KPMG

Technology Cluster Manager

Technology Centre Systems Programme (TCSP)

Ministry of Micro, Small and Medium Enterprises

WHITE PAPER
ON
PRECISION MANUFACTURING

K N Gopala Krishna- Training and Technology Expert

CTTC Bhubaneswar

June, 2019

Table of Contents

1. Introduction

Precision manufacturing is a sub-discipline of mechanical engineering (along with electrical, electronics and instrumentation engineering) concerned with production of parts with high tolerances, precise structure and shape in a repeatable and stable manner. In precision manufacturing the emphasis is on the design and performance of precision machines, tools and tooling elements, related metrology and selection of suitable material for precision machining processes.

Modern precision manufacturing demands improved competitiveness which has led to the development of a new generation of industrial machinery which is capable of incorporating machine vision enabling greater precision and coordination, closer process control, high quality machining and improved quality control.

Precision manufacturing is not only used to make smaller items, but can be applied to almost any manufacturing scenario where high precision is required. In fact, leading steel fabricators in the United States making large fabrication components have transitioned to a precision manufacturing component manufacturing.

Modern precision manufacturing also allows for an increased level of traceability which is a basic requirement of industries in medical devices and automotive parts manufacturing. Precision manufacturing is not the destination but a continuous process of improvement and integration.

2. Overview of the sector

Precision manufacturing is used to some extent in all industries, however, the five main industries where Precision manufacturing is extensively being used and are being considered potential growth areas for growth of precision manufacturing are as follows:

a) **Aerospace:** INR 5 lakh crore ($ 100 billion) will be invested on acquisitions in the aerospace and defence sector in India in the next ten years.
b) **Defence:** India has one of the largest defence budgets, representing 12 % of the total Central Government expenditure for the year.
c) **Tool and Die making:** According to the Indian tool room manufacturing forums, the domestic average market size of die and mould industry could touch around Rs 30,000 crore by 2021.
d) **Automobiles:** As per the Automotive Mission Plan 2026, the government and industry has set a target to triple industry revenues to $300 billion, and expand exports sevenfold to $80 billion by 2026[1]. To meet these aims, it is estimated that the sector could contribute more than 60 million additional direct and indirect jobs, and the result could be improved manufacturing competitiveness and reduced emissions.
e) **Medical industry:** Healthcare market in India is expected to reach US$ 372 billion by 2022 driven by rising incomes, greater health awareness, lifestyle diseases and increasing access to insurance.

Aerospace and Defence industries would continue to be the main drivers for precision manufacturing activities in view of large number of precision components, complexity and high volume of precision components required in these industries.

[1] The Future of the automobile Industry India, Mckinsey report

3. Domestic Market

The Precision manufacturing industry in India is expected to grow at an average rate of 8% in 2019-20 and beyond. This strong growth potential of the industry is attracting original equipment manufacturers (OEMs) in this sector to setup facilities in India. The long gestation period is not deterring companies since the ones who have already made capital investments are anticipating a CAGR of nearly 30 per cent every year.

According to Global Aerospace and Defence Industry Outlook, 2019, India is expected to become the "third largest" aviation market by 2025. It is estimated that 478 million Indian passengers are expected to travel by 2036 leading to a demand for additional 2000 new aircrafts. Also, there was a significant increase of 7.7 percent in Defence Budget (2018-19) of India as compared to the budget of 2017-18. The increased spending on defence procurement would provide and impetus to the precision manufacturing in India.

The Government is providing all required resources and creating a robust framework for the growth of the sectors. Some of favourable policies and initiatives that is expected to boost the growth of the sector are as follows:

National Manufacturing Policy: The policy is aimed to boost manufacturing sector growth to 12-14% over the medium term to make it the engine of growth for the economy in order to increase manufacturing sector contribution to 25% of the nation's GDP. It is envisaged that the manufacturing sector will help in creation of 100 million additional jobs by 2022. It encompasses a policy level support to the sector and ensure sustainability of growth, particularly with regard to the environment including energy efficiency, optimal utilization of natural resources and restoration of damaged/ degraded eco-systems.

The Defence Procurement Policy (DPP 2018): The defence procurement policy give a greater fillip to Indian defence manufacturing industry by modified offset clauses. This will help rerouting procurement funds paid to international contractors back into India in terms of localization of components and technology transfer to manufacture offset component locally. This may help international players get a low cost manufacturing base and in return, gave Indian companies access to technology and help establish India as a hub for aerospace components.

Focus on aerospace industry making India an aerospace hub: The first Aerospace and Precision Engineering SEZ Park is coming up in Telangana. Reliance Defence Limited is planning a global aerospace technology research centre in Bengaluru. Aequs Aerospace has initiated the aerospace ecosystem in Belagavi leading to several contracts in aerospace manufacturing coming to India.

Challenges in the industry

Infrastructure deficiencies: Complex land acquisition procedures and lack of reliable and reasonably priced power are some of the major challenges in the sector

Lack of skilled manpower: There is lack of technicians with specific skill sets required for precision manufacturing especially in Aerospace and Defence sector. Companies have to invest substantially in providing specialised training to upskill employees to produce products of international standards.

Tax support: India's tax framework needs rationalisation and sector-specific incentives would be required to be developed and implement to for favourable growth of the sector. For example, benefits similar to those provided to service sectors, such as IT and ITeS need to be extended to aircraft MRO (Maintenance Repair and Overhauling) sector which is a major revenue earner.

4. Global Perspective

After a lackluster 2017, the global aerospace and defense (A&D) industry has revived in 2018 with increase in passenger travel demand and increase in global military expenditure. The industry is expected to continue its growth trajectory in 2019, led by growing commercial aircraft production and strong defense spending. In the commercial aerospace sector, aircraft order backlog remains at an all-time high as demand for next-generation, fuel-efficient aircraft continues to surge with the rise in oil prices. With the aircraft backlog at its peak (more than 14000 aircraft), manufacturers are expected to ramp up production rates, hence, driving growth in the sector. It is estimated that 38,000 aircraft expected to be produced globally in the next 20 years.

In the defence sector, heightened global tensions and geopolitical risks, recovery in the US defense budget, and higher defense spending by other major regional powers such as China, India, and Japan are expected to drive global defense sector growth in 2019 and beyond. Changes in the international trade agreements are likely to disrupt the global supply chain and increase costs.

Though the global industry growth is primarily led by the United States, some of the other key regions that are expected to contribute to industry performance in the near future include China, France, India, Japan, the Middle East, and the United Kingdom.

5. Leading global technologies and techniques

Precision manufacturing has been revolutionized through the opportunities available in adopting advanced manufacturing techniques & capabilities and in information technology (IT) throughout the lifecycle of the product/service. The result is increased visibility into operations, significant cost savings, reduced cycle times leading to faster production and much better customer support. Industry 4.0 techniques have thus become a key differentiator for companies to stay ahead of competitors.

Industry sources list the following as the top seven manufacturing trends for 2019 which applies equally well to precision manufacturing:

5.1 IIoT (Industrial Internet of Things)

Internet of Things (IoT) is a network of devices which can sense, accumulate and transfer data over the internet without any human intervention. The devices can be remotely monitored and controlled Thus IoT can said to create a cyber-physical world.

IIoT is the application of IoT to Industry including manufacturing. The aim is to have seamless integration of various manufacturing machines and devices having capabilities like sensing, identification, processing, communication, actuation without or with minimum human intervention. The popularity of IoT and the reasons why it will expand exponentially is primarily due to three factors widely available Internet access, smaller sensors, cloud computing.

The implementation of IIoT requires establishing an infrastructure which can be divided into four stages:
Stage 1. Sensors / Actuators: Sensors collect data from the environment or object under measurement and turn it into useful data. Ex. Temperature sensors, humidity sensors, camera systems, CCTVs, water-level detectors, air quality sensors etc.Actuators change the physical conditions. Ex, Actuator shuts off a power supply, adjusts an air flow valve, or moves a robotic arm to the required position.

While some sensors / actuators require separate power sources, low-power wireless sensors drawing Power over Ethernet (wired LAN) have become prevalent thus rapidly expanding the scope of IoT.

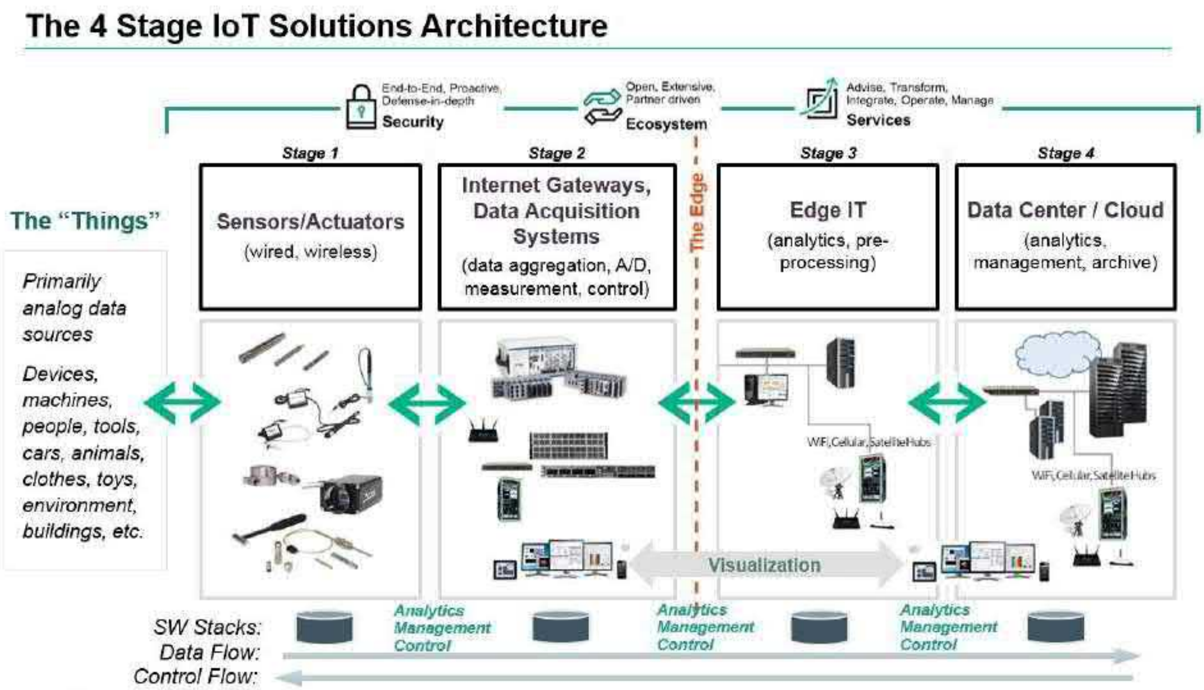


Fig 4. Four stages of IoT solutions architecture (Thanks to Techbeacon)

STAGE 2. DAS systems (Data acquisition / conversion / aggregation): The DAS architecture acquires the Analog data generated by sensors and converts it to digital data. The data is then aggregated and sent to the next stage for pre-processing.

STAGE 3. Edge IT (Data pre-processing): Once IoT data has been digitized and aggregated, it needs to be pre-processed by Edge IT systems before the data enters the main data centre. This is required as large quantities of data are generated especially when a large number of sensors are in existence. Sending this data directly to the data center may swamp the core IT infrastructure. Also, the data coming out of the sensors may need to be appropriately pre-processed to make it suitable for processing by the core IT infrastructure. If some issues require immediate attention (say impending failures) then they are identified at this stage and by using visualization technology the information can be presented in easy-to-understand dashboards or graphs.

STAGE 4. The data center and cloud: Wherever in-depth processing of data is required and immediate feedback is not important, the data gets forwarded to physical data center or cloud-based systems, where more powerful IT systems can analyze, manage, and securely store the data. Results take a little longer to get from Stage 4, but the analysis is more in-depth, and you can combine your sensor data with data obtained from other sources for better insights. Stage 4 processing may take place on-premises, in the cloud, or in a hybrid cloud system.

The good news is that even existing machines can be converted to IIoT enabled ones through retrofitting of sensors and actuators. Also accessing the data and analysis results can be done through Tablets and mobiles making it convenient and less expensive.

Implementing IIoT can help a company to achieve a variety of goals including cost reduction, increased efficiency, improved safety, meeting compliance requirements, and product innovation.

5.2 Predictive Maintenance Technology

Critical Machines and Equipment are becoming more and more expensive. Any breakdown results in substantial financial losses due to downtime, repairs, and loss of productivity. Even a single hour of breakdown can lead to loss of several lakhs of rupees. Hence a key priority for manufacturers is to ensure that all critical machines and equipment are functioning optimally.

Traditional breakdown maintenance is no longer valid and preventive maintenance which is a static procedure is also not reliable enough. Hence companies are turning to predictive maintenance technology to help them ensure optimal equipment performance.

The principle of predictive maintenance is that when Machines and Equipment are performing their tasks, they give out clues as to their health and performance. Some indicators are dimensional variation, finish variation, excessive temperature, noise, vibrations etc.

Predictive maintenance programs collect data regarding these clues using suitable sensors and instruments attached to the machines/equipment. Using IoT technology the data collection process is automated and analysing the data (using machine learning, artificial intelligence and model generation) helps manufacturers to develop a better understanding of the way the systems work and when they will probably fail. This dynamic system gives the ability to predict the optimum time for performing maintenance and this saves manufacturers valuable time, money, and resources. Since monitoring and data collection happens when the equipment is in operation, production loss does not occur. Initiating a predictive maintenance programme requires effort but the advantages can be huge.

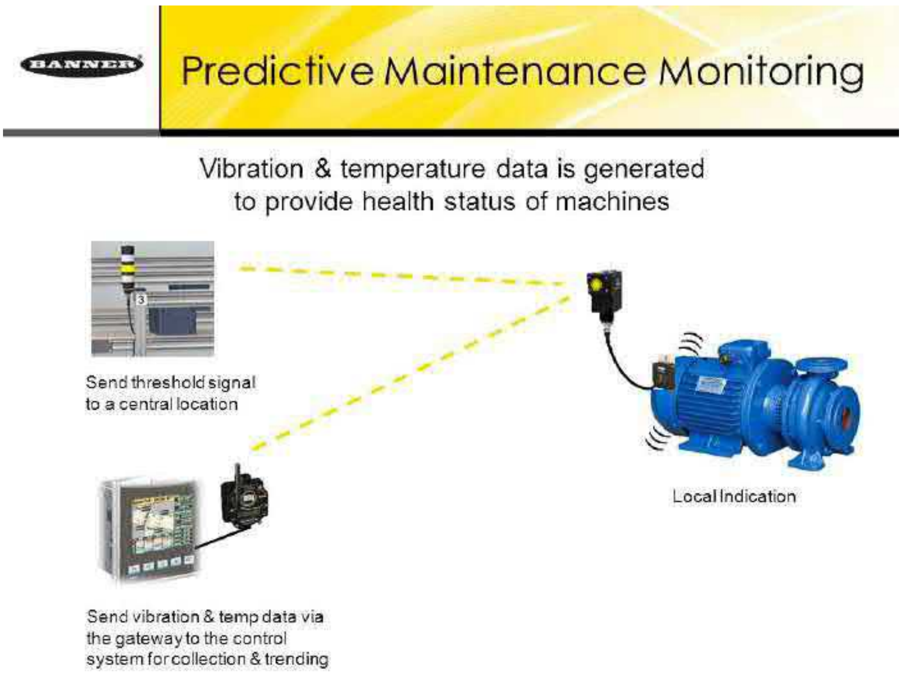


Fig 5 : Equipment data collection and sharing for predictive maintenance

Fig 6: Data collection for monitoring a turbine (Thanks to Hitachi solutions)

5.3 3D printing (Additive manufacturing – AM)

These are a class of processes where material (typically in form of powdered grains) is added layer by layer with the help of computerized 3D model. After the deposition of each layer, lasers or glue are used to fuse it to the previous layer. Thus gradually a three-dimensional object is formed which can have any shape, size or geometry. This is in contrast to conventional machining process, where material is removed from a stock item.

Earlier, inkjet printer heads were used to deposit a binder material onto a powder bed layer by layer. Hence it was called "3D printing". Now the correct technical term is Additive manufacturing.

Historically, jigs, fixtures and moulds used in mass production were produced using expensive processes and used to take months and would be very expensive. 3D printing makes it possible for tooling to be completed on-site, cost effectively and in much shorter times, typically in days.

In the 1990s, 3D printing techniques were considered suitable only for the production of functional or aesthetical prototypes and hence it was called as rapid prototyping. Today, the control and precision which can be achieved and the wide range of materials available has made 3D printing a viable industrial manufacturing process. Hence, it has been adopted by the automotive and aerospace manufacturing industries.

Fig 9. Complex Plastic components made using 3D printing

5.4 Reality technologies (AR and VR) Man – Machine Partnerships

Augmented reality (AR) superimposes a computer-generated image or digital elements on an user's view of the real world, thus providing a composite view. The digital elements are added through wearable (goggles or headsets) or more commonly by using the camera on a smartphone.

AR for error-free production: AR is being used in the assembly of Ducati motorcycle engine. The operator is wearing transparent AR goggles through which he can see the engine. Instructions are flashed on the goggle inner surface.

Fig. 10 Instructions flashed on the goggles

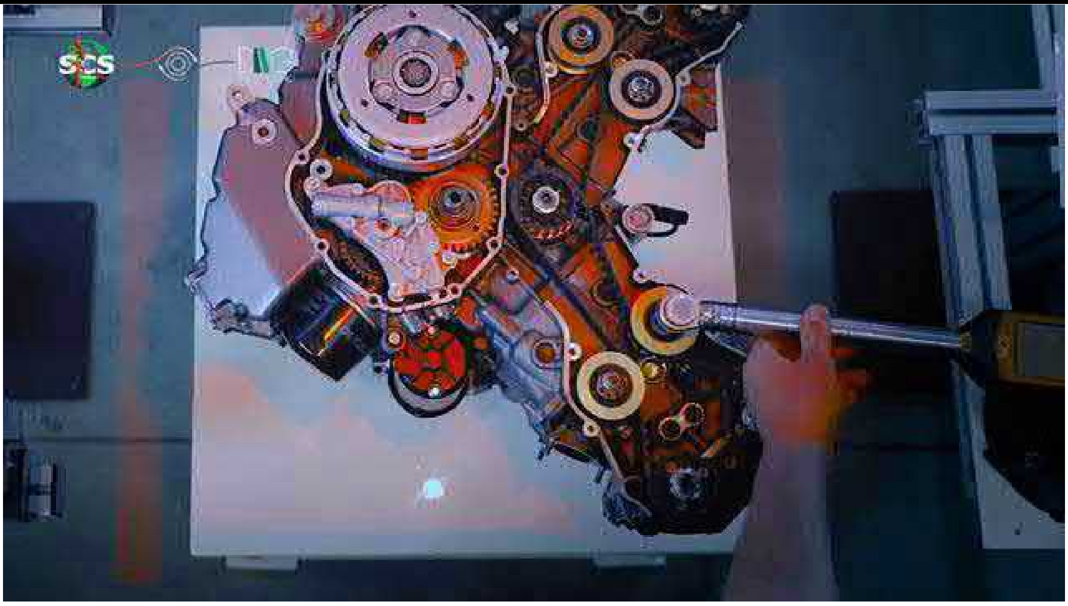


Fig. 11 Red light flashes to indicate wrong assembly sequence

AR Remote Maintenance and Inspection: Using AR, trained specialists virtually visit a manufacturing facility to perform safety inspections and routine maintenance easily and more often since physical visits are not required. Hence, problems could be caught much earlier before they present a loss of manufacturing time, resources, or even worker lives.

Using VR and tele-robotics (remote controlled robot arms and tools) delicate repairs can be performed by an expert who is located half the world away. A local maintenance person can also follow the expert's advice over AR to perform the repairs.

Fig 12. Remote maintenance using AR (Thanks to Gabler)

Virtual reality (VR) is a three-dimensional, computer generated environment which can be explored and interacted with by a person. By use of IT tools the physical world is shut out and the person undergoes an immersive experience. Wearables (goggles or headsets) provide the virtual environment to create near to real environment for enhanced user experience. Hand-held wireless/wired controllers help user to customize the interactions with his environment.

Ford Immersive Vehicle Environment: Ford was one of the first car manufacturers to adopt VR in its processes. Its engineers are able to design and build an entire car, from the power train to the upholstery, in a virtual environment. It utilises FIVE, Ford Immersive Vehicle Environment system which converts CAD designs into virtual cars. Using extremely high-resolution models and textures, engineers are able to inspect car components as well as walk around and inside the vehicle itself.

Fig 13. Ford Immersive Vehicle Environment (Thanks to Ford Co.)

The FIVE technology also allows Ford designers to collaborate with each other across continents. Marketing specialists in Australia can virtually tour a new vehicle with the engineering team USA without travelling.

- **VR for Safety issues identification and Training:** Where safety is critical, head-mounted displays are used to recreate manufacturing lines in the virtual world, Experts can then locate potential safety hazards before the product is even made or before it reaches a client.

Fig 14. A Virtual mannequin goes through the process steps (Thanks to Gabler)

Designers and clients, no matter where they are physically located, can together explore and interact with a piece of equipment in VR. By sending a virtual mannequin through the process steps, costly or dangerous mistakes can be identified. Gabler says that VR has helped them to reduce development time by 15% and led to increased safety and quality.

5.5 Measurement technology 4.0

Precision manufacturing requires precise, accurate and high resolution measurement systems which are ideally integrated with the production systems in a closed loop.

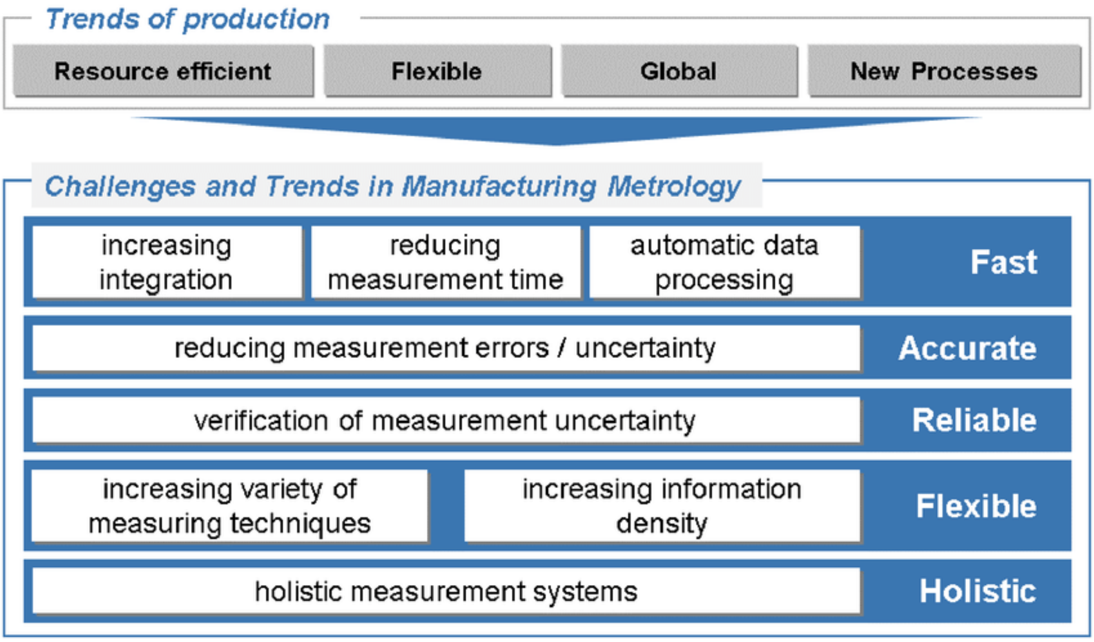


Fig 15 Challenges and trends in manufacturing metrology

(Thanks to Imkamp, D & Berthold, J.)

Speed plays an important role in production process, hence, the measurement technology used should provide information fast for conformity checking and process control, any delay may slow down entire production progress. Measurement result, including measurement uncertainty, should be within the specification limits, Hence measurement uncertainty plays a major role in ensuring accurate and reliable measurement.

Measurement uncertainty is contributed by variation in the various elements of the measurement system like measuring instrument, person performing the measurement/setting, measurement methods used, calibration standards used, environmental factors in which measurement are made etc. In many areas of modern production, however, the measurement uncertainty is often no longer adequate for checking the tolerances required by the standard. This is a challenge which needs to be addressed by addressing the various sources of variations.

The measurement system in figure 16 is linked to the production machines. This enables the production to be corrected automatically should there be errors compared to tolerances. This ensures faster measurement and better work piece quality making the production processes significantly more reliable.

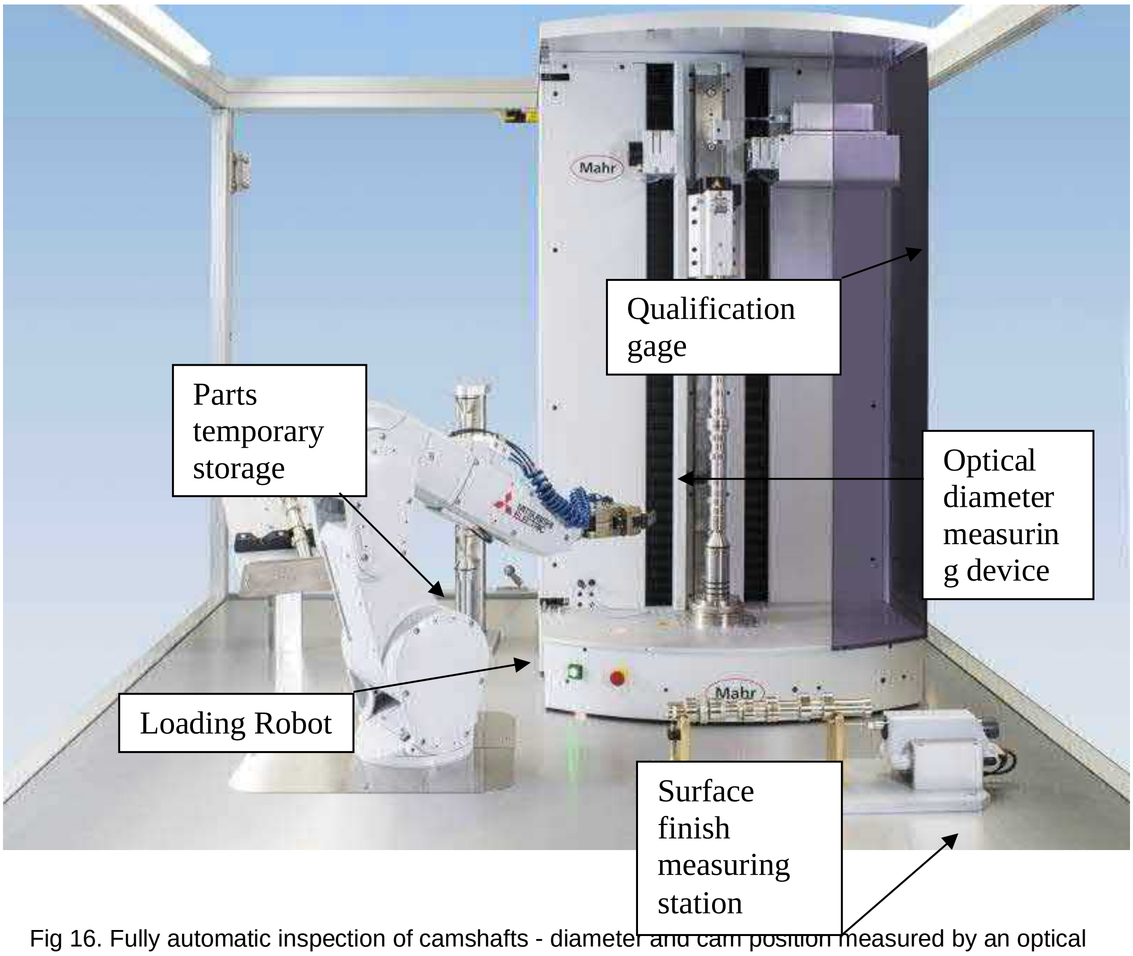
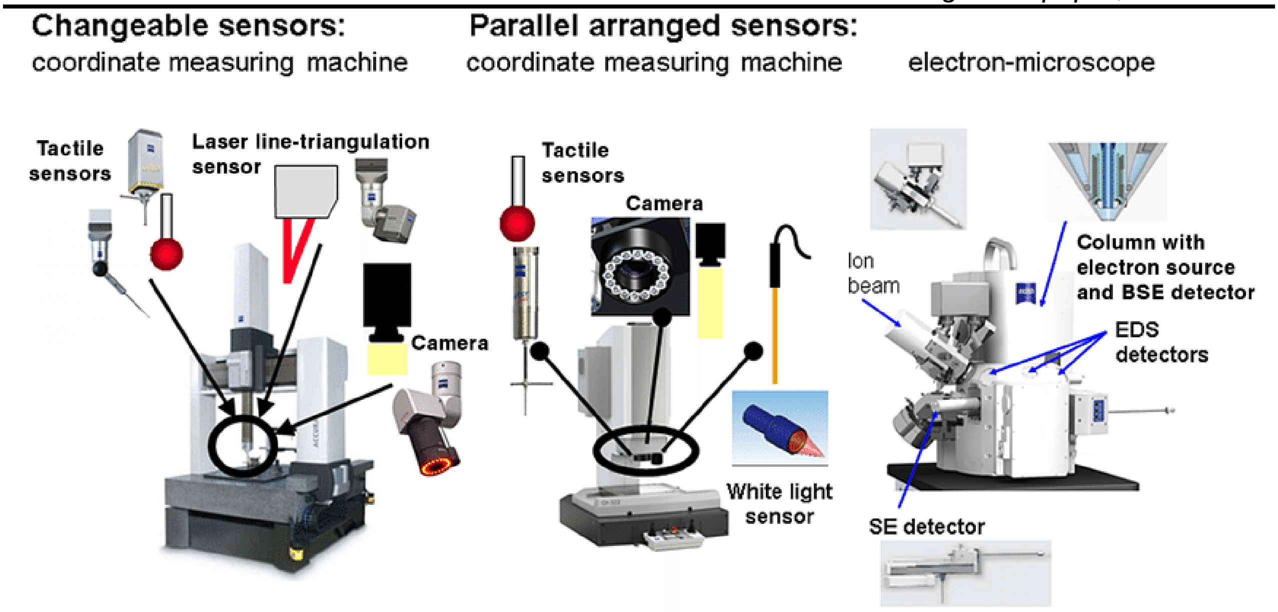


Fig 16. Fully automatic inspection of camshafts - diameter and cam position measured by an optical measuring device and surface finish by an additional measuring station.

The variety of measurement systems used in manufacturing is growing and so also their ability to adapt to different measuring tasks under different conditions, computed tomography and imaging optical systems, are able to capture very different features of a component and, thus, respond flexibly to changes in measurement requirements.



(BSE = Back Scattered Electrons, SE = Secondary Electrons, EDS = Energy Dispersive X-ray Spectroscopy)

Fig 17 Examples of multi-sensor implementations in coordinate measuring machines and electron microscopes (Thanks to Imkamp, D & Berthold, J.)

5.6 Big Data Analytics

Data has long been the lifeblood of manufacturing especially precision manufacturing. Companies have used it to increase efficiencies, improve performance and productivity, and reduce waste. With the advent of Industry 4.0, IoT, and smaller, smarter and cheaper sensors, almost every surface has become a sensor for data collection and huge amounts of data are collected. Availability of powerful cloud computing has made the big data collected usable.

Manufacturers are beginning to deploy big data analytics slice and dice data in ways that provide them with a comprehensive understanding of their business. Manufacturer today, want to gain control of the vast amounts of data their company creates and ensure they have access to the right information for productivity improvement and enhanced decision-making.

Fig 18 Different analyses / outputs of Big Data Analytics

6. Adoption of technology by TC and MSME

The following section describes the adoptability of these technologies with respect to CTTC and MSMEs. The adoption of technology is based on interaction with MSMEs belonging to PCC, GEC BBSR and GEC Cuttuck.

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
IIoT	• Wide variety of data can be captured and analysed • Data which was lying unused can now be accessed, analysed and trends/actionable information can be generated to enhance man-machine interactions • IIoT can help achieve a variety of goals including cost reduction increased efficiency, improved safety, meeting compliance requirements, product innovation	**Suitability:** Yes. Many of the machines are already IoT enabled. Retrofitting of sensors to older machines is possible. Organisational maturity for implementing Stages 2, 3 and 4 exists, Detailed technical and financial planning and implementation is required. Remote control of high cycle-time machines like EDM would be possible.	**Suitability:** Basic implementation of stages 1 and 2 can be considered in certain MSMEs <u>which have basic systems in place</u>. Ex. CCTV cameras with outputs accessed and recorded by mobiles / tabs. Would help in periodic analysis of work flow / process flow / activity and efficiency.
		Replicability: High, after pilot is successful.	**Replicability:** Low, because of the cost involved vis-a-vis the scale of operations.
		Scalability: High. IoT readiness can be made a basic requirement for new machines / equipment. After the pilot is successful, retrofitting of sensors to older machines can be taken up.	**Scalability:** Cost/benefit ratio is expected to be high again because of the scale of operations.
		Ease of adoption: Should not be an issue since the organisation has been exhibiting a readiness to	**Ease of adoption:** Very difficult since most of the MSMEs lack basic SOPs and WIs.

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
		embrace new technology and change.	
		Ease of implementation: Not difficult. However, requires focussed effort and appreciation of the benefits.	**Ease of implementation:** Very difficult since most of the MSMEs lack basic SOPs.
PREDICTIVE MAINTENANCE	• Prediction of when equipment would probably fail thereby enabling ability to predict when the optimum time to perform maintenance is. • This saves manufacturers valuable time, money, and resources. • Since monitoring and data collection happens when the equipment is in operation, production loss does not occur.	**Suitability:** Yes. Expensive and high precision machines. Continuously and heavily loaded with high margin orders. Hence high cost of stoppage. Reliable operations and long machine life are critical. High organisational maturity and availability of skilled maintenance personnel and technicians.	**Suitability:** Not at the moment. Maintenance in most of the MSMEs happens only after breakdown. Preventive maintenance in very few cases. Low on the maturity scale.
		Replicability: High, after pilot is successful.	**Replicability:** Low. They need to first move to comprehensive preventive maintenance before considering predictive maintenance.
		Scalability: Good For new machines / equipment inbuilt preventive maintenance signal sensors can be made a basic requirement along with the supporting software / analysis tools. After the pilot is successful,	**Scalability:** Low. They need to first move to comprehensive preventive maintenance before considering predictive maintenance.

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
		possibility of retrofitting sensors to older machines can be considered.	
		Ease of adoption: Should not be an issue since the organisation has been exhibiting a readiness to embrace new technology and change.	**Ease of adoption:** Very difficult since most of the MSMEs lack a comprehensive maintenance plan and also basic SOPs and WIs for the maintenance process.
		Ease of implementation: Not difficult. However, requires focussed effort and appreciation of the benefits.	**Ease of implementation:** Very difficult since most of the MSMEs lack a comprehensive maintenance plan and also basic SOPs and WIs for the maintenance process.
3D PRINTING	• Can produce parts with highly complex shapes and complicated geometries where traditional manufacturing processes would not be feasible or would be very expensive. • Production on demand • Rapid Prototyping for design verification	**Suitability:** Yes. A 3D printer for metal parts is already available. Another 3D printer for composite materials including plastic is being established. Study of demand followed by procurement of latest machines could make this a separate revenue stream. MSMEs could also utilise the facility for prototyping.	**Suitability:** Not suitable at present. The technology appears to be too advanced. The MSMEs can make use of the 3D printers available in CTTC.
		Replicability: High. .	**Replicability:** NA.
		Scalability: High. Specific configuration machines can be added for particular requirements.	Scalability :NA
		Ease of adoption: Should not be an issue since the TC has experience with the technology.	**Ease of adoption:** Very difficult.

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
		Ease of implementation: Should not be difficult in view of earlier experience.	**Ease of implementation:** Very difficult.
AR / VR	• Error-free production • Possibility of remote maintenance • Creating a virtual immersive environment for experiencing and validating from a remote location • Safety issues identification and training • Process steps qualification and validation	**Suitability:** Yes. VR for offline training before OJT and AR for error-free production / assembly and remote machine maintenance are possibilities. New training programs on AR /VR techniques could cater to a niche audience.	**Suitability:** Not suitable at present. The technology appears to be too advanced. .
		Replicability: Has to be considered case by case after the pilot is successful.	**Replicability:** NA.
		Scalability: High based on the success of the pilot.	**Scalability:** NA
		Ease of adoption: Initially challenging. Areas of application need to be identified.	**Ease of adoption:** Very difficult.
		Ease of implementation: Should not be an issue since the installation of hardware/software and training would be provided by the vendor. However, a system needs to be established for the activity.	**Ease of implementation:** Very difficult.
ADVANCED MEASUREMENT TECHNOLOGY	• Measurements will be fast, accurate and reliable	**Suitability:** Yes and is **Important**. TC has two CMMs and both have high load for inspection of precision aerospace components.	**Suitability:** Not at present.

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
		Addition of sensors and automation of multiple inspection processes would speed up the inspection activity.	
		Replicability: High. Pilot on first CMM can be translated to the second one.	**Replicability:** NA.
		Scalability: High. These features can be integrated if a new CMM is to be procured.	**Scalability:** NA
		Ease of adoption: It is a challenging task but should not be an issue since the organisation has been exhibiting a readiness to embrace new technology and change.	**Ease of adoption:** NA
		Ease of implementation: Not difficult. However, requires focussed effort.	**Ease of implementation:** NA
BIG DATA ANALYTICS	• Companies gain control of the vast amounts of data they create each day • Enhanced decision making as they have access to the right information to drive productivity and enhance decision-making	**Suitability:** Not immediately. Suggest that it should follow ERP implementation and stabilisation so that reliable data is looked at as an asset and a source of information for improvement.	**Suitability:** Not immediately.
		Replicability: High, after pilot is successful.	**Replicability:** NA
		Scalability: High, if the correct software is added. Adding data from	**Scalability:** NA

Technology	Advantages	Adoption by CTTC	Adoption by MSMEs
		new machines and analysing the same should be simple.	
		Ease of adoption: Can be a challenge since it would require experts to analyse the data statistically and graphically and present the results in a way understandable to the users. A positive is that the organisation has been exhibiting a readiness to embrace new technology and change.	**Ease of adoption:** NA.
		Ease of implementation: Should not be difficult since the installation of hardware/software and training is provided by the vendor. However, a system needs to be established for the activity.	**Ease of implementation:** NA

For further information, please connect with:

Vivek Agarwal

Partner– Infrastructure, Government and Healthcare (IGH)
KPMG in India
T: +91 98117 05760
E: vivekagarwal1@kpmg.com

Punita Bansal

Associate Director – Infrastructure, Government and Healthcare (IGH)
KPMG in India
T: +91 9910009401
E: punitabansal@kpmg.com