When it works in combination with DOAS, it steers the energy-efficient operation of the system. Chilled Beams curtail the energy consumption by 20-25% in contrast to traditional systems, emerging as the most energy-efficient solution.

Likewise, Energy Recovery Ventilators (ERVs) allow remarkable energy savings when working towards

maintaining good air quality within the enclosed space. Well equipped with EcoFresh Energy Recovery Wheels, the system drives the recovery of both sensible and latent energy, resulting in high energy transfer efficiency.

Innovation, Energy Efficiency, and a Commitment to a Greener Future

Drawing parallels from competitive solutions offered by DRI, it can be established that the company is committed to achieving the overarching goal of a greener future. With strong roots in innovation, it boasts intensive research and development with a focus on curating advanced technologies that exhibit unmatched performance and contribute to the sustainability of the systems at the same time. It is well aligned to gauge the emerging industrial dynamics and introduce next-generation solutions accordingly.

Driven by the purpose of reducing the environmental impact, DRI itself incorporates sustainability into its practices, where one of its facilities in Manesar has been accredited with Platinum Certified Green Factory Building. Therefore, DRI is at the forefront of reducing, reusing, and recycling resources, which is in tandem with curbing resource wastage aimed at contributing to sustainable growth.

Conclusion

DRI's portfolio of advanced ventilation, dehumidification, and energy recovery solutions underscores its unwavering commitment to a cleaner, more sustainable industrial future. Through technologies such as TFA, DOAS, Chilled Beams, and ERVs, the company consistently delivers systems that elevate indoor air quality while significantly reducing energy usage and operational costs. Backed by robust R&D and a deep understanding of global environmental demands, DRI continues to develop next-generation solutions that align with the industry's shift toward greener operations. With initiatives like its Platinum Certified Green Factory in Manesar, DRI not only advocates sustainability—it practices it. As industries strive to balance performance with environmental responsibility, DRI stands as a model of how innovation and sustainability can seamlessly converge.

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Water: The Propellant Powering Space's Next Leap

This article states that the future of sustainable space propulsion is shifting rapidly toward greener, safer, and more efficient alternatives—placing water at the forefront as the next revolutionary space propellant.

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Associate Director- Propulsion &
Founding Member, Stardour Aerospace
Technologies Pvt. Ltd.


STAR SPHERE

Space exploration is entering a new era where sustainability and safety are becoming just as important as performance. For decades, spacecraft relied on toxic and complex chemical propellants, but recent advances have shifted the focus toward greener alternatives. Among these, water has emerged as a promising, game-changing propellant—offering safety, abundance, versatility, and long-term potential for future missions. This article explores how water is reshaping the future of space propulsion and why it is gaining global attention as the next big leap in sustainable space travel.

Green Revolution in Space Propulsion

For several decades, spacecraft have been utilising powerful yet often toxic, corrosive, hazardous, and expensive-to-handle chemical propellants. In recent times, space exploration has shifted towards a greener and cleaner propellant era to drive satellites.

A few green alternatives, such as HTP, ASCENT, and LMP-103S, are being employed instead of conventional chemical propellants, with a focus on safety, environmental impact, and cost concerns.

In terms of sustainability, deep space exploration, and interplanetary ambitions, an improbable fuel has surfaced - "WATER"!

Water is emerging as the future fuel as it amalgamates safety, in-space availability, versatility, compelling performance, and cost efficiency for future missions, aligning with upcoming space reforms & regulations and operational demands.

Water is environmentally friendly, non-toxic, non-corrosive, and highly stable across a wide range of operational conditions, unlike traditional hazardous propellants such as Hydrazine, MMH, UDMH, N2O4, MON – 3, and other Earth-storable fuels. The challenges of personnel risk during handling, fuelling / servicing, integration, and safety aspects associated with these conventional propellants are beyond doubt eliminated. With zero complexity in fuelling operations and simpler tank storage feasibility, water emanates to be the ultimate green propellant.

Moreover, water is abundantly available not only on Earth but also on celestial bodies like the Moon, Mars, and asteroids. This reduces dependency on Earth-based propellant launches, as in-situ resource utilization (ISRU) can be employed. This is one of the biggest advantages of using water as a propellant improving overall payload capability and cost-effectiveness of spacecraft.

ISRU seeds an innovative vision for sustainable space exploration, including propellant depots in space and lunar or Martian supply chains.

Water is already being utilised by crew aboard spacecraft for drinking, hygiene, cooling, and oxygen support. When stored water is also used as a propellant for orbital manoeuvring and station keeping, it helps reduce overall mass. This multi-functionality of water combining propulsion, life support, and power is vividly acknowledged by ESA.

Water, when transformed into an energetic form, can be employed across multiple propulsion modes, viz., bi-propellant thrusters, electrothermal thrusters, and plasma thrusters.

Demonstrations and Global Developments

NASA's Pathfinder Technology Demonstrator (PTD-1) successfully proved water propulsion in orbit, attaining approximately 310 seconds of specific impulse using the HYDROS thruster.

This HYDROS hardware unit is a water-based propulsion system designed for CubeSats. Credits: Tethers Unlimited Inc. / Mason Freedman [1]

Additionally, one of NASA's technical reports indicated that water propulsion systems exhibit a thrust-to-power ratio of ~0.2 N/kW and electrical conversion efficiencies exceeding 85%.

Similarly, ESA, along with its industry partners pursuing water propulsion technologies, had accomplished performance up to 14 times higher than electric propulsion systems at comparable input power. This showcases strong competition with conventional rocket fuels.

Pioneering Efforts in Asia

Tokyo-based deep-space technology organisation Pale Blue had trademarked multiple types of water-based propulsion systems. The company had successfully demonstrated the potential of water propulsion through various small satellite missions using their in-house developed resistojets and ion thrusters, proving the technology's integrity, feasibility, and reliability.

PBR-20: Pale Blue's water resistojet. Credits: Pale Blue [2]

The AQT-D (Aqua Thruster Demonstrator) was the first ISS-deployed satellite using a water-based propulsion system called AQUARIUS-1U (Aqua Resistojet Propulsion System -1U), developed by the University of Tokyo. It utilises water as propellant for trajectory control and reaction

wheel desaturation of the 6U CubeSat EQUULEUS (EQUilibriUm Lunar-Earth point 6U Spacecraft).

AQT-D Credits: [3]

The ESA's AQUAMAG project further advances water propulsion technology by using magnesium and steam to generate a controlled hybrid engine capable of throttleable thrust, supporting de-orbiting or rendezvous missions.

Challenges and the Road Ahead

Although water-based propulsion systems offer numerous advantages, several challenges remain crucial for their effective implementation. Advanced propulsion technologies like these require robust power supplies, miniaturised fluidic and versatile mechanical systems, and efficient propellant management devices. And with very little precedence and experimental data, this is a niche in propulsion that needs fundamental R&D: something that Stardour has always focused on.

Further challenges include thermal management system preventing freezing in storage systems and fluid lines under harsh temperature gradients and vacuum conditions due to water's low freezing point. Thus, operational complexities are foreseen with these systems.

Additionally, ISRU-based propulsion systems face difficulties related to resource extraction, processing, and on-site utilisation.

Nonetheless, collaborative efforts across space agencies, research institutions, and private industries continue to drive the development of advanced propulsion technologies like water-based systems. These efforts aim to enhance performance, simplify operational complexities and integration, and ultimately create cost-effective, reliable, and sustainable propulsion solutions for deep-space missions.

Illustration of the Pathfinder Technology Demonstrator-1 spacecraft demonstrating a water-based propulsion system in low-Earth orbit. Credits: NASA [1]

Conclusion

Water is a simple yet powerful, distinctive and unique fuel that integrates enhanced performance, safety, versatility, and multi-functional capabilities, offering long-term sustainability and cost-effectiveness for future deep space explorations. It outshines as an indispensable choice for future space propellants clean, green, abundantly available across the solar system, and supporting both life and propulsion activities.

With its ability to function in multi-mode propulsion techniques, and the potential of ISRU technology enabling in-space refuelling, water represents a transformative step in sustainable space travel.

NASA and ESA have already laid the foundation for water-based propulsion systems. This technology is poised to emerge as a promising propulsion eventually replacing toxic conventional propellants in deeper and more advanced missions.

Water is not only a precious resource for humanity; it may also be the key to unravelling the mysteries of the universe and this is exactly why Stardour is pioneering this technology.

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