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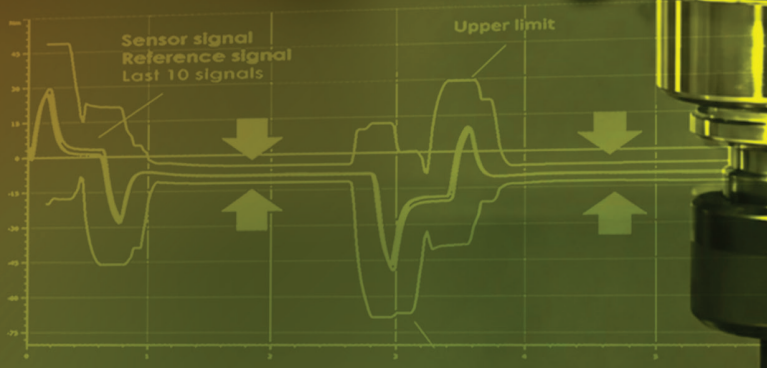
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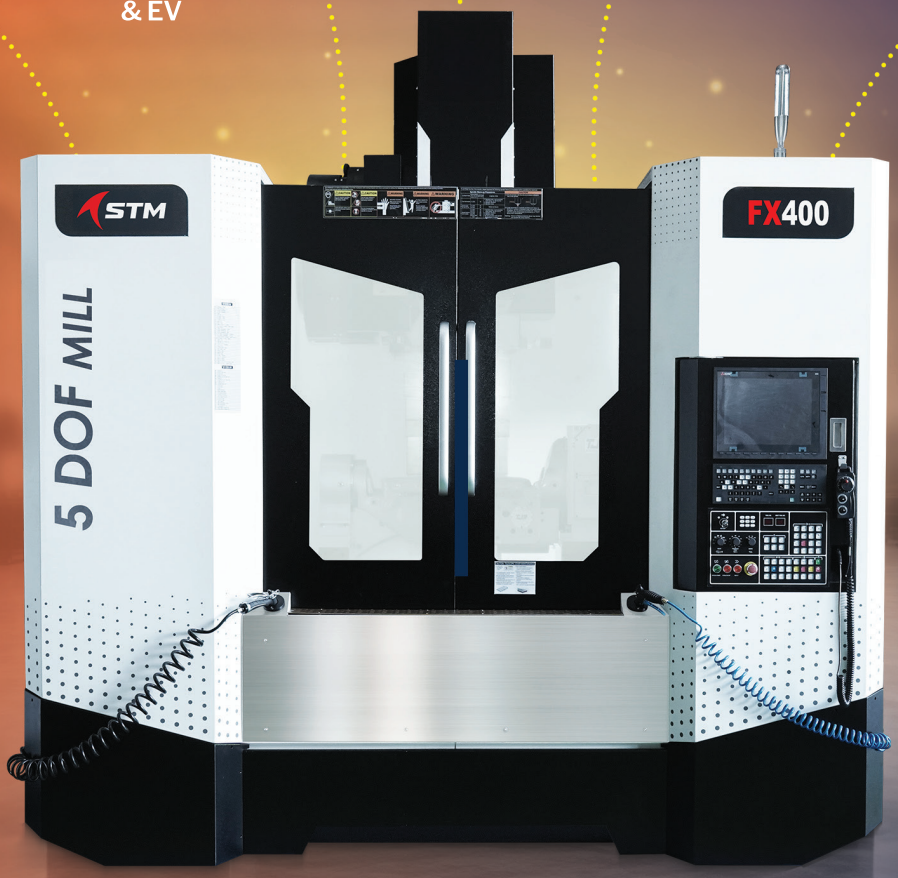
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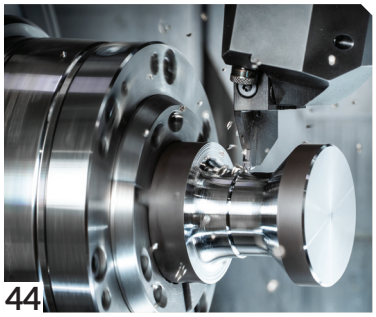
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RESILIENCE AND OPTIMISM DRIVE INDIA'S MACHINE TOOL SECTOR





MOHINI KELKAR
PRESIDENT
IMTMA

Dear Readers,

India is striving to navigate the evolving geopolitical dynamics and energy crises. The country is on track to build resilience and establish a technology-empowered, globally competitive ecosystem. The policy environment remains positive for MSMEs, with a sustained focus on strengthening supply chains, improving liquidity, and enhancing competitiveness.

Buoyed by these factors, the Indian machine tool industry has maintained optimism as it prepares for its next move. The industry ranks 5th in consumption and 9th in production for the year 2025, as per the latest World Machine Tool Survey 2026 by Gardner Intelligence. Rising demand for machine tools, particularly high-precision machinery, signals new opportunities for the machine tool industry.

Indian Machine Tool Manufacturers' Association (IMTMA) is gearing up to host the next edition of the National Productivity Summit, which will showcase breakthrough manufacturing practices, technological advancements, and operational efficiencies across India's industrial ecosystem on November 25–26, 2026 in Coimbatore. I urge the manufacturing community to participate in the Summit.

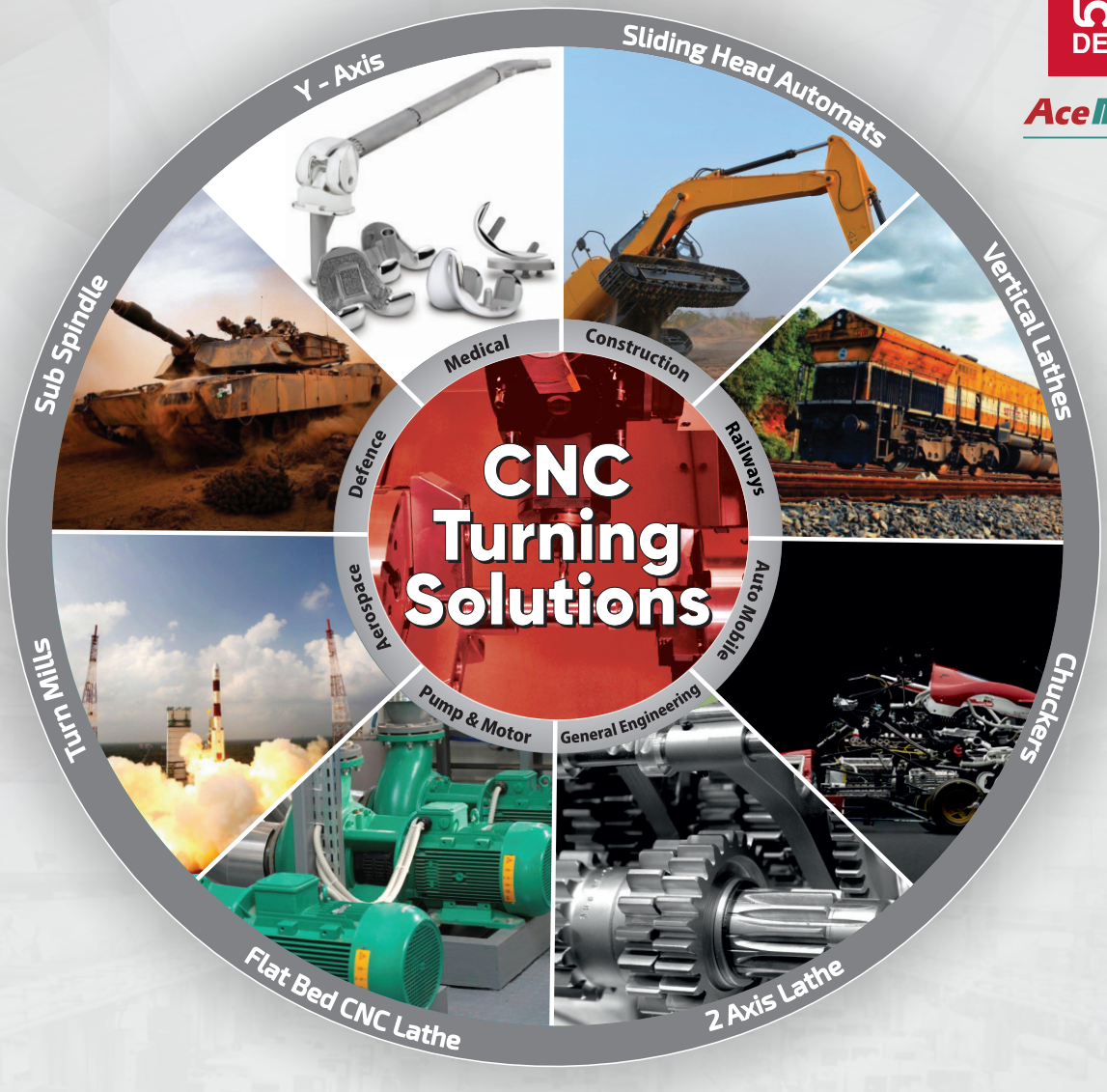
IMTMA is gearing up to host the next edition of the National Productivity Summit, which will showcase breakthrough manufacturing practices, technological advancements, and operational efficiencies across India's industrial ecosystem on November 25–26, 2026 in Coimbatore.

I wish readers an inspiring and enriching reading experience with this edition of MMI.

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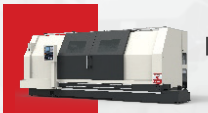

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Dear Readers,

Manufacturing industries in India are evolving at a rapid pace, led by technological advancements, digitalization, and the increasing demand for precision, productivity, and competitiveness.

This edition of Modern Manufacturing India (MMI) spotlights a range of perspectives that reflect the shifts and opportunities that are emerging across the industrial landscape. It largely focuses on aerospace machining, exploring the technologies, capabilities, and manufacturing practices needed to meet the rising demands of this high-precision sector.

Drawing on the views expressed by some companies, an article by the Indian Machine Tool Manufacturers' Association (IMTMA) examines the evolving requirements of aerospace manufacturing and opportunities for the Indian machine tool industry to strengthen its role in the growing ecosystem.

A case study on filtration in aerospace component machining highlights the critical role of process control and cleanliness in achieving consistent quality and performance. The evolving role of metrology in enabling precision, quality assurance, and reliable manufacturing has also been discussed.

Additionally, the edition also marks TaeguTec India's 25-year journey, reflecting on its growth and contribution to the country's manufacturing ecosystem. We also examine the growing adoption of artificial intelligence in manufacturing and its potential to transform productivity, decision-making, and operational excellence. An insightful article on learnings from building great teams explores how these principles can be applied to strengthen collaboration, leadership, and organizational performance in the manufacturing sector.

The issue further looks at advanced machining solutions for the railway industry, highlighting technologies supporting the evolving requirements of this important sector. Post-show reports from the Symposium on Automation & Robotics and Pune Machine Tool Expo and Factory Equipment Expo 2026 capture the technologies, ideas, and industry interactions that shaped these important platforms. Looking ahead, our JIMTOF 2026 Preview offers a glimpse into the technologies and trends expected to shape the global machine tool industry.

This edition of Modern Manufacturing India (MMI) spotlights a range of perspectives that reflect the shifts and opportunities that are emerging across the industrial landscape. It largely focuses on aerospace machining, exploring the technologies, capabilities, and manufacturing practices needed to meet the rising demands of this high-precision sector.

We hope this edition offers sharp insights, fresh perspectives, and actionable ideas for the manufacturing community. IMTMA thanks all contributors, partners, and readers for their continued support and welcomes their feedback to make MMI an increasingly valuable resource for the industry.

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WHEN STEEL, SCIENCE, AND SUNRISE ALIGN

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"Great engineering is invisible. When precision does its job perfectly, the world simply calls it normal."

In this issue, we go beneath the fuselage to explore the relentless technology and precision that make flight look effortless.

Welcome aboard!

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Source: IMTMA

L-R: Jibak Dasgupta, Director General & CEO, IMTMA; Soumya Ranjan, Director, Ernst & Young LLP; Mohini Kelkar, President, IMTMA; Dr Shivkumar Kalyanaraman, CEO, ANRF; Prof B Gurumoorthy, Honorary Professor, IISc; and Vikram Salunke, Vice President, IMTMA, at IMTMA's 80th AGM

A new IMTMA Executive Committee for 2026–2027 was formed at the AGM with Mohini Kelkar as President and Vikram Salunke as Vice President.

The 80th Annual General Meeting (AGM) of IMTMA was held on September 24, 2026, at BIEC, Bengaluru, bringing together perspectives from research, academia and industry. A Special Session featured Dr Shivkumar Kalyanaraman, Chief Executive Officer, Anusandhan National Research Foundation (ANRF), Government of India; Prof B Gurumoorthy, Honorary Professor, Department of Design & Manufacturing and Department of Mechanical Engineering, Indian Institute of Science (IISc), Bengaluru; and Soumya Ranjan, Director, Ernst & Young LLP.

Strengthening Research and Innovation

Dr Kalyanaraman delivered the keynote address on the role of ANRF in strengthening India's research and innovation ecosystem. He highlighted the importance of high-impact research, stronger academia–industry collaboration, and translating research outcomes into meaningful applications.

Connecting Academia with Industry

Prof Gurumoorthy spoke on 'Industry–Academia Collaboration: Myth or Reality'. Drawing on examples of successful collaborations, he highlighted the need for stronger models that connect academic research with industry requirements and support technology development and innovation.

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Building a Global Machine Tool Powerhouse

Ranjan presented on 'Transforming India into a Global Powerhouse for Advanced Machine Tools'. He highlighted the strategic and financial implications of the Indian machine tool industry's dependence on imports and the need for proactive measures to strengthen domestic capabilities. He also outlined opportunities arising from sectors including electronics, semiconductors, renewable energy, shipbuilding and electric vehicles, which can create new avenues for the growth of the machine tool industry.

Source: IMTMA



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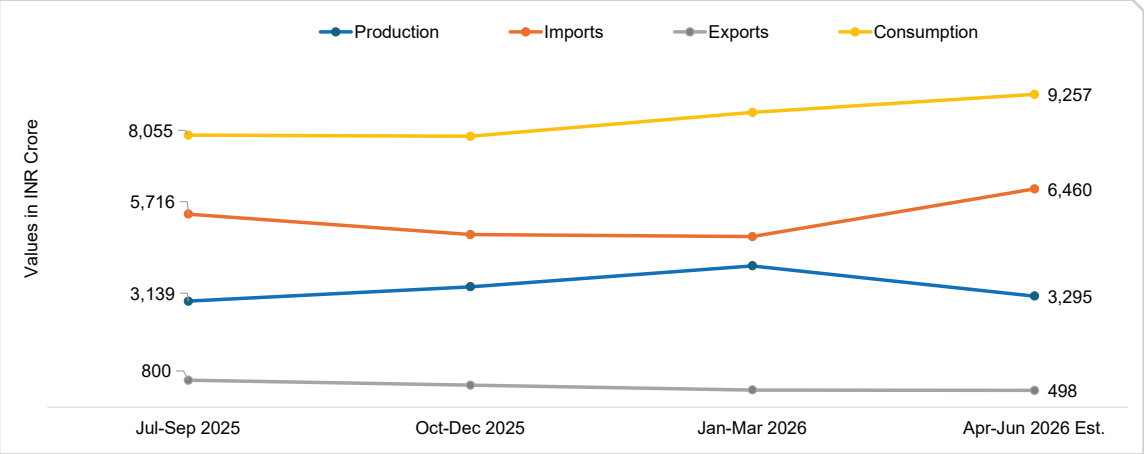
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GROWTH DRIVES MACHINE TOOL DEMAND

India's robust economic activity and continued focus on investment are creating favorable conditions for manufacturing. The machine tool industry is reflecting this positive outlook, with production rising approximately 26 percent and consumption growing 20 percent in Q1 FY27.



Source: IMTMA

Table 1. Indian Machine Tool Industry Trend

The production of the Indian machine tool industry in Q1 FY27 is estimated to have increased by approximately 26 percent year-on-year, reaching around INR 3,295 crore (US$ 348 million).

The economic performance indicators for July 2026 reflect a continued expansion in economic activity, with manufacturing and services PMI remaining firmly above the benchmark level of 50. Overall industrial activity also strengthened, with IIP growth reaching a 23-month high of 7.3 percent in June 2026.

Inflation and Fiscal Conditions

Inflationary pressures remained relatively contained at the retail level, with CPI inflation stable at a seven-month high of 4.4 percent in July 2026, slightly above the RBI's medium-term target of 4 percent. However, WPI inflation remained elevated at 9.8 percent during the month.

In Q1 FY2026-27, gross tax revenues grew 3.7 percent, total expenditure 11 percent, and capital expenditure 23.7 percent, while the fiscal deficit stood at 18.2 percent of the annual budgeted target.

Credit and Investment Support Growth

Gross bank credit growth accelerated to a 25-month high of 18.6 percent in June 2026, while net FDI and FPI recorded inflows of US$ 1.3 billion and US$ 2.5 billion, respectively. The RBI kept the repo rate unchanged at 5.25 percent in August, retaining a neutral policy stance.

Trade and Global Outlook

In external trade, merchandise export growth accelerated to 19.6 percent in July 2026, while imports grew by 17.5 percent, resulting in the trade deficit widening to US$ 32.0 billion.

The IMF has projected global growth at 3.0 percent in 2026 and 3.4 percent in 2027. With buoyant demand and continued government focus on capital expenditure, India's real GDP growth in FY2026-27 is expected at 7.0–7.2 percent, while nominal growth is projected at 12.5–13.0 percent.

Machine Tool Industry Expands

According to the latest World Machine Tool Survey by Gardner Intelligence, India ranked 5th in consumption and 9th globally in production in 2025.

The industry's imports in Q1 FY27 saw a rise of 12 percent year-on-year, amounting to INR 6,460 crore (US$ 682 million). Machine tool exports from India declined by 20 percent during Q1 FY27, amounting to INR 498 crore (US$ 53 million), while consumption is estimated to have increased by about 20 percent to reach INR 9,257 crore (US$ 978 million).

Source: Data Analytics & Policy Team, IMTMA

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Source: Magic Wand Media

INDIA'S MACHINE TOOL INDUSTRY MEETS ITS AEROSPACE MOMENT

At the recent Bangalore Space Expo, held at Bangalore International Exhibition Centre (BIEC), the conversations kept circling back to the same paradox: India's aerospace and space manufacturers are scaling up ambitiously, but the Indian machine tool industry needs to brace for rising demand, which is largely being met by companies from Europe and America.

For the machine tool industry, the expanding space, aerospace, and defence ecosystem is opening up a wealth of new opportunities.

India's space economy, according to the Department of Space, is valued at INR 80,323 crore (US$ 8.4 billion) and is projected to grow about five times to reach INR 3.8 to INR 4.3 lakh crore (US$ 40-45 billion) in a decade. In defence, according to the Ministry of Defence, Government of India, domestic production reached a record INR 0.178 lakh crore (US$ 1.86 billion) in FY2025-26, with exports touching INR 38,424 crore (US$ 4.02 billion). At the same time, the Government of India is pushing aircraft component manufacturing as part of its ambition to establish India as a global aerospace hub.

Across these sectors, ambition is rising swiftly, yet aerospace manufacturers who spoke to the Indian Machine Tool Manufacturers' Association (IMTMA) said that India's domestic machine tool industry, while improving rapidly in specific segments, still needs to bridge the gap, as the aerospace sector depends on advanced, high-precision, multi-axis, and material-specific machining.

Where India Already Delivers

Commenting on the state of domestic capability, an aerospace industry representative said that precision manufacturing in India has largely 'sorted itself out'. Additive manufacturing, which is increasingly central to lightweight aerospace components, is a genuine bright spot for the Indian machine tool industry.

Elsewhere, it is a mixed picture: roll-forming machinery and composite-processing equipment remain underdeveloped domestically. CNC turning centers and VMCs capable of handling large-format parts — those in the 800 mm range that aerospace structures often demand — are not yet made in India at the required scale.

AnduraX, which builds reusable spaceplanes and runs a

Source: IMTMA

genuinely hybrid shopfloor, said that high-precision composite machining is done using Indian-made equipment, while ceramic matrix composite machining, a more specialized, heat-tolerant category, is imported.

Another company, which supplies both the aerospace and defence industry, leans further towards imported precision tools from Germany and Italy, citing spindle capacity as the deciding factor. Some of its imported machines carry up to 12 spindles and run 32-axis configurations, against the 12-axis machines typical of domestic equivalents, enabling far greater multitasking on a single component.

What Matters Beyond Capability

Cost, serviceability, lead time, and application requirements all play a role in machine selection. Avasarala Technologies, for example, uses imported milling, turning, wire-cutting, and grinding machines where the combination of machine performance, reliability, and long-term service support makes them the more practical choice for its operations. The experience highlights an important consideration for the next phase of Make in India: adoption will depend not only on machine capability and precision, but also on competitive lifecycle costs, responsive after-sales support, availability of spares, and strong maintenance ecosystems.

Xovian Aerospace's approach illustrates a further nuance: satellite manufacturing itself is outsourced to established Indian vendors using domestic machine tools. The company uses domestic equipment also for testing, especially for the first few satellites. While Xovian does have in-house testing capacity both domestic and foreign equipment is used for testing. The mix of foreign to domestic testing equipment can be said to be around 40:60 (foreign equipment proportion is around 40%). Using foreign equipment makes sense, if there is a need for specific precision hardware that is not available with Indian vendors or the equipment cannot be fabricated locally.

Industry sources said that some companies source machines from Europe due to accuracy, usage optimization, and lead time, while continuing to buy CNC turning machines and VMCs from Indian manufacturers where domestic capability already meets their needs. According to analysts, ordering a machine domestically today carries a lead time of roughly six months. The gap becomes commercially significant when actual production accuracy requirements, which can be as tight as 0.05 mm on some components, leave little room for delay.

While Indian companies take about six months, imported machines from established international companies carry their own extended waiting periods once shipping, customisation, and installation are factored in. This means that lead time, not just accuracy, is now a live procurement variable across the sector, whichever directions manufacturers ultimately choose.

The Bigger Supply-Chain Question

Taken together, these accounts sketch an industry in transition rather than one cleanly divided between imports and domestic production. India's machine tool industry has made real headway in additive manufacturing, in mid-range CNC machine tools and VMCs, and in components that do not demand extreme multi-axis precision or exotic material handling. What remains a structural gap is at the high end: large-format turning, ceramic matrix, and composite-specific machining, ultra-high-spindle-count centers, and equipment where servicing infrastructure is still catching up to the machines themselves.

This is precisely where the gap matters most to India's aerospace and space ambitions, as these are the categories that will determine how quickly indigenous propulsion, satellite, and reusable-vehicle programs can scale. A reduced lead time, manufacturers across the expo agreed, would do more for near-term competitiveness than incremental gains in machine precision alone. The industry consensus pointed towards six months to a year as the workable window aerospace production actually needs, against the considerably longer cycles many currently face.

Building for the Next Phase

India's machine tool industry is maturing unevenly. It is strongest where volume and standardization help, while specialized, high-precision capabilities required by the aerospace and space sectors remain more challenging to develop.

As India makes rapid advancements in the space, aerospace, and defence sectors, aerospace manufacturers suggest that the next phase of import substitution will depend not on cost alone, but on lead time, servicing depth, and the ability to match the capabilities already delivered by established machine tool makers worldwide — spindle for spindle and micron for micron.

As India makes rapid advancements in the space, aerospace, and defence sectors, aerospace manufacturers suggest that the next phase of import substitution will depend not on cost alone, but on lead time, servicing depth, and the ability to match the capabilities already delivered by established machine tool makers worldwide.

Article compiled with inputs from Avasarala Technologies Ltd, Xovian Aerospace, and AnduraX.

WHAT GOOGLE LEARNED ABOUT BUILDING GREAT TEAMS

What makes a great team? Google set out to find the answer through Project Aristotle, studying more than 180 teams. The findings were surprising: high-performing teams were not necessarily made up of the smartest people, but of people who worked together in the right environment — one built on trust, clarity, purpose, and psychological safety.



Source: Magic Wand Media

REJI VARGHESE
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Every engineering company wants better teams and hence spend a lot of time hiring capable engineers. They invest in expensive CNC machines, automation, ERP systems, and training programs. Yet many struggle with missed deadlines, quality issues, communication gaps, endless firefighting, and people blaming each other.

To find out why some teams consistently outperformed others, Google launched a research project called Project Aristotle in 2012. Researchers studied more than 180 teams over several years. They looked at educational qualifications, personality types, seniority, management styles, and even whether team members socialized outside work.

The conclusion surprised them.

The study found that the best teams were not built by collecting the smartest or those with the best qualifications. The best teams were built by creating the right environment for ordinary people to do their best work.

For engineering companies, that lesson is worth paying attention to. Designing a new machine, launching a production line, or solving a customer problem rarely depends on one brilliant engineer. Success usually comes from several departments working together, often under tight deadlines.

Google identified five characteristics that appeared repeatedly in its highest-performing teams.

> "When colleagues consistently deliver on their commitments, trust, which is the basis of any success, grows naturally. Teams spend less time checking on one another and more time solving customer problems, improving products, and finding better ways of working."
>
> **Pradeep Patil**
> **Managing Director**
> **TRUMPF India Pvt Ltd**



Source: TRUMPF India Pvt Ltd

Psychological Safety

This was the biggest finding — people performed better when they felt safe to speak up.

That sounds simple, but it is surprisingly rare. Every company has seen situations where a young engineer notices a problem in a design but keeps quiet because everyone else in the room is more senior. Sometimes an assembly line worker spots an issue long before anyone in management does, but decides it isn't worth saying anything.

Those moments are expensive.

Harvard professor Amy Edmondson defines psychological safety as the confidence that people can ask questions, admit mistakes, and challenge ideas without being embarrassed or punished.

Deepa Agarwal, Founder and Chief Inclusion Officer, Re-Link, says, "People often think that psychological safety is a bit abstract and difficult to measure. In reality, it can be assessed by simply noticing the behavioral signals of every team member across multiple parameters, such as whether someone shares ideas or perspectives only when asked, does not ask questions or seek guidance out of fear, does not voice disagreement openly, or tends to keep interactions work-related, even when there are opportunities to build connections. Chances are that their psychological safety may be lower."

She adds, "In our work with leaders, we help them map where psychological safety appears strong or weak through behavioral indicators. We help them look for patterns across multiple indicators. This assists them in getting a clear picture of where they stand as a team, which aspects need to be strengthened, and for whom."

"As an example, in one team, the leader identified that the safety score was lowest when it came to sharing opposing views. This made the leader reflect upon how easily they dismiss other people's ideas if those ideas did not fit into their mental model. This was causing the team to be less innovative. This was followed up with the leader going through a program on developing a growth mindset," she adds further.

Dependability

Every manufacturing company depends on trust. Production trusts purchasing to get materials on time. Quality trusts production to follow the process. Sales trusts engineering to deliver what has been promised to the customer.

When that trust breaks down, everyone starts checking everyone else's work. Meetings become longer. Emails become longer. Progress becomes slower.

Pradeep Patil, Managing Director, TRUMPF India Pvt Ltd, says, "When colleagues consistently deliver on their commitments, trust, which is the basis of any success, grows naturally. Teams spend less time checking on one another and more time solving customer problems, improving products, and finding better ways of working. In my experience, dependable people are the foundation of dependable organizations."

Structure and Clarity

Good engineers enjoy solving difficult technical problems. They should not have to spend half the day figuring out who is responsible for what.

Google found that successful teams had clear goals and well-defined roles. Everyone understood what success looked like.

In manufacturing, confusion is expensive. Clear responsibilities save an enormous amount of time.

Patil says, "People do their best work when they know exactly what they're trying to achieve and how they contribute to the bigger picture. When

Harvard professor Amy Edmondson defines psychological safety as the confidence that people can ask questions, admit mistakes, and challenge ideas without being embarrassed or punished.



"In our work with leaders, we help them map where psychological safety appears strong or weak through behavioral indicators. We help them look for patterns across multiple indicators. This assists them in getting a clear picture of where they stand as a team, which aspects need to be strengthened, and for whom."

Deepa Agarwal
Founder and Chief Inclusion Officer
Re-Link

Source: Re-Link

A simple conversation saying, "Your idea really made a difference," can have far more impact than a motivational speech. People remember knowing that their work mattered.

goals are clearly defined and responsibilities are well understood, teams can make decisions quickly like any entrepreneur, support one another, and stay focused on delivering results. Good leadership is often about providing that clarity, psychological safety, and then trusting people to do their jobs."

Meaning

Engineers like solving problems. That is one reason many engineers entered the profession in the first place. But people also want to know that their work matters.

Agarwal says, "An important aspect for a team to be effective is having a shared vision. When all the individuals on the team attach a personal meaning and share the same parameters for what success looks like, they are more likely to collaborate and look beyond their personal prejudices and biases to accomplish the goal. Leaders play a critical, facilitative role in helping their teams draw value and connect to a shared sense of purpose."

Impact

The final characteristic was impact. People want to see that their work makes a difference.

Most factories already measure productivity, rejection rates, delivery performance, and machine utilization. Those numbers are important.

What often gets overlooked is telling the people behind those improvements that they made them happen. A simple conversation saying, "Your idea really made a difference," can have far more impact than a motivational speech. People remember knowing that their work mattered.

A Lesson for Indian Manufacturing

Indian manufacturing has become remarkably sophisticated over the last decade. Today, Indian companies supply precision components to the aerospace, automotive, electronics, medical devices, and semiconductor industries around the world. Indian factories increasingly match global standards in technology.

The next challenge is people.

Many organizations still have cultures where junior engineers hesitate to question senior managers. In some meetings, the highest-ranking person speaks first and everyone else nods politely. That approach can hide problems and bury good ideas. The people closest to the problem often know where the real improvements lie.

Building Better Teams

The encouraging part about Google's research is that none of these five characteristics requires huge budgets. They cost very little.

Listening costs nothing.

Giving people the confidence to ask questions costs nothing.

Clarifying responsibilities costs nothing.

Telling someone that their work made a real difference costs nothing.

Factories invest crores in new equipment every year. Those investments are essential. But the biggest improvement may come from something much simpler — creating a workplace where people trust one another, speak honestly and work together with a shared purpose.

Machines improve productivity. People improve companies.

Reji Varghese is the President of RV Forms & Gears, a 54-year-old engineering company based in Chennai, India. A dedicated meditation practitioner since 2015, he writes on business, manufacturing, leadership and contemplative practice for a range of Indian and international publications.

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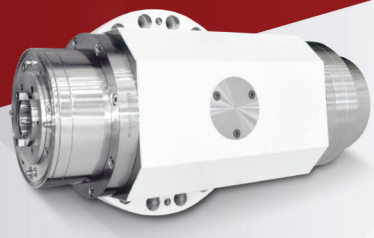
Belt-Drive Spindle - Milling



Direct-Drive Spindle



Motorized Spindle - Turning



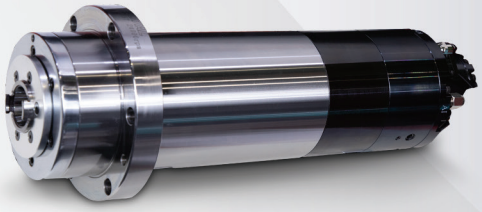
Motorized Spindle - Multi-Spindle



Motorized Spindle - Milling (40,000 rpm)



Belt-Drive Spindle - Turning



Motorized Spindle - Milling

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WHY WORKFORCE LEARNING NEEDS A RESET

As manufacturing rapidly adopts AI, robotics, and automation, the skills required of its workforce are changing too. This makes continuous, relevant, and work-focused learning increasingly important to help employees adapt to the technologies shaping the future of manufacturing.



Source: Magic Wand Media

SAMEER NIGAM
CEO & Co-Founder
Stratbeans



A new era of technology adaptation is emerging within the manufacturing industry. Artificial intelligence, robotics, automation, and other related innovations are changing the way factories work, the way decisions are made, and even the way workers operate in production spaces. However, along with accelerated investments in technology, a deeper question arises – is the current workforce equally prepared to adapt to change?

While introducing any new technology is a challenge for manufacturers, the major issue is to ensure that workers have the necessary skills and willingness to work with the technology effectively. An entirely automated production process requires workers who can analyze the information gathered, address emerging issues, and make decisions.

It is here that the approach to workforce learning needs to be reconsidered. Traditional approaches based on specific courses, occasional seminars, and standard content do not always prove effective in constantly changing circumstances.

The Skills Gap is Evolving into a Dynamic Issue

Manufacturing has never been a homogeneous industry. People have always worked across various roles, functions, machines, processes, and levels of experience. The deployment of AI technologies adds yet another aspect of heterogeneity, since people's skill requirements may change as technologies get integrated into daily operations.

A person who is working with an automated process may require a totally different set of competencies than someone who works on interpreting the data produced by connected devices. At the same time, a manager may be aware of the principles of using AI for decision-making, while engineers and data analysts may have a deeper understanding of the technology.

That means that assessing skills gap cannot be done once a year. Companies should have a clearer view of where their capabilities are, where the gaps are, and what kinds of skills will become essential as technology adoption continues. Assessing skills, analyzing performance data, and mapping skills to roles will help companies go beyond assump-

tions about the capabilities of their workforces.

The goal is not to find out what people do not know, but to understand what competencies are needed for the next tasks.

Moving Beyond One-Size-Fits-All Training

Traditionally, corporate training has been based on an underlying belief that employees in a certain role share similar training requirements. This belief becomes harder to sustain as manufacturing jobs become more technology-based.

Imagine two workers who work at the same production facility, one of whom has several years of experience working with a certain machine, while the other is new to the job and is still learning the basics. Providing training to both workers through the same learning program might meet the requirement, but not their individual needs.

A more practical approach would be to personalize learning based on employees' roles, current skills, and future needs.

It doesn't mean creating a unique program for each worker individually, but it means analyzing existing information about workers and figuring out where to start and what should be learned next.

Learning Has to Move Closer to the Work

The one constraint that is really hard to address in manufacturing is time. The production schedule does not always allow for long learning classes or training courses. Employees must learn how to do things without having a big impact on the process. That is why the integration of learning into the workflow becomes so crucial.

Organizations no longer treat learning as something that occurs separately from employees' work. Organizations can use short learning interventions that can be integrated into the workflow. Different digital modules, simulations, assessments, contextually relevant resources, and help available on demand could assist employees with particular skills or knowledge whenever necessary.

If a new machine, process, or digital tool is introduced, it would not be necessary to wait until the next training session. Learning could be offered along with the implementation process.

It is also a recognition of the truth about modern manufacturing: learning doesn't end when the course finishes. Processes change; learning needs also change.

Learning Measurement Through Business Metrics

Another area that needs resetting is the approach that organizations take toward measuring learning.

Completion rate, attendance, and results can provide meaningful insights, but they do not always reflect whether the learning led to improved performance on the shop floor or alignment with business goals.

Organizations should start linking their capabilities to performance.

Depending on the function, what needs to be measured through performance metrics may include productivity, quality, safety, downtime, compliance with processes, or technology adoption. Metrics are different for different companies, but the idea is always the same – learning should lead to improved performance, not just increased completion rates.

AI will help identify patterns within learning and workforce data, which will make it easier to assess whether enhancement in capabilities have translated into improvements in operations and to see what else needs to be done to achieve the desired results.

This is likely to redefine the role of the L&D function. It will no longer be a support function delivering training programs, but rather a strategic partner in the workforce transformation journey.

Building a Workforce That Can Adapt

There won't be any solution to the manufacturing skills challenge through one-off reskilling programs. The world of technology is constantly changing, and so are the systems that support it. So, the more realistic option would be to create a culture of continuous capability building.

Manufacturing companies will have to hire workers capable of operating in a new reality, learning new systems, and working alongside emerging technologies. At the same time, they will still have to develop skills among their workers such as critical thinking, problem-solving, decision-making, and collaboration.

This way, instead of training people to use a particular technology, manufacturing leaders will have to build a flexible workforce able to work with different technologies.

Therefore, there is an important paradigm shift that manufacturing leaders will have to make in terms of AI adoption. It shouldn't be considered solely from the point of view of the machinery, software, or automation that needs to be invested in, but also from the perspective of whether people will be ready to work with all these tools.

The next steps in manufacturing transformation will thus require manufacturing organizations to reconsider the whole process of learning, making it continuous, relevant to the particular job and directly connected to business outcomes. Learning may thus become an enabler of sustainable development when it is seen as part of the technology strategy.

The next steps in manufacturing transformation will require manufacturing organizations to reconsider the whole process of learning, making it continuous, relevant to the particular job and directly connected to business outcomes.

Machining Aerospace Metal

Anyone who has walked the engineering clusters of Peenya or Coimbatore, or the vendor aisles at Aero India, knows that Indian precision machining has quietly become world-class. Our Tier-2 and Tier-3 shops hold AS9100 certification standards, deliver against Airbus and Boeing offsets, and feed HAL, DRDO and ISRO programs. The bottleneck in Indian aerospace manufacturing is no longer skill or equipment. It is the metal itself.

Machining Complexity

The difficulty is not one of operator skill. Titanium and nickel superalloys are built to hold their strength at temperatures that would destroy ordinary steel, and that very virtue makes them difficult to machine. In a well-behaved material, most of the heat generated leaves with the chip; in titanium, which conducts heat poorly, it has nowhere to go but into the tool. It is the cutting edge, not the workpiece, that suffers.

Everything else follows. These alloys work-harden under the tool, so a light or rubbing pass leaves a hardened skin the next pass must fight through. At high temperatures, chemical affinity can cause hot chips to weld onto the rake face, forming a built-up edge that alters the cut before breaking away and carrying part of the insert with it. Abrasive particles grind at the flank, and notch wear at the depth-of-cut line can finish an insert in a single pass.

> **Until this month, India had no independent laboratory so accredited: TCR Engineering's units in Navi Mumbai and Vadodara received the first approval in August 2026. Before that, specimens travelled to America or Singapore.**

What It Costs on the Shop Floor

The consequences are unforgiving. Cutting speeds are a fraction of those for steel, so cycle times stretch and machine-hour costing goes out of the window. Inserts must be changed on a predicted schedule rather than when they look worn, because a superalloy tool does not fail gracefully. Rigid fixturing and high-pressure coolant are requirements, not refinements.

The stakes are higher here than in Toulouse or Seattle. Buy-to-fly ratios on machined structures are poor, and a scrapped part is lost imported metal, replaced only after months and in foreign exchange. The discipline to cut these alloys well is worth building only if the material arrives reliably.



NIKHIL NAYAK
Managing Director
NN Combined Engineering Agencies Pvt Ltd

The Supply Question

Reliable supply is the question. India imports roughly 70 percent of its aerospace-grade raw material, for structural reasons. We hold some of the world's largest reserves of titanium-bearing minerals, yet domestic sponge comes from one producer, Kerala Minerals and Metals Ltd (KMML), capped at 500 tonne a year since 2011. Mishra Dhatu Nigam (MIDHANI) Hyderabad was until recently our only mill for aerospace-grade titanium and nickel superalloys; PTC Industries commissioned the first private vacuum arc remelting furnace in January 2025. For many superalloy grades MIDHANI still stands alone, and it must itself import nickel, cobalt and tungsten, keeping a strategic 'metal bank' to hold production steady.

Certification compounds the scarcity: clearing a locally melted batch of alloy as airworthy through CEMILAC takes years, so capacity cannot become supply on demand. Mills prefer bulk orders, and Tier-3 unit needing smaller amounts has to turn to specialty importers, adding to the costs.

For Airbus and Boeing work, a further layer applies. Every batch must trace back to a mill on the OEM's Approved Vendor List, and flight-critical heat treatment and testing must be NADCAP-accredited.

Until this month, India had no independent laboratory so accredited: TCR Engineering's units in Navi Mumbai and Vadodara received the first approval in August 2026. Before that, specimens travelled to America or Singapore.

What Needs to Change

The first movers exist: a private melt shop, an accredited laboratory, clearances for MIDHANI material from GE Aerospace. What is lacking is a reliable supply chain. The Ministry of Defence has begun naming raw materials as well as components; the sixth indigenization list, notified this month, includes them. But a list bans an import; it does not melt an ingot. And it binds defence procurement only, leaving commercial work to fend for itself. Three things need money: sponge and melt capacity, more accredited laboratories, and service centers willing to sell small lots to small shops.

Demand is not the constraint. Indian carriers have placed some of the largest aircraft orders in history, and AMCA will need alloys we cannot presently melt at scale. The work will come; whether the value stays here is another matter. A supplier base that machines imported material earns the conversion margin and little else. It remains a capacity option rather than a partner designed in from the start. Material capability changes that and cannot be improvised once the order arrives — which is the argument for beginning now.

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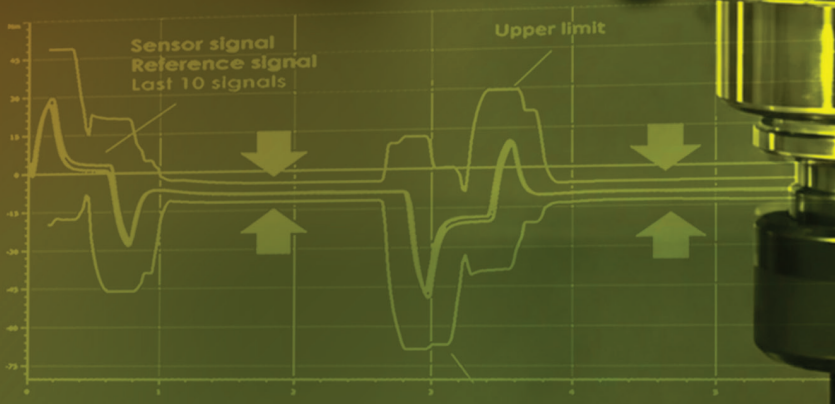
Indian Machine Tool Manufacturers' Association

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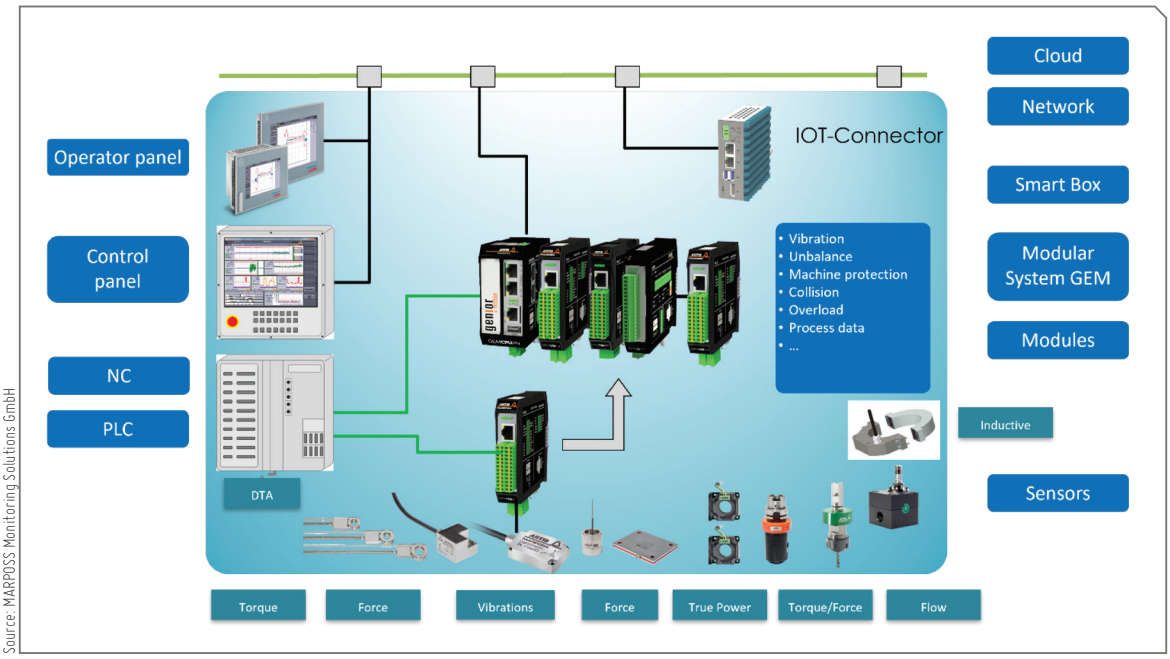
COLLISION PROTECTION
TOOL BREAKAGE TOOL MISSING
TOOL WEAR
MICRO-BREAKAGE / START-UP
SPINDLE HEALTH

ENABLING Autonomous Manufacturing

The transition to unmanned manufacturing requires seamless, real-time monitoring of all machining processes. This article explores how the GENIOR MODULAR process monitoring system and GEMCMS collision monitoring system from Marposs (Artis), in combination with the corresponding visualization and analysis software, can support safe and reliable autonomous production.

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Source: MARPOSS Monitoring Solutions GmbH

GENIOR MODULAR – Modular System — vertical and horizontal integration

Rising cost pressures, the shortage of qualified machinists, and the need to utilize expensive machine parks around the clock are forcing the industry toward automation. 'Lights-Out Manufacturing' describes the vision of a factory that operates with high productivity during night and weekend shifts without any personnel — with the lights turned off.

However, this autonomy carries a massive risk: if human sensory perception (hearing abnormal machining noises, seeing chip jams, feeling vibrations) is eliminated, the machine tool loses its final safety mechanism. A single undetected tool breakage at the start of an 8-hour unmanned shift can trigger a cascade of scrap production, quality issues or, in the worst case, destroy the main spindle.

Use of Monitoring Systems

The applications of monitoring systems are diverse and span various stages of manufacturing.

- Detection of breakage, missing parts, and wear in machining production
- Machine protection and collision detection
- Prevention of scrap, rework, and consequential damage
- Detection of clamping errors, incorrect components, unbalances and faulty processes
- Condition-based monitoring (CBM) of bearings, ball screws and other machine components
- Adaptive control for increasing machine productivity and overload prevention
- Acquisition and processing of process data
- Process visualization, documentation and reporting
- Energy monitoring of machines and aggregates
- Source of information for other third-party systems
- Data provision for cloud-based systems
- Fulfilling production specifications for aircraft (e.g. P11TF12), energy management (e.g. ISO 50001) and other.

The Technological Nervous System: GENIOR MODULAR & GEMCMS

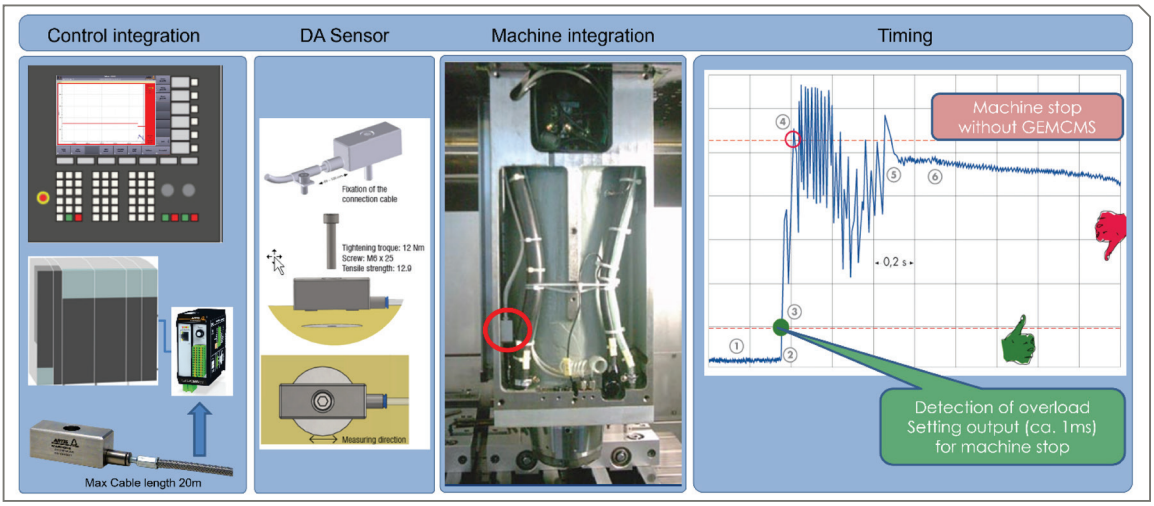
With the Artis monitoring systems, Marposs offers a market-leading solution specifically developed to address the challenges mentioned above. The system consists of the core components: sensors, measurement converters, and a main unit. The visualization opens a window to the machining process.

GENIOR MODULAR

GENIOR MODULAR is a modular system for protecting tools and machines that is installed in the control cabinet. Using self-contained and extremely fast measurement modules, it processes sensor signals in the millisecond range and can communicate directly with the CNC control via fieldbuses such as Profibus, Profinet and EtherNet/IP to receive interface signals for control and, in turn, trigger feed stops, tool changes, or emergency-stop commands.

Vertical integration refers to the alignment of information technology (IT) and operational technology (OT) across different hierarchical levels of a produc-

GENIOR MODULAR is a modular system for protecting tools and machines that is installed in the control cabinet. Using self-contained and extremely fast measurement modules, it processes sensor signals in the millisecond range.



Source: MARPOSS Monitoring Solutions GmbH

GEMCMS – Machine protection with force monitoring

The GEMCMS system from Artis is a highly advanced, self-contained machine protection and collision detection system developed to prevent or reduce costly consequential damage caused by programming, setup, or operating errors on machine tools, robots, and handling.

tion facility. GENIOR MODULAR achieves this by serving as the data bridge from the raw cutting edge of a machine tool up to executive-level database servers.

Hardware integration is horizontally scalable. On a standard DIN mounting rail, a primary CPU module can be linked to secondary software plug-ins or auxiliary sensor modules using an 'In-Rail' CAN-bus connector. This allows a facility to tailor different machines for diverse tasks (e.g., combining collision avoidance with gear hobbing or adaptive control) while using the exact same base architecture.

GEMCMS

The GEMCMS system from Artis is a highly advanced, self-contained machine protection and collision detection system. It was specifically developed to prevent or reduce costly consequential damage to an absolute minimum caused by programming, setup, or operating errors on machine tools, robots, and handling systems.

The Sensor Matrix: Seamless Detection of All Physical Effects

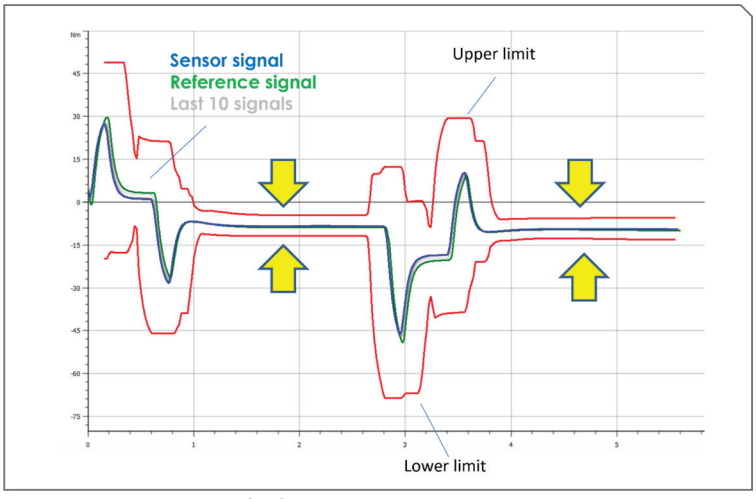
A machining process emits various physical signals. GENIOR MODULAR stands out because it can simultaneously capture and correlate the entire range of these signals using dedicated sensors and sensor modules.

Active Power Monitoring (True Power)

Measuring the power consumption of spindle and axis motors is a cost-effective method for process monitoring. The Artis systems can either read this data directly in digital form from the CNC bus or capture it as an analogue signal via active power transducers (e.g. control cabinet modules). A tool breakage leads to an abrupt drop in power, while continuous wear causes power consumption to rise slowly.

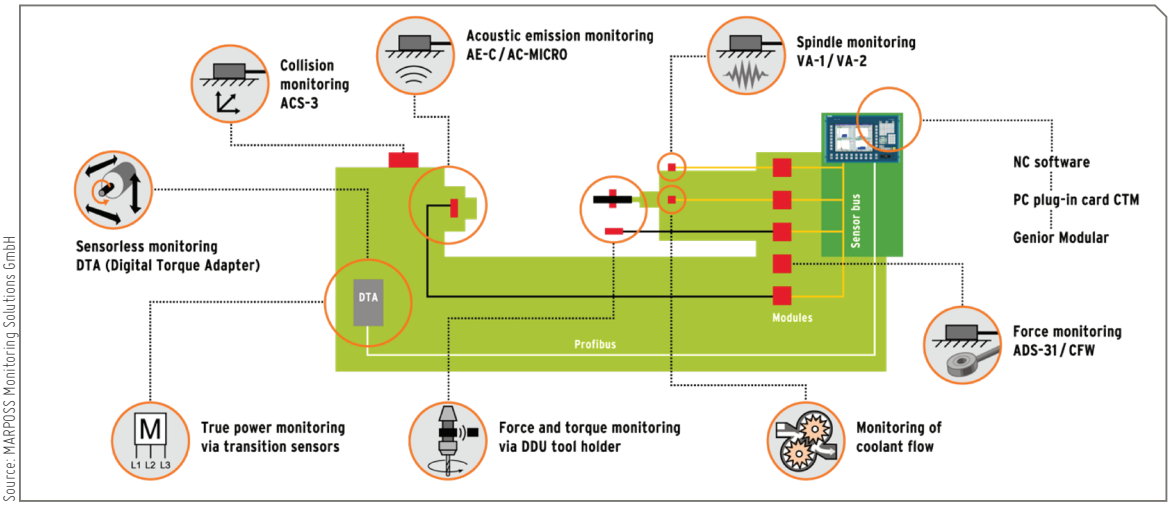
Torque Monitoring (Digital Torque)

Measuring the torque of spindle and axis motors is usually the most cost-effective method of process monitoring when this data is read directly in digital form from the CNC. A tool breakage typically causes a sudden drop in torque, while continuous wear causes the torque to rise slowly. The advantage of this method lies in its sensorless integration, as the data can be read directly from the NC core, for example via a so-called compile or PLC cycle.



Source: MARPOSS Monitoring Solutions GmbH

Typical signal curve for torque [Nm]



Source: MARPOSS Monitoring Solutions GmbH

Sensors in machine tools

Force and Strain Monitoring

Using strain sensors applied directly to the spindle mount or machine bed, the GENIOR MODULAR measures mechanical deformations in the micrometer range. This enables precise monitoring of feed forces and immediately detects overloads. The technology can be strain gauge- or piezo-based, depending on the required sensitivity and measurement times.

Vibration Monitoring (Vibration/Acceleration)

Piezoelectric or MEMS (micro-electromechanical systems) acceleration sensors monitor the vibration behavior of the spindle. They serve, on the one hand, to detect process-damaging chatter and, on the other hand, as a primary indicator of the spindle's condition (predictive maintenance). The technology used depends on the required frequency range. MEMS-based sensors are normally cheaper but restricted in the frequency range.

Structural Noise Monitoring (Acoustic Emission - AE)

Structure-borne sound sensors detect high-frequency vibrations in the range of 50 kHz to 400 kHz, which lie far outside the human hearing range. This sensor technology is extremely sensitive and detects micro-cracking of carbide cutting edges milliseconds before the actual fracture, as well as the first physical contact between the tool and the workpiece (cutting-in monitoring). This is essential for very small tools (drills < 1 mm), where the change in active power would be too small for reliable detection.

Process and Collision Monitoring in Autonomous Operation

Real-Time Collision Protection (One-Millisecond Response)

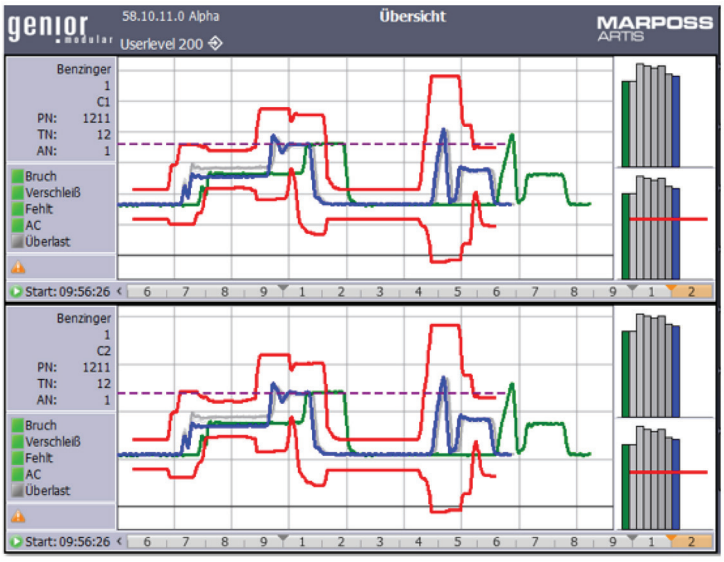
In the event of a collision during rapid traverse (e.g., due to incorrect zero-point offset), milliseconds count. The GEMCMS evaluates the signals from strain or acceleration sensors with an internal cycle time of less than 1 ms. If a defined collision threshold is exceeded, the system triggers a direct hardware interrupt to the drive controller or the emergency stop chain. The drives are actively counter-controlled or de-energized before the kinetic energy can irreparably deform the spindle bearings.

Dynamic Envelope Curve Monitoring in GEM

For process monitoring, the system autonomously learns the normal signal curve of a tool during the production of the first good parts (teach-in phase). GEM automatically establishes dynamic en-

Structural Noise Monitoring is a sensor technology that is extremely sensitive and detects micro-cracking of carbide cutting edges milliseconds before the actual fracture, as well as the first physical contact between the tool and the workpiece (cutting-in monitoring).

Monitoring Objective	Sensor / Module Used	Action in Lights-Out Operation
Collision Protection	Piezo Strain / Acceleration	Immediate feed stop (<1ms) to minimize damage.
Tool Breakage Tool Missing Tool Wear	Active Power/torque (GEM) / Fieldbus	Immediate stop (<10ms) or stop after process end; request for a sister tool to the CNC control.
Micro-breakage / Start-up	Structure-borne Noise (AE Sensor)	Stop before the next step, eject the part.
Spindle Health	Vibration Module	Shut down the machine for unmanned shifts when critical values are reached.



Source: MARPOSS Monitoring Solutions GmbH

2-channel adaptive control with envelope curve adaptation

Only this deep integration of real-time protection, wear detection, and predictive maintenance makes unmanned operation a safe, highly profitable reality while simultaneously ensuring workpiece quality.

velopes (warning and shutdown thresholds) around this curve.

If the upper warning threshold is exceeded due to increasing wear, GENIOR MODULAR notifies the CNC that the tool must be replaced with a sister tool after completion of the current part. If the shutdown threshold (e.g., in the event of tool breakage) is exceeded, the machine stops immediately to prevent consequential damage. In addition to envelope strategies, a wide range of other algorithms is available to solve almost any monitoring task.

Adaptive Process Control

In machining technology, Adaptive Control (AC) refers to systems that monitor cutting forces and machine conditions in real time. The feed rate is automatically adjusted to the material and tool wear. To prevent the machine from stopping completely when encountering particularly hard areas in the material, MIN defines the absolute minimum value that the feed rate must not fall below at any time in order to avoid tool damage. On the other hand, a MAX value defines the maximum feed rate.

The innovative adaptive control in the GENIOR MODULAR (GEM) allows multiple machining stations to be regulated with regard to idle runs and insufficient or excessive cutting performance, even if they are controlled by a common feed drive. A new feature is the intelligent envelope curve adaptation simultaneously to ensure reliable and sensitive monitoring.

This allows the benefits of an AC system to be combined with optimal tool monitoring. These benefits include compensation for workpiece or material inhomogeneities, tool protection through torque or force control, automatic adjustment for tool wear, increased machining speed while maintaining consistently high quality, and improved process reliability for complex geometries. Some customers have achieved cycle time savings of up to 10 percent.

Condition-Based & Predictive Maintenance in Lights-Out Operation

Before starting an unmanned shift, it must be ensured that the machine can mechanically withstand the hours ahead. GENIOR MODULAR enables condition-based monitoring (CBM):

Spindle climate test / imbalance analysis: An automated test cycle can be run before the shift begins. The system measures the mechanical vibrations of the spindle at various speeds. If the root-mean-square (RMS) values of the vibration increase over time, this indicates incipient bearing damage. The system blocks the machine from running the autonomous shift and issues a warning message.

Business Value & ROI

The investment in a Marposs Artis GENIOR MODULAR system typically pays for itself within a few months in a lights-out scenario:

- **Increased machine uptime:** Confidence in the automatic protection system allows for additional unmanned shifts on weekends, which drastically increases OEE.
- **Prevention of total losses:** The protection of a single motor spindle (often costing between US$ 30,000 and US$ 50,000 plus lost production) fully recoups the cost of the monitoring technology. In the case of expensive tools, such as those used in gear hobbing, costs can quickly run into several thousand euros if faults are detected too late.
- **Consistent quality:** By detecting process drift and wear in a timely manner, the production of scrap during unmanned operation is effectively reduced to zero.

Conclusion

Lights-out manufacturing poses an incalculable economic risk without intelligent, sensor-based process monitoring. The Artis GENIOR MODULAR system from Marposs, together with the GEMCMS collision monitoring system, provides the technological infrastructure to equip machine tools with the necessary 'sensory organs'.



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BUILDING INDIA'S AEROSPACE EDGE

As India strengthens its position as a global aerospace manufacturing hub, Hical Technologies is preparing for its next phase of growth. In the following interview with Soumi Mitra, Editor-in-Chief, Modern Manufacturing India, Yashas Jaiveer, Managing Director, Hical Technologies, shares his perspective on building global customer trust, scaling zero-defect manufacturing, expanding capacity and R&D, and moving the company towards higher-value engineering and complete aerospace systems.

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With global OEMs aggressively looking for 'China+1' alternatives and reliable geopolitical partners, how is Hical capitalizing on this moment to become a strategic partner for international aerospace giants?

Hical's aerospace journey was not driven by a recent China+1 strategy. India's capabilities were built over several decades through institutions such as ISRO, DRDO, HAL, and other public-sector aerospace organizations, which established a strong ecosystem for machining, plating, qualification, and other critical processes. Private companies with strong engineering and quality cultures were then able to build on this foundation. Hical entered aerospace nearly two decades ago because it could absorb complex engineering requirements, maintain high reliability, and scale within this established ecosystem.

Today India is recognized as a credible, tier-1 manufacturing hub for complex, mission-critical systems. What were the critical capability milestones in terms of quality standards, IP protection, and certification ecosystems that Hical and the wider Indian industry had to reach to earn this deep global trust?



Source: Hical Technologies

Yashas Jaiveer, Managing Director, Hical Technologies

India earned global trust by consistently meeting demanding standards — AS9100, ISO requirements, Nadcap special-process approvals, clean-room assembly requirements, and customer-specific quality systems. Tools such as APQP (Advanced Product Quality Planning) ensure that quality, manufacturability, and risk mitigation are addressed during engineering and new-product introduction, rather than after production begins.

At Hical, this capability was developed systematically across nearly 600 part numbers, supported by zero-defect performance, strong on-time delivery, and global supplier recognitions. Equally important has been Hical's consistent record of integrity, ethical conduct, and protection of customer intellectual property.

The regulatory landscape in Indian defence procurement

emphasizes offsets and transfer-of-technology (ToT). Rather than treating offsets as a mere transactional compliance check, how is Hical leveraging these frameworks to forge deeper international co-development partnerships that bring true, proprietary aerospace design and manufacturing capabilities to Indian shores?

Global aerospace companies increasingly select Indian partners not only because of offset obligations, but because of proven quality, delivery, engineering capability, and IP protection. The next phase will move beyond component manufacturing towards complete systems, built-to-specification products, and higher-value engineering partnerships.

Offsets are seen as platforms for long-term partnerships, joint ventures, co-development, and the creation of proprietary design and manufacturing capabilities in India.

From a leadership and operational standpoint, how do you cultivate a 'zero-defect' culture across a scaling workforce when the precision requirements leave absolutely no room for error?

A zero-defect culture begins with leadership commitment and extends to every person involved in operations. The recruitment process must identify individuals who understand the seriousness of flight-safety-critical manufacturing, followed by continuous training in AS9100, Nadcap, and customer-specific requirements.

Employees must have the authority to stop production when a potential defect is identified. Chronic issues are addressed through cross-functional root-cause analysis and permanent corrective action. Independent quality representatives act as the customer's voice on the inside, ensuring no product is released without full compliance.

> "India's capabilities were built over several decades through institutions such as ISRO, DRDO, HAL, and other public-sector aerospace organizations, which established a strong ecosystem for machining, plating, qualification, and other critical processes. Hical entered aerospace nearly two decades ago because it could absorb complex engineering requirements, maintain high reliability, and scale by building on this foundation."
>
> **Yashas Jaiveer**
> **Managing Director**
> **Hical Technologies**

How has Hical developed its cross-disciplinary engineering capabilities to design and manufacture components that must withstand extreme thermal, gravitational, and electromagnetic stress without sacrificing performance?

Hical combines mechanical, electrical, electromagnetic, materials, and manufacturing engineering expertise to develop products for demanding aerospace and space environments. These products undergo rigorous qualification for thermal, vibration, gravitational, and electromagnetic conditions.

For applications such as satellite scanning and positioning systems, designs may require lightweight construction, high reliability, and multiple levels of redundancy. In-house qualification capabilities allow engineers to validate materials, designs, and performance through extensive testing and iterative development.

Precision engineering in defence and aerospace is increasingly becoming a battle of materials science, working with exotic alloys, advanced composites, and strict lightweighting requirements. What are the key manufacturing and machining technologies Hical has invested in to stay ahead of these evolving material specifications?

Aerospace and defence products frequently require titanium, Inconel, aluminum, special alloys, and specialized grades of stainless steel — all procured from approved sources and processed through tightly controlled, fully traceable manufacturing routes.

The approach combines precision machining, advanced metrology, process validation, fabrication, and qualified special processes. Since materials and sources cannot be changed without customer approval and requalification, strict configuration control and process discipline are as important as the machining technology itself.

Having spent nearly 16 years in Hical, you are now driving its next major phase of growth as Managing Director. Executive leadership looks very different as a company scales than it does during the foundational years. What are your primary strategic imperatives for the company over the next 3 to 5 years, and how are you structuring the organization to absorb much larger global contract volumes?

Hical has three principal priorities. The first is operational excellence — maintaining zero-defect quality and on-time delivery as more than 500 qualified First Article Inspections transition into higher-volume production.

The second is capacity and vertical integration. New facilities

Over the next decade, Hical aims to become a globally significant supplier of complete electromechanical and hydraulic systems for commercial aircraft, business jets, fighter aircraft, defence, and space platforms.

in Devanahalli and Hosur will expand systems integration, precision machining, fabrication, and Nadcap-approved special-process capabilities.

The third is design and R&D. The company intends to expand its design organization significantly and invest in advanced engineering software and technologies, enabling a much larger portfolio of built-to-specification electromechanical products and systems.

In an intensely competitive market for engineers, what is your strategy for attracting, upskilling, and retaining the next generation of aerospace manufacturing leaders within India?

The strategy is to offer engineers more than a conventional manufacturing career — the opportunity to work on mission-critical global aerospace, defence, and space programs and see the direct impact of their work.

Hical will strengthen partnerships with universities, engineering colleges, and technical institutes in and around Bengaluru, supported by internships, apprenticeships, and structured graduate programs. Employees will receive cross-functional exposure, technical certification, mentorship, and clearly defined career paths. Retention will be driven by continuous learning, merit-based growth, leadership opportunities, and the pride of developing complex products in India for global platforms.

When global prime contractors think of mission-critical systems a decade from now, what specific space do you intend for Hical to occupy?

Over the next decade, the ambition is to become a globally significant supplier of complete electromechanical and hydraulic systems for commercial aircraft, business jets, fighter aircraft, defence, and space platforms.

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KEEPING INCONEL 718 MACHINING COOL AND CLEAN

Machining Inconel 718 places demanding requirements on coolant cleanliness, temperature control, and chip management. At MTU Aero Engines, a centralized KNOLL system addresses these challenges while supporting automated production.



Source: KNOLL Maschinenbau GmbH

Typical low-pressure turbine disc

Inconel 718 is a nickel-based alloy that can withstand extreme temperatures and pressure differences – ideal for use in the aerospace industry. However, machining it places high demands on machines, tools, and the cooling lubricant (KSS). To ensure that KSS is always clean, at the right temperature, and available in the right quantity, MTU Aero Engines, a leading German engine manufacturer, has opted for a central KSS cleaning and chip disposal system from KNOLL.

MTU, headquartered in Munich, specializes in the development, production, and maintenance of civil and military engines in all thrust and power categories. The Munich plant is not only the administrative headquarters, but also an important production location. Among other items, components are produced here for the eco-efficient geared turbofan engines from Pratt & Whitney, which use 25 percent less fuel compared to conventional engines.

These engines are in high demand, which is why MTU expects their production volume to grow. This forecast was also a decisive factor in the construction of a new multi-story production building, whose ground floor low-pressure turbine discs have been turned and milled largely automatically since the beginning of 2024.

Source: KNOLL Maschinenbau GmbH



Machining the nickel-based alloy Inconel 718 places high demands on the machine, tool and cooling lubricant.



The centrifugal separator in the bypass prevents the finest particles from accumulating in the cooling lubricant.

"To achieve maximum process reliability in this new production facility, a reliable supply of clean, precisely tempered coolant is essential," emphasizes Zeljko Leovac, the workshop team leader responsible. "This can only be achieved economically with a central KSS system. "If each system had its own KSS system, the space required in the hall would be too great."

Positive Experience With Central Systems

There were several reasons why the contract for such a central cooling lubricant system was awarded to KNOLL Maschinenbau in Bad Saulgau. Christina Braun, who was responsible for the procurement of the central cooling lubricant system and the processing machines for the low-pressure turbine disc production and is now the project manager, reports, "We have been working successfully with KNOLL systems for cleaning cooling lubricant emulsion for 40 years, initially exclusively with decentralized solutions. For several years, we have also had two large KNOLL central systems installed in our titanium processing halls, and we are very satisfied with them."

In the new production hall, only Inconel 718 is machined. "We wanted to recover these chips, sorted by type, and to send them for recycling," explains Braun, an important requirement that KNOLL was able to fulfil, as were the requirements for a technical availability of at least 99 percent, for consistent redundancy and low maintenance costs, as well as sustainability and minimal space requirements.

The KNOLL system is located in a separate extension of the

Inconel 718 is a nickel-based alloy that can withstand extreme temperatures and pressure differences – ideal for use in the aerospace industry. However, machining it places high demands on machines, tools, and the cooling lubricant.



An important component of the new production system at MTU – the cooling lubricant central system that KNOLL delivered, which is responsible for cleaning, tempering, and refilling the medium.



The new production hall is designed for the manufacture of low-pressure turbine discs made of Inconel. Up to 6,000 components will be produced here each year, rising to 12,000 in the final stage of expansion.



All of the turning and milling machines for the new MTU production system are equipped with a pressure booster station (left) and a return pump station with a chip reducer (right), both from KNOLL Maschinenbau.



In the foreground on the left: Three frequency-controlled process pumps with a respective pumping capacity of 2000 l/min. They ensure that the machines are supplied as needed, making the supply energy efficient.

Maintaining the cooling lubricant emulsion involves not only filtration but also ensuring that the composition is exactly right. It is therefore essential to take a sample once a week and have it analyzed in a laboratory.

hall so that it remains as quiet as possible in the production area. "This has already proven itself in the existing central KSS systems," says Braun. The 40 m^3 dirty water tank with scraper conveyor, and an equally large buffer tank for when major maintenance work is due, are now located in an area of around 190 m^2. In addition to the pumps, filters, and other components, an automated chip container station is also available there.

KNOLL Components on the Machine Tools

KNOLL service begins at the turning and milling centers that the machine manufacturers have had equipped with KNOLL pressure boosting stations for an efficient internal coolant supply (ICS) for the tools.

In addition, the machines are equipped with return pump stations including chip reducers for the cooling lubricant and chip transport to the central system. Lothar Schmid, responsible for this project at KNOLL, says, "We designed the chip reducers used especially for the abrasive Inconel chips and tested them with original chips."

When designing the return pump stations, the project planning team considered both the delivery height up to the ceiling of the hall and the amount of the cooling lubricant-chip mixture that would be produced.

Equipped for the Future

The new MTU manufacturing system will be implemented in two stages, ultimately comprising eight turning and seven milling centers, including fully automated component and tool set-up. In the current first stage, only half of the capacity is available. The second stage is planned for completion by 2036.

The central cooling lubricant system has already been designed for the final expansion stage, with a tank volume of around 40 m^3 and a maximum volume flow of 3,300 l/min.

In addition, a second tank of the same size has been installed, in which the entire cooling lubricant volume can be buffered for major maintenance work.

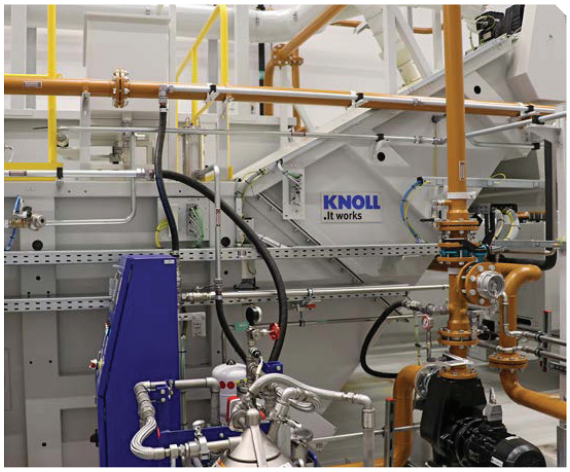
The required nominal filter fineness of 25 µm is achieved in three stages: First, sedimentation takes place in the dirty water tank. Via a lifting system, the cooling lubricant then passes through three drum gap filters with a 0.2 mm gap width and finally two reverse flow filters, which ensure the main filtration quality of 25 µm.

Extensive Special Equipment

To ensure the high quality of the cooling lubricant and the machined components in the long term, additional components are required. For example, a KNOLL VL1000 vacuum filter with 20 µm filter fleece is installed to clean the backwashed medium. A centrifugal separator working in the bypass is also used for bath maintenance. It prevents the finest particles from accumulating in the cooling lubricant. In addition, a downstream magnetic separator removes the pipeline abrasion caused by the abrasive Inconel chips from the cooling lubricant. A foreign oil separator removes unwanted lubricant components.

Good Maintenance Pays Off

Maintaining the cooling lubricant emulsion involves not only filtration but also ensuring that the composition is exactly right. It is therefore



The largest element of the KNOLL central system: The 40 m^3 dirty water tank with a scraper conveyor that separates the Inconel chips from the cooling lubricant.



At the end of the sludge remover, the Inconel chips are conveyed via a swivel chute into the special container (in the background). The container station, designed for seven containers, allows unmanned weekend operation.

essential to take a sample once a week and have it analyzed in a laboratory.

"Once for the entire production system," emphasizes Leovac. "With decentralized cooling lubricant systems, a sample must be taken at each machine and adjusted if necessary. The central system saves a lot of maintenance work in this regard."

The cooling lubricant system is refilled automatically. In this process, either tap water or deionized water with added cooling lubricant concentrate is added. Other additives such as fungicides and defoamers can also be added automatically to ensure that the cooling lubricant remains stable.

According to Leovac, this is extremely important so that "we can ensure consistently high component quality." The same applies to a constant cooling lubricant temperature, which KNOLL maintains at a tolerance of ±1 Kelvin by using two safety heat exchangers.

Container Station for Chip Disposal

A large quantity of chips results from machining the low-pressure turbine discs. In the case of pure Inconel, the chips are not considered waste, but rather a valuable raw material. For this reason, MTU works together with a recycling company that takes the chips back, melts them down, and makes them available again as raw material. The tasks of the KNOLL system planners also included ensuring that the chips separated from the cooling lubricant are automatically filled into special containers provided by MTU. Since the volume of a single container is insufficient for the 40 hours of unmanned weekend operation, a container station had to be implemented in which several containers can be automatically filled and buffered.

Automation - Another KNOLL Competence

"Here, we benefited from the experience we have gained in previous projects," says Gerhard Fink, Area Sales Manager, KNOLL. "We have also equipped the two other central systems at MTU with a similar station, which we have further refined here and adapted to the current conditions."

Given the confined space, it was particularly challenging to ensure that the loading and unloading station was easily accessible to the forklift truck and to maintain safety distances – which was ultimately achieved.

The implemented solution is based on an accumulating roller transport system developed by KNOLL that offers space for up to seven containers (a buffer section for three full and three empty containers as well as a place in the filling station).

Partnership at Eye Level

From the design to the assembly of the central cooling lubricant system and the container station, the collaboration between KNOLL and MTU was characterized by a high level of commitment on both sides.

"KNOLL always addressed our requests," Braun confirms. Schmid emphasizes that MTU very quickly gave all the necessary approvals and provided the necessary resources to quickly implement the solutions discussed.

Leovac is particularly pleased about having a year without an interruption in the cooling lubricant supply, "Since the filling, the system has been running smoothly. We really appreciate that."

From the design to the assembly of the central cooling lubricant system and the container station, the collaboration between KNOLL and MTU was characterized by a high level of commitment on both sides.



Source: TaeguTec India

HONING LOCAL CAPABILITY FOR 25 YEARS

Over the past 25 years, TaeguTec India has transitioned from a tungsten powder processing company into a highly specialized cutting tool brand. The company's journey has been shaped by its Bengaluru manufacturing facility, application-focused technical support, local engineering capabilities, and efforts to develop specialized talent.

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A defining early milestone for TaeguTec India was the inauguration of its state-of-the-art Bengaluru facility in 2001, helping the company become one of the industry's top three players within five years. "Technologically, transitioning from a tungsten powder processing company into a highly specialized cutting tool brand was a pivotal shift," says L Krishnan, Managing Director, TaeguTec India Pvt Ltd.

This evolution, coupled with the establishment of the company's dedicated Indian R&D center in 2003, enabled it to consistently launch generational technology campaigns and engineer tailored solutions for local complexities. "Our foundational ambition was to build a world-class manufacturing organization in India capable of competing globally," explains Krishnan.

Rethinking Tooling Through Total Cost of Ownership

Customer expectations across core sectors such as automotive, aerospace, and energy have also evolved. According to Krishnan, the most profound evolution is the industry's shift from 'price-sensitivity to risk-mitigation'.

"Previously, procurement focused on the initial acquisition cost. Today, manufacturers

evaluate tooling based entirely on the total cost of ownership and overall equipment effectiveness (OEE)," he elaborates. "While cutting tools represent merely 1 to 1.5 percent of component costs, an unreliable tool causes heavy financial losses through machine downtime."

This has bolstered customers' demand for supply chain predictability and unwavering process reliability. TaeguTec India adapted by deploying a rigorous 'Material × Operation' matrix, ensuring that its technical support engineers address core metallurgical challenges directly at the spindle.

Taking Expertise to the Shop Floor

The company's approach extends beyond advanced metal cutting tools to working with manufacturers on specific machining requirements. "True productivity requires optimizing the entire manufacturing ecosystem," states Krishnan. "Our sales and application teams across India partner with customers right from the component design stage, delivering engineered, turnkey setups that de-risk the manufacturing process before the spindle even turns."

By analyzing specific operations alongside workpiece materials, the company engineers bespoke solutions that maximize output without sacrificing stability. Furthermore, TaeguTec India actively recommends right-sizing cutting tools, such as deploying its compact Rhino geometries, which provide exceptional rigidity while eliminating the massive waste of oversized carbide, fundamentally lowering the total cost per component.

Growing the People Behind Technology

Employee development has remained another focus through the company's 25-year journey. "We firmly believe that an organization succeeds only when its people succeed," states Krishnan. "In this highly specialized domain, talent retention and development are critical. Over the last two decades, we have continuously nurtured the next generation of innovators through robust Graduate and Diploma Engineer Trainee (GET/DET) programs and structured paid internships."

This ensures a steady pipeline of highly skilled professionals. Beyond professional upskilling, TaeguTec India also actively invests in creating a workplace culture of belonging, celebration, and care. "By valuing our people as much as performance, we foster a loyal, technically astute workforce capable of leading the industry forward," he adds.



Source: TaeguTec India Pvt Ltd

> "The most profound evolution is the industry's shift from price-sensitivity to risk-mitigation. Previously, procurement focused on the initial acquisition cost. Today, manufacturers evaluate tooling based entirely on the total cost of ownership and overall equipment effectiveness (OEE)."
>
> **L Krishnan**
> **Managing Director**
> **TaeguTec India Pvt Ltd**

Supporting Global-Ready Manufacturing

As India transitions into a sophisticated global manufacturing hub, domestic companies are rapidly expanding into high-value supply chains across the different sectors. "To compete globally, Indian manufacturers cannot rely on fragile, commoditized supply chains; they require absolute process stability, zero defects, and high predictability," emphasizes TaeguTec India MD.

TaeguTec India acts as a strategic enabler for this transition. "Leveraging our localized Bengaluru manufacturing footprint and dedicated Indian R&D capabilities, we provide world-class standard and custom-engineered tooling," he further states.

Towards Smarter and Circular Tooling

Looking ahead, TaeguTec India identifies digital enablement, localized innovation, and circularity as priority areas for its next phase of growth. The company plans to continue developing high-feed, application-specific tooling for emerging difficult-to-machine alloys.

Crucially, sustainability is also expected to anchor the company's strategy. As Krishnan points out, "Building on our achievement of sourcing 98 percent of our energy from renewable sources and maintaining zero liquid discharge, we are expanding our vertical integration into tungsten recycling to ensure a secure, circular supply chain."

In this highly specialized domain, talent retention and development are critical. Over the last two decades, the company has continuously nurtured the next generation of innovators through robust Graduate and Diploma Engineer Trainee (GET/DET) programs and structured paid internships.

MACHINING BETWEEN TWO SHOULDERS

Unlike conventional longitudinal or face turning, grooving confines the cutting edge between the two shoulders of the workpiece. This creates unique challenges for chip evacuation, tool life, cooling, and process stability. This article explores the key technologies and strategies that can help manufacturers achieve reliable, high-quality grooving and parting-off processes.



Source: HORN/NNCEA

Trochoidal grooving expands the possibilities of conventional grooving processes.

NIKHIL NAYAK
Managing Director
NN Combined Engineering Agencies Pvt Ltd



Grooving, including parting-off and profile grooving, is one of the most demanding processes in turning. In contrast to conventional longitudinal or face turning, the cutting edge machines the workpiece between two shoulders during grooving and parting-off. It is precisely these boundary conditions that fundamentally characterize the process. While the chips can flow relatively freely during longitudinal turning, in grooving the workpiece shoulders confine the cutting edge on the left and right. For more than 50 years, Paul Horn GmbH has been developing solutions for precisely these machining operations and is regarded worldwide as a specialist in this field.

In grooving, the chip essentially leaves the machining zone upwards and against the feed direction. This places greater demands on tool geometry, chip formation, cooling and process stability. Even minor deviations can cause chip wrapping, increased wear, poor surface quality, or even tool breakage. Grooving is, therefore, far from a simple process. Only the coordinated interplay of tool technology, coating, machine stability, clamping technology, and process control ensures consistent results. The aim is always to shape the chip in a controlled manner, safely remove it from the groove, and, at the same time, achieve long tool life and reproducible machining results.

Importance of Cutting Edge Geometry

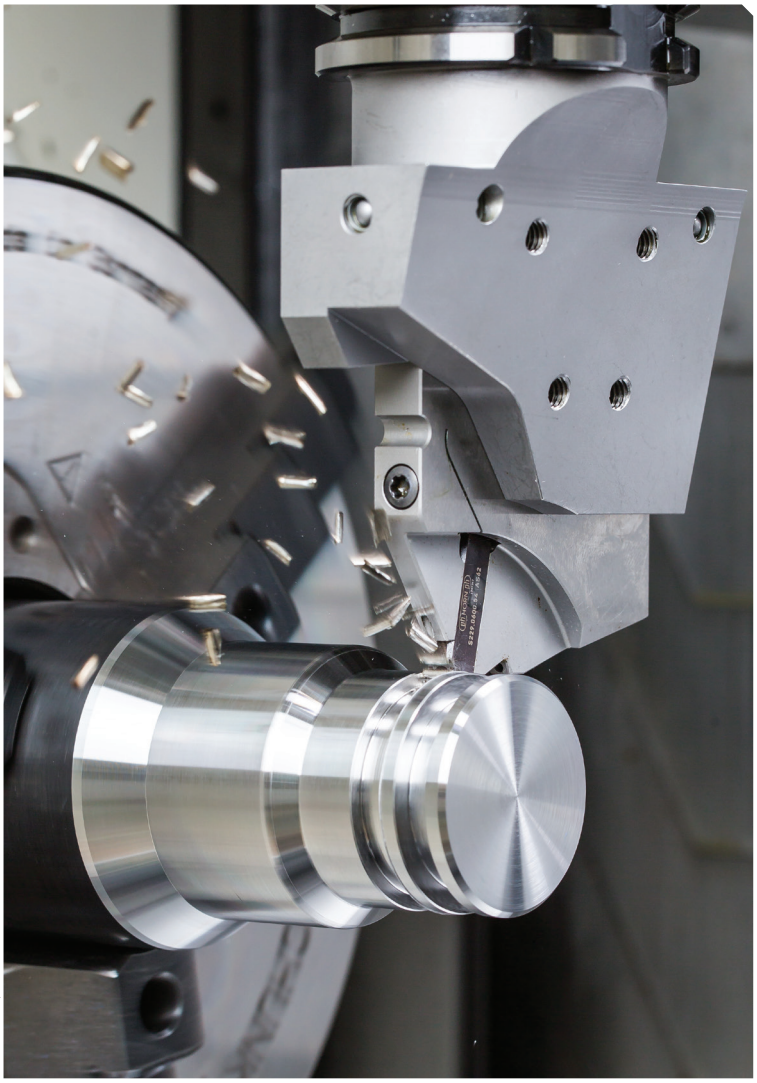
The cutting edge geometry has a significant influence on grooving and parting-off. Its main tasks are to guide the chips in a controlled manner and to shape them precisely.

In chip control, the geometry produces short, manageable chip shapes such as helical chips, spiral chips, comma-shaped chips, segmented chips, and discontinuous chips. This prevents chip wrapping and reduces process disruptions. Long swarf ribbons, on the other hand, wrap around the workpiece or tool, impede chip flow, and degrade surface quality. At the same time, the geometry selectively reshapes and tapers the swarf. This tapering enables the swarf to be safely evacuated from the groove, even in confined machining situations. Without targeted chip breaking, wide swarf is produced that rubs against the sides of the groove and damages the workpiece surface.

The influence of the geometry is particularly evident when comparing different chip breaker profiles. Ground, round chip-breaker profiles often have only a minimal effect on the chip, which flows largely uncontrolled and forms long ribbons. Geometries with pronounced chip breaking profiles, on the other hand, produce short, controlled, and highly deformed chips. This controlled chip formation is the basis for stable machining processes. Particularly with stainless materials such as 1.4305, the correct geometry determines process reliability and tool life. Even at cutting speeds of around 100 m/min and feeds of approximately 0.12 mm/rev, chip formation has a significant influence on the machining result.

Trochoidal Grooving

Trochoidal grooving expands the possibilities of conventional grooving processes. Instead of machining the entire groove in a full-depth cut, the tool moves along the workpiece following a superimposed path. This strategy reduces the load on the tool. At the same time, chip evacuation is improved because smaller chip cross-sections are produced. This method offers particular advantages for deep grooving or when processing materials that are difficult to machine. Typical process parameters include, for example, cutting speeds of around 280 m/min and feeds of up to 0.6 mm/rev. Minimum depths of cut of approximately 0.7 mm and maximum depths of cut up to 1.5 mm are employed. The cutting angle typically ranges between 40° and 60°. Smaller engagement angles lower the radial forces. At the same time, the thermal load on the cutting edge is reduced. The process is particularly suitable for modern, high-performance machining and achieving high metal removal rates.



Source: HORN/NNCEA

During grooving, the chip essentially leaves the machining zone upwards and against the feed direction.

Grooving is far from a simple process. Only the coordinated interplay of tool technology, coating, machine stability, clamping technology, and process control ensures consistent results.

The Importance of Modern Coatings

The coating on modern grooving inserts influences cost-effectiveness and process reliability. It reduces wear, minimizes friction between the chip and the tool, prevents built-up edges, and enables higher cutting parameters.

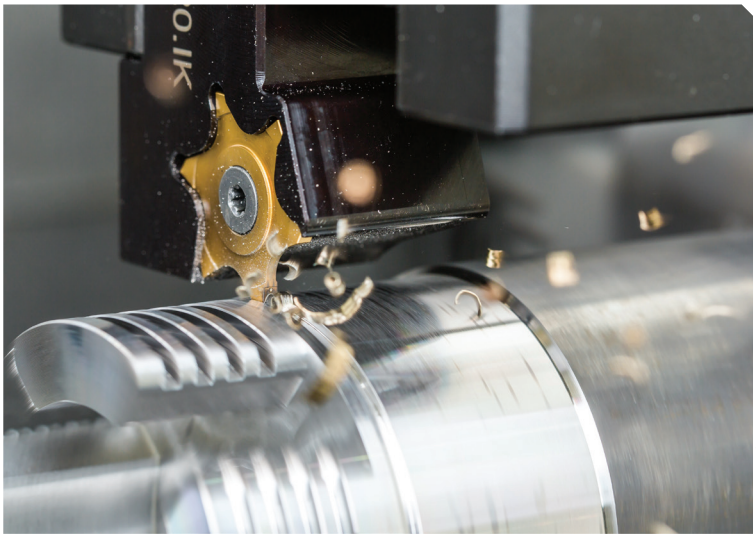
At the same time, a suitable coating improves wear detection and increases process stability. Numerous influencing factors must be considered when developing tool coatings. They include the chemical interaction between the tool and the workpiece material, the cutting edge radius, the coating process, and the mechanical properties of the coating. However, the interplay of all these elements remains critical. If the geometry, substrate, and coating are not compatible, internal stresses arise within the coating. These can improve hardness and toughness but can also cause cracking or spalling.

A coating adapted to the process influences tool life. However, the coating must not be considered in isolation. The interplay of the entire machining process remains key. Machine stability, workpiece clamping, tool holder, cooling strategy, and cutting parameters directly affect the performance of the insert. Practical trials show that significant increases in tool life are possible simply through the use of adapted coatings. At the same time, unsuitable combinations of geometry, coating, and process parameters quickly lead to premature wear. Process design always requires a holistic view of the entire machining system.

Controlled chip formation is the basis for stable machining processes. Particularly with stainless materials such as 1.4305, the correct geometry determines process reliability and tool life.

Cooling During the Grooving Process

Cooling plays a crucial role in grooving. It reduces the thermal stress on the cutting edge, while the coolant actively supports chip removal from the cutting zone. High temperatures are generated, particularly when grooving stainless steel. Practical studies reveal differences between various cooling strategies. When external coolant supply is low pressure, severe wear often occurs on the rake face. If the coolant pressure is increased, wear is significantly reduced.



Source: HORN/NNCEA

The coating on modern grooving inserts has a decisive influence on cost-effectiveness and process reliability. It reduces wear, minimizes friction between the chip and the tool, prevents built-up edge, and enables higher cutting parameters.

Systems that direct coolant to the rake face achieve excellent results. Modern tool holders with integrated coolant supply enable targeted cooling directly to the cutting zone. This reduces the thermal stress on the cutting edge. Furthermore, chip evacuation is improved. Modern toolholder systems supply the rake and flank faces precisely via integrated cooling channels. Direct coolant supply lifts the chip early and transports it out of the groove in a controlled manner. The tool holders usually feature universal coolant connections via slots or G1/8" ports.

It is not only the coolant supply, but also the composition of the coolant that influences the machining process. Even small changes in the oil content of an emulsion can have a significant impact on tool life. Practical examples show that increasing the oil content from 11 percent to 13 percent when machining Inconel 718 can double tool life. Particularly with high-temperature-resistant materials, a higher lubricant content lessens the friction between the chip and the tool. This reduces temperature and wear, while simultaneously improving chip formation.

Parting-off in the X and Y Axes

Parting-off is the final machining step at the main spindle. Errors in this process lead directly to scrap or damage to the component. Traditionally, parting-off is performed along the X-axis. In this case, the cutting forces act perpendicular to the tool holder. As the distance between the cutting edge and the holder increases, the overhang and hence the bending moment grows and the stress and susceptibility to vibration rise. When parting-off via the Y-axis, the direction of the resulting cutting force changes. A majority of the force is absorbed by the rigid machine structure, while only a small proportion is directed against the feed mechanism. The resulting force is transmitted into the tool holder at an angle of approximately 30 degrees. Consequently, the effective tendency to bend is significantly reduced. In addition, chip evacuation is improved, as chip discharge is directly downwards into the machine bed.

The different force ratios directly affect the load on the insert seat. Assuming forces of 2000 N perpendicular to the cutting edge



Source: HORN/NNCEA

Complex forms can be machined in a single pass in series production using profiled inserts.

and 400 N radially, parting off along the X-axis results in a significantly higher load due to the high bending moment.

With Y-axis parting, this load is reduced by around 30 percent. Consequently, processes run more smoothly and with reduced vibration. Practical examples show that switching from X-axis to Y-axis parting improves both tool life and process stability.

In some applications, tool life has been more than doubled while keeping cutting parameters unchanged. At the same time, the noise level is reduced. However, Y-parting requires that the machine and control system support the necessary axis travels and machining strategies.

Grooving of Complex Contours

Complex contours, such as multi-tooth profiles, place stringent demands on the process strategy. One option is to create the contour conventionally, step by step, using a grooving tool. In this case, individual grooves are programmed and executed sequentially. This method is particularly suitable for prototypes or small batches.

For large production runs, however, the programming and machining effort increases considerably. Alternatively, form grooving tools enable the entire contour to be produced in a single machining operation using a specially designed form-profiling edge that creates the entire geometry in one go. The advantages are high repeatability and short machining times. However, the large length of the cutting edge engaged at any one time generates high machining forces that can cause vibration, surface marks, and dimensional deviations.

Tangential profile grooving extends the classic form grooving process with a significantly more stable strategy. The insert is typically seated at an angle of approximately 45° in the insert seat. The tool does not enter the workpiece radially but is guided tangentially past the workpiece. In this process, the individual elements of the contour are created sequentially. In contrast to radial form grooving, the entire cutting edge width does not engage with the material simultaneously. Measurements taken with force measuring systems show clear differences between the two methods. In conventional form grooving, cutting forces of almost 6,000 N can occur. In tangential profile grooving, the forces are significantly lower. The reduced load ensures smoother cutting processes, less machine stress, and lower noise levels. Furthermore, the surface finish of the turned part is improved.

HORN in India

Precision Tooling Solutions for the Metal Cutting Industry from Paul Horn GmbH are available in India via NN Combined Engineering Agencies Pvt Ltd (NNCEA) in cooperation with select OEM partners. NNCEA provides complete logistics and supply chain management solutions for several major players in the Indian aerospace industry.

It is not only the coolant supply, but also the composition of the coolant that influences the machining process. Even small changes in the oil content of an emulsion can have a significant impact on tool life.

STREAMLINING LONG-PROFILE MACHINING

Dowaldwerke has expanded its machining capabilities for long aluminum profiles with a CHIRON MILL 3000 machining center. The solution enables more operations to be completed in a single clamping, reducing repositioning, setup time, and non-productive operations while improving process efficiency.



Source: CHIRON Group SE

High cutting performance, a large working area with an X-axis travel of 3,000 mm, and flexible configuration options make the MILL 3000 the centerpiece of the new production solution.

Source: CHIRON Group SE

Dowaldwerke GmbH has once again opted for a machining center from the CHIRON Group for processing aluminum profiles. With a MILL 3000, the company is expanding its production of long hollow sections. The new machine offers technical advantages such as fewer clamping points, easier handling, and reduced non-productive times, while the established cooperation with CHIRON Group and employees' positive experience with the existing solution also supported the decision.

Both the existing MILL 2000 and the new MILL 3000 are used primarily for producing aluminum profiles and tread plates for rail vehicles. Typical workpieces include profiles for interior door systems, boarding aids, bridging platform edges, and other railway technology components. The machining operations include drilling, contour and edge milling, as well as lateral machining. Many of these hollow aluminum sections are more than two meters long, and machining such long components with the existing production solution required additional time and manpower.

The company was therefore looking for a more efficient solution for machining these components. At the same time, it decided to expand its in-house production. "Since external providers could not meet our requirements for either precision or machining travel, it was clear to us that we would bring this production in-house, using a solution that could machine long workpieces economically while meeting our requirements for quality and productivity," says Rico Eißler, Managing Director, Dowaldwerke GmbH.

Dowaldwerke: Partner for Railway Technology and Hydraulics

Dowaldwerke GmbH, based in Dippoldiswalde in Saxony, is part

of the Richard Grießbach Holding group of companies with around 350 employees. In the field of railway technology, the portfolio includes vacuum toilets, interior door systems, partition walls, and boarding aids for well-known European manufacturers of rail vehicles. In the field of hydraulics, the company mainly manufactures hydraulic cylinders for agricultural and construction machinery as well as other vehicles.

Dowaldwerke has been using a MILL 2000 machining center for processing aluminum profiles for several years. According to Eißler, the machine has proved reliable in daily production. He also values the partnership with CHIRON Group, which is based on close cooperation and a shared focus on developing the right solution for each machining requirement.

When investing in new manufacturing solutions, Dowaldwerke involves the future users in the decision-making process. The milling specialists are responsible for programming, setting up, and processing their workpieces, making ease of operation and efficient workflows important considerations. For Cutting Machine Operator Lisa-Marie Ganz, the MILL 3000 emerged as a suitable solution for the long profiles: "We were already familiar with the machine concept and its operation and had good experience with it."

Tailor-made Concept for Long Profiles

Together with the Dowaldwerke team, the CHIRON Group developed a manufacturing concept based on a milling center from the MILL Series. The machines are characterized by high cutting performance and, depending on the variant, cover workpiece lengths of 800 mm to 8,000 mm. Large, flexible working spaces allow for the machining of larger workpieces or multiple clamping, while high dynamics, powerful drives, fast setup, and ease of operation support efficient production across different part variants. "The challenge was to machine the workpieces in one clamping if possible. This required a precisely coordinated production concept that offers sufficient flexibility for the various profile types and geometries," explains Frank Scheibe, Technical Consulting and Sales, CHIRON Group. The goal was to consistently reduce the number of clamping processes and reference points and to map different profile variants on a uniform production platform. The individually designed swing bridge makes a significant contribution to this.

The Fourth Axis Makes All the Difference

A key element of the production concept is the swivel bridge, which functions as an attached fourth axis. It allows the workpiece to be swivelled by 90 degrees, enabling lateral machining without reclamping. This improves process efficiency by reducing both the number of clamping operations and reference points. "Thanks to the swivel function, we can carry out many machining operations directly on the workpiece without reclamping. This simplifies the process and saves time in production," adds Ganz.

The clamping technology provides another advantage. A single clamping jaw is sufficient for complete machining of a profile, while machining between the clamping devices is also possible. This reduces setup effort, simplifies the handling of long profiles, and improves process reliability.

Short tool-change times were another advantage for David Steinigen, Head of Work Preparation, Dowaldwerke. "We have a lot of tool changes and thus have a clear advantage in the program sequence. We can change tools as often as we like without it having to take up a lot of time."

Building on a Strong Partnership

In addition to the technical capabilities of the MILL 3000 and the customized production concept, Dowaldwerke also placed importance on its longstanding cooperation with the CHIRON Group.

"Why did we choose a CHIRON Group machine again? Ultimately, beyond the quality of the machining centers, it is the cooperation that matters. The team is very cooperative and solution-oriented," sums up Eißler.



Source: CHIRON Group SE

The individually designed swing bridge enables lateral machining without reclamping and reduces the number of reference points required.

The new machine MILL 3000 offers technical advantages such as fewer clamping points, easier handling, and reduced non-productive times, while the established cooperation with CHIRON Group and employees' positive experience with the existing solution also supported the decision.

EXPLORING THE FUTURE OF INTELLIGENT MANUFACTURING

From intelligent machining and flexible automation to AI-driven manufacturing, the ninth edition of the Symposium on Automation & Robotics, organized by the Indian Machine Tool Manufacturers' Association (IMTMA) at the Bangalore International Exhibition Centre (BIEC), explored the technologies, strategies, and organizational shifts shaping the next phase of industrial production.



Source: IMTMA

Spanning two days, the conference and concurrent exhibition brought together over 250 delegates, 750 trade visitors, and more than 30 pioneering solution providers to explore the future of intelligent manufacturing.

The inaugural ceremony was graced by Dr Ravi Guttal, CTO, Aequs Ltd; V Sriram Kumar, CEO, ELCIA; and Sundariya S, Chairman, IMTMA Regional Council South. Jibak Dasgupta, Director General & CEO, IMTMA, was also present at the inauguration.

Setting a forward-looking tone, Guttal emphasized that long-term industrial competitiveness hinges on evolving core MES data into autonomous AI agents, urging manufacturers to invest in robust MES architectures to ensure AI is truly fit-for-purpose. Reinforcing the strategic imperative, Kumar, in his address, called on the Indian machine tool industry to transition from merely building capacity to establishing domestic IP, local design, and rigorous R&D powered by smart robotics.

Engineering Fundamentals, Global Shifts & Organizational Readiness

Day 1 focused on the foundational disciplines required to transition from manual operations to self-correcting, intelligent production.

Beginning with the foundational enablers, Ramesh Ramachandar (Festo) underscored that safety architecture, energy-efficient pneumatics, and open connectivity must be engineered upfront rather than retrofitted.

The discussions then turned to global supply chain realities. In two fireside chats moderated by Nishant Kashyap, BP Shiv (TAFE) and Vidyadhar J (Sansera Engineering) discussed how precision automation builds the process consistency required for Indian discrete manufacturers to capitalize on the 'China+1' shift.

The symposium also explored intelligent machining and capacity, Upendra Vanarase (TRIO Motion) highlighted the necessity of building intelligence on rigid mechanical baselines. Adding to this, Ashwin Udayashankar (SCHUNK Intec) discussed smart automation, enabling flexible

Source: IMTMA



Source: IMTMA

and future-ready manufacturing, while Tatsuya Matsuda (Mitsubishi Electric) addressed maximizing spindle utilization through robotic loading.

The human dimension of automation was subsequently addressed in the session on building an automation-ready organization. Moderated by Chandrashekar Bharathi (Ace-Micromatic MIT), the leadership panel brought together D Uma Maheshwar (GE Aerospace Engineering Center), Dr Vishwas Puttige (amace Solutions), Thej Kumar (Toyoda Gosei South India), and Dr Naveen Arulselvan (ATI Robotics). The panelists examined why technically sound projects often stall without proper change management, workforce upskilling, and organizational governance aligned with new shop-floor technologies.

Scalability, Brownfield Integration & Financial Justification

Building on the discussions of Day 1, Day 2 pivoted towards practical execution, scalability, and economic viability.

Opening the day, the keynote by Ajay Gopalaswamy (DiFACTO Robotics) presented a blueprint for elevating India from a systems integrator to a global robotics product powerhouse.

The symposium then turned to flexible and brownfield execution. Anuj Bihani (Alstrut India) demonstrated how modular cell designs absorb shifting product variants, while Sandeep Shetty (Toyota Kirloskar Auto Parts) presented a case study on retrofitting legacy machines with robotics, safety recertification, and signal extraction.

Moving from individual applications to enterprise-wide adoption, George Rajan (Honeywell Aerospace) outlined governance frameworks to scale pilot cells plant-wide. MR Seetharam (Synthesis Winding / ELCIA) analyzed national adoption trends, while Srinivas P Kamisetty (Kabelschlepp) detailed the uptime value of critical motion infrastructure.

The symposium concluded its conference sessions with a focus on automation ROI and financial confidence. Moderated by V Jagannath, EVP & COO, M2NXT, the closing panel featured Upendra Vanarase (TRIO Motion Technology), Mahendra Patil (FANUC India), Ranjan Singh Chadha (Festo), Mushtaq Jamal (Bevel Gears India), and Ashwin Udayashankar (SCHUNK Intec India). The panelists dismantled traditional skill-displacement metrics, providing frameworks to assess total cost of ownership (TCO), identify hidden operational costs, and establish realistic payback timelines that secure boardroom and finance approvals for automation investments.

Concurrent Exhibition & Strategic Takeaway

Complementing the conference, the concurrent exhibition provided attendees with hands-on access to live demonstrations from over 30 leading robotics and automation providers.

Together, the two-day symposium and exhibition provided a platform for industry stakeholders to examine the engineering, organizational, technological, and financial considerations shaping the adoption of intelligent manufacturing. The discussions highlighted the need for robust technological foundations, workforce readiness, scalable solutions, and clear financial justification as manufacturers move towards increasingly automated and intelligent production environments.

Spanning two days, the conference and concurrent exhibition brought together over 250 delegates, 750 trade visitors, and more than 30 pioneering solution providers to explore the future of intelligent manufacturing.

PMTX 2026 BRINGS MANUFACTURING TECHNOLOGIES TO PUNE

Organized by IMTMA, the fourth edition of Pune Machine Tool Expo (PMTX) and the third edition of Factory Equipment Expo (FACTEQ), held in Pune from September 7–10, at the Pune International Exhibition & Convention Centre (PIECC), Moshi, Pune, brought together manufacturers, technology providers and industry professionals, showcasing solutions across the manufacturing ecosystem.

The twin exhibitions brought together over 170 exhibitors, 300 trade delegations, and 18,000 visitors, providing a platform for manufacturers and technology providers to engage with customers, explore new technologies, and identify opportunities for collaboration.

PMTX 2026 featured a range of machine tools and manufacturing technologies, while FACTEQ 2026 complemented the exhibition with solutions covering factory equipment, automation, material handling, storage systems and plant infrastructure. Together, the exhibitions presented technologies spanning metal cutting and forming, tooling, automation, robotics, metrology, digital manufacturing, precision engineering, and allied areas.

The exhibitions also reflected the growing technology requirements of India's manufacturing sector, with visitors from across major industrial clusters exploring solutions aimed at improving productivity, precision, quality, and manufacturing efficiency.

The strong visitor turnout and active engagement across the exhibition halls provided exhibitors with opportunities to interact with existing and prospective customers, establish new business connections and explore potential collaborations. The four-day event thus served as a platform for technology discovery, industry networking, and business engagement in the western region.



Source: MMI

As India continues to strengthen its manufacturing capabilities and move towards higher-value production, platforms such as PMTX and FACTEQ provide an opportunity for manufacturers to connect with technology providers and explore solutions that can support their evolving production requirements.

Spotlight on Pune

The inaugural ceremony was led by industry leaders including Arvind Goel, Vice Chairman, Tata AutoComp Systems Ltd; Mohini Kelkar, President, IMTMA; Vikram Salunke, Vice President, IMTMA; and Jibak Dasgupta, DG & CEO, IMTMA.

Guest of Honor Goel stressed on local manufacturing. He said India's growing manufacturing ecosystem offers significant opportunities for the machine tool industry. India will be one of the key focuses for the growth which is expected year after year. Highlighting the need for greater domestic capability, Goel urged the industry to build a stronger manufacturing base within India. He called upon the machine tool industry to be at least the third largest manufacturer in the world.

Speaking about IMTMA's decision to organize the expo in Pune, Kelkar said, "Pune being one of the strong bases for automotive and engineering companies, it demands a huge amount of high precision manufacturing tech-

Source: Team MMI

nologies which are catered by the machine tool industry. IMTMA has a strong presence in Maharashtra with around 180 members and for last two decades, the Association has been extending support to industries through various initiatives."

Adding to Kelkar's views, Jibak Dasgupta, Director General & CEO - IMTMA said, "Pune being a stronghold for various manufacturing industries, IMTMA is organizing PMTX and FACTEQ to reach out to the manufacturing community in the region. The shows are growing significantly with every edition, and we are seeing a great enthusiasm from both manufacturers and users of machine tools."

Exhibitors' Take

The strong response from exhibitors at PMTX 2026 reflected Pune's importance as a major manufacturing and industrial hub in Western India. Ravi Bhintade, Deputy General Manager, Ace Designers Ltd, appreciated the platform provided by IMTMA, pointing to the tremendous opportunities and sustained growth potential in the Pune industrial belt. With Western India being a powerhouse for automotive, engineering and precision industries, he noted that the response and quality of industry engagement at the booth had been exceptional. AceMicromatic Group continues to focus on high-productivity machining, smart engineering and cost-effective automation tailored to the region's evolving manufacturing demands.

Anil Bhardwaj, Managing Director, Mazak India, described Pune as the 'most important hub' and highlighted the importance of platforms such as PMTX in reconnecting with the industry, sharing knowledge and fostering new collaborations. The company's continued production of precision machines at its India plant in Pune was also highlighted as a testament to its long-term commitment to the Indian manufacturing ecosystem.

The importance of Pune's industrial corridor was echoed by Rahul Pawar, Regional Manager—Sales, Jyoti CNC Automation Ltd. As Western India consolidates its reputation as a global hub for automotive, engineering, heavy fabrication and precision machining, Pune has emerged as an anchor ecosystem where high-volume production meets exacting quality standards. Pawar noted that the real benchmark of a successful tradeshow lies in meaningful dialogue on the show floor. At PMTX 2026, the focus extended beyond machine demonstrations to deepening ties with long-standing partners, engaging directly with end-users and cultivating new alliances.

Batliboi Machine Tools Group also highlighted the strong buyer response at the show. Siddu Nironi, General Manager, Sales & Service, observed that high-intent buyers and packed aisles characterized the opening days at the company's booth. Given the scale of Pune's engineering and automotive belt, he described PMTX as a mandatory fixture on Batliboi's event calendar. According to him, the expo attracted plant heads and purchase leads with a clear intent to close machine deals, making the show an important platform for connecting machine builders with manufacturing shop floors and capturing active capital investment opportunities.

For Meiban Engineering Technologies Pvt Ltd, the show demonstrated the value of bringing high-precision automation to India's automotive heartland. Rishi Kapoor, Senior Vice-President, noted that PMTX 2026 demonstrated how technology dialogues can quickly translate into commercial commitments when high-precision automation meets a strong manufacturing ecosystem.

UCAM, participating in PMTX for the fourth time, also leveraged the exhibition to connect with Pune's machine tool and automotive ecosystem. Vijay Zaritaklikar, National Manager – Sales, UCAM, highlighted the company's position as one of the largest manufacturers of rotary tables and a preferred partner for machine tool builders and end-users. With Pune serving as a major hub for automotive components, he noted that UCAM offers a range of solutions for the automotive industry and that PMTX is creating "very good business opportunities."

Overall, the exhibitors' feedback underlined PMTX 2026's role not only as a showcase for machine tools and manufacturing technologies, but also as a platform for meaningful industry engagement, business development, customer interaction and new opportunities across Pune and the wider Western Indian manufacturing ecosystem.



Source: MMI

As Western India consolidates its reputation as a global hub for automotive, engineering, heavy fabrication and precision machining, Pune has emerged as an anchor ecosystem where high-volume production meets exacting quality standards.

INSIDE THE BLUEPRINT FOR JIMTOF 2026

At Tokyo Big Sight, where the architectural skyline meets the waters of Tokyo Bay, an industrial quiet precedes what promises to be a defining moment for global manufacturing. Across six days, from October 26-31, 2026, the venue will host the 33rd edition of the Japan International Machine Tool Fair (JIMTOF 2026).



Source: JMTBA

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Adorned with folded origami motifs symbolizing technology taking flight, the fair's theme captures an industry undergoing a profound structural shift. Machine tools are no longer isolated cutting engines; they are transforming into intelligent, self-optimizing nodes designed to address global supply chain shocks, persistent labor shortages, and stringent decarbonization mandates.

Scaling New Heights Amid Complex Spaces

Organized jointly by the Japan Machine Tool Builders' Association (JMTBA) and Tokyo Big Sight Inc., JIMTOF has served as a global industrial barometer for over six decades. The 2026 edition stands out not only for its technical ambition, but also for its structural resilience. The organizers have expanded the event footprint to accommodate 1,134 exhibiting companies from 22 countries and regions across 4,422 booths, marking the second-largest exhibition scale in JIMTOF's history.

Central to this footprint is the impressive JMTBA member presence with 99 association companies slated to occupy 1,756 booths. Among those, 46 member firms are scheduling global debuts for new technologies, while every participating member will showcase upgrades geared toward enterprise-wide process optimization. To maintain navigation clarity, booths across East, West, and South Halls remain strictly organized by machinery and accessory categories.

Technological Pillars Shaping the Floor

According to Shigetomo Sakamoto, Chairman, JMTBA, JIMTOF 2026 serves as a living laboratory for four core industrial shifts:

From Machine Data to Orchestrated AI: The introduction of



Source: JMTBA

"At JIMTOF 2026, we are witnessing a fundamental leap from standard robotic automation to 'autonomation' where AI-driven machining, digital twins, and Green Transformation (GX) initiatives redefine productivity and sustainability for the next quarter-century."

Shigetomo Sakamoto
Chairman
JMTBA



Source: JMTBA

generative AI has accelerated software adoption beyond simple diagnostic logging into real-time operational execution. Visitors will observe AI models managing design workflows, predictive maintenance routines, automated quality inspection, and dynamic work cell coordination across connected equipment.

Digital Twins and Green Transformation (GX): Digital twin technology is expanding from isolated spindle modeling to comprehensive, real-time factory emulation. By mapping energy draw and CO_2 output across entire production lines, exhibitors will demonstrate how virtual monitoring directly aligns green metrics with overall equipment effectiveness (OEE).

The Shift to Autonomous Systems: Addressing structural labor shortages requires systems that move beyond fixed robotic tasks. Exhibitors will feature integrated cells combining machine tools, Autonomous Mobile Robots (AMRs), collaborative units, and AI vision systems capable of autonomous part recognition, position self-correction, and adaptive handling.

Industrial-Grade Additive Manufacturing (AM): Additive technology continues its migration from rapid prototyping to serial production. Focus areas will highlight complete AM ecosystems spanning generative design software, powder metallurgy systems, post-processing tools, and integrated non-destructive testing for complex components in aerospace, medical, and energy applications.



Source: JMTBA

Where Human Tactile Skill Meets Robotics

JIMTOF 2026 will present a dedicated dual-zone special exhibition highlighting AI and robotics:

- ***Humanoid Robotics Zone:*** Under the banner 'Machine Tools Supporting the Evolution of Japanese-Made Humanoids', this exhibit traces the high-precision machining, gearing, and component fabrication required to power the next generation of humanoid platforms.
- ***Collaborative Kisage (Hand-Scraping) Zone:*** Themed 'Craftsmen and Robots: A Challenge in Collaborative Kisage Work—the Crystallization

Hosting 1,134 exhibitors from 22 countries across 4,422 booths, JIMTOF 2026 achieves the second-largest participation in event history, overcoming major venue space renovations at Tokyo Big Sight.



Source: JMTBA

> "JMTBA is committed to deepening ties with the Indian manufacturing sector. Building upon the successful foundation laid in 2024, we are actively facilitating direct business matching between Indian distributors and our member builders at JIMTOF 2026."
>
> **Kazuo Yuhara**
> **President**
> **JMTBA**



Source: JMTBA

The show features AI-driven automation, digital twins, and a special exhibition pairing Japanese humanoid robotics with live daily demonstrations of traditional kisage hand-scraping by master craftsmen.

of Skilled Craftsmanship', this live exhibit brings traditional hand-scraping (kisage) into conversation with modern automation. Master craftsmen from member companies will offer daily demonstrations and interactive workshops, illustrating how tactile precision informs modern mechanical guidance systems.

Knowledge Sharing and Workforce Cultivation

Knowledge exchange remains a central function of the fair. Coinciding with the exhibition, the 21st International Machine Tool Engineers Conference (IMEC 2026) will convene under the overarching theme 'The Machine Tool Industry's Challenge for a New Quarter-Century'.

(i) ***Technical Sessions on October 28–29:*** Featuring 15 curated technical papers delivered by international research leaders and engineering experts.

(ii) ***Academic Poster Session on October 28–30:*** Set in South Hall 4, showcasing 56 university and institutional research projects focused on cutting-edge machining technologies, with authors hosting daily open Q&A sessions.

Concurrently, JMTBA is expanding its talent development programs. STEM students from across Japan will participate in hands-on jig boring machine workshops, guided exhibitor tours, and the national 'Machine Tool Top Seminar', culminating in an evening networking session with senior manufacturing executives on the event's final day.

Global Industrial Alliances

Highlighting JIMTOF's international reach, Kazuo Yuhara, President, JMTBA, emphasized strengthening cross-border supply chains, particularly with rapid-growth manufacturing hubs. Building upon initiatives introduced in 2024, JMTBA will host a structured bilateral business-matching program inviting eight senior executives from five leading Indian machine tool dealerships to establish direct distribution alliances with Japanese builders during the show.

Countdown to the Show

As Tokyo Big Sight prepares to open its doors this October, JIMTOF 2026 offers an integrated view of modern manufacturing, where traditional master craftsmanship and high-level algorithmic automation converge to shape the industry's next quarter-century.

Exhibits on Display

Machine Tools - Metal Cutting, Metal Forming

Machine Tool Accessories - Tools for machines (cutting tool & wear-resistant tool) diamond, CBN tools, grinding wheels and abrasives, gears and gear devices, oil hydraulic, water hydraulic and pneumatic machinery, and precision measuring machines and instruments

Optical Measuring instruments - Testing machinery, controller and related software (CAD/CAM)

Associated machinery and equipment, raw materials and technologies.


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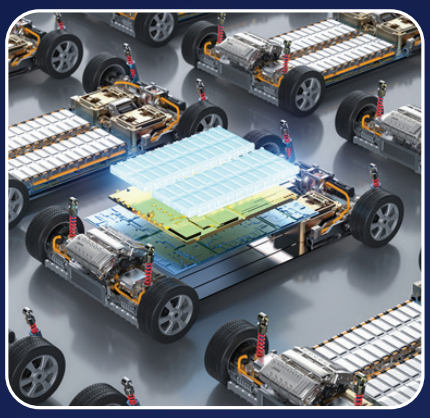
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