## Industry 4.0 Awareness Seminars Reports Template

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Date of the Seminar</td>
<td>21 June 2019</td>
</tr>
<tr>
<td>2.</td>
<td>Organizers</td>
<td>CII and CMTI</td>
</tr>
<tr>
<td>3.</td>
<td>Title of the seminar</td>
<td>Awareness Programme on Smart Manufacturing and Industry 4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The Indian Perspective</td>
</tr>
<tr>
<td>4.</td>
<td>Programme</td>
<td>Annexure 1</td>
</tr>
<tr>
<td>5.</td>
<td>Report: suggested contents</td>
<td><strong>Main takeaway / good suggestions</strong></td>
</tr>
<tr>
<td></td>
<td>( 1 ) Main takeaway / good suggestions</td>
<td>• Information on Smart Sensors and controllers, smart machines &amp; intelligent machining</td>
</tr>
<tr>
<td></td>
<td>( 2 ) Clusters covered - Coimbatore</td>
<td>• Learning importance of machine accuracy</td>
</tr>
<tr>
<td></td>
<td>( 3 ) Nos attended - 75</td>
<td>• Understanding of big data and cloud computing</td>
</tr>
<tr>
<td></td>
<td>( 4 ) Success stories that need to be compiled / shared – PPT on Smart Sensors &amp; Controllers</td>
<td>• Industry &amp; Research institutes are way to behind in technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Detailed study is required before implementing smart</td>
</tr>
<tr>
<td>6.</td>
<td>List of Speakers with contact details</td>
<td>Annexure 2</td>
</tr>
<tr>
<td>7.</td>
<td>Presentations</td>
<td>Annexure 4</td>
</tr>
<tr>
<td>8.</td>
<td>Resource persons for providing consultancy, skilling, guidance etc.</td>
<td><strong>Prof Dr P Radhakrishnan, Director</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nanotech Research Facility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSG Institute of Advanced Studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Mr V S Shanmugaraj</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scientist - F &amp; Head SVT</td>
</tr>
<tr>
<td>9.</td>
<td>Photographs</td>
<td>Annexure 3</td>
</tr>
<tr>
<td>10.</td>
<td>Learnings from the seminar</td>
<td>Audience wanted more case studies rather than theoretical presentations</td>
</tr>
</tbody>
</table>
**Awareness Programme on Smart Manufacturing and Industry 4.0  
*The Indian Perspective***

*Date:* 21 June 2019  
*Time:* 1500 – 1905 hrs  
*Venue:* Hotel The Residency Towers, Coimbatore, Tamil Nadu

**PROGRAMME**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Speaker/Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500 – 1515 hrs</td>
<td>Registration</td>
<td></td>
</tr>
</tbody>
</table>
| 1515 – 1530 hrs | Welcome Remarks and context setting                | Dr N Balashanmugam  
Joint Director  
Central Manufacturing Technology Institute |
| 1530 – 1540 hrs | Address by                                         | Prof Mohan  
Emeritus Professor  
IISc                                                       |
| 1540 – 1550 hrs | Address by                                         | Prof Dr P Radhakrishnan, Director  
Nanotech Research Facility  
PSG Institute of Advanced Studies |
| 1550 – 1600 hrs | Special Address by Chief Guest                     | Mr M Ramesh  
Past Chairman, CII Coimbatore Zone &  
Managing Director  
Alphacraft Pvt Ltd |
| 1600 – 1610 hrs | Tea Break                                          |                                                          |
| 1610 – 1640 hrs | Connecting Man and Machine for Smart Factory       | Dr. Kaustubh Nande  
Director Marketing  
MSC Software Corporation, Hexagon Group |
| 1640 – 1710 hrs | Smart Machines & Intelligent Machining             | Mr Prakash Vinod  
Scientist - F & Head  
NMTC |

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**Annexure 1**

[Logo: Confederation of Indian Industry]  
[Logo: Department of Heavy Industry Government of India]  
[Logo: Central Manufacturing Technology Institute]
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1710 - 1740 hrs</td>
<td>Smart Sensors &amp; Controllers</td>
<td>Mr V S Shanmugaraj&lt;br&gt;Scientist - F &amp; Head&lt;br&gt;SVT</td>
</tr>
<tr>
<td>1740 – 1810 hrs</td>
<td>Smart precision metrology</td>
<td>Mr K Niranjan Reddy&lt;br&gt;Scientist - E &amp; Head&lt;br&gt;UPE</td>
</tr>
<tr>
<td>1810 – 1840 hrs</td>
<td>CMTI Technologies &amp; Technology Transfer Modalities</td>
<td>Dr N Balashanmugam&lt;br&gt;Joint Director&lt;br&gt;Central Manufacturing Technology Institute</td>
</tr>
<tr>
<td>1840 – 1900 hrs</td>
<td>Q &amp; A</td>
<td></td>
</tr>
<tr>
<td>1900 – 1905 hrs</td>
<td>Summing Up</td>
<td></td>
</tr>
<tr>
<td>1905 hrs</td>
<td>Dinner</td>
<td></td>
</tr>
</tbody>
</table>
**Annexure 2**

**Speaker Details**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Name</th>
<th>Designation</th>
<th>Company Name</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Mr M Ramesh</td>
<td>Past Chairman, CII Coimbatore Zone &amp; Managing Director</td>
<td>Alphacraft Pvt Ltd</td>
<td>9843018651</td>
<td><a href="mailto:ramesh@alphcraft.in">ramesh@alphcraft.in</a></td>
</tr>
<tr>
<td>2.</td>
<td>Dr N Balashanmugam</td>
<td>Joint Director</td>
<td>CMTI</td>
<td>9449842676</td>
<td>balashanmugam@<a href="mailto:cmti@nic.in">cmti@nic.in</a></td>
</tr>
<tr>
<td>3.</td>
<td>Mr V S Shanmugaraj</td>
<td>Scientist - F &amp; Head</td>
<td>CMTI</td>
<td>9449842688</td>
<td><a href="mailto:shanmugaraj.cmti@nic.in">shanmugaraj.cmti@nic.in</a></td>
</tr>
<tr>
<td>4.</td>
<td>Prof Mohan</td>
<td>Emeritus Professor</td>
<td>IISC</td>
<td>91-80-2293 3291</td>
<td><a href="mailto:smohan46@yahoo.co.in">smohan46@yahoo.co.in</a></td>
</tr>
<tr>
<td>5.</td>
<td>Dr. Kaustubh Nande</td>
<td>Director Marketing</td>
<td>MSC Software Corporation, Hexagon Group</td>
<td>9742236532</td>
<td><a href="mailto:kaustubh.nande@mscsoftware.com">kaustubh.nande@mscsoftware.com</a></td>
</tr>
<tr>
<td>6.</td>
<td>Mr Prakash Vinod</td>
<td>Scientist - F &amp; Head</td>
<td>NMTC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Prof Dr P Radhakrishnan</td>
<td>Director</td>
<td>PSG Institute of Advanced Studies</td>
<td>91-4224344000</td>
<td><a href="mailto:director@psgias.ac.in">director@psgias.ac.in</a></td>
</tr>
<tr>
<td>8.</td>
<td>Mr K Niranjan Reddy</td>
<td>Scientist - E &amp; Head</td>
<td>UPE</td>
<td>9449842672</td>
<td><a href="mailto:niranjan.cmti@nic.in">niranjan.cmti@nic.in</a></td>
</tr>
</tbody>
</table>
Annexure 3

Photo gallery
Presentations
CMTI Technologies & Modalities for Technology Transfer

By
Dr. N.Balashanmugam
Joint Director, CMTI, Bangalore
Germanium and silicon for IR optics, Night Vision, Thermography System

Metal Mirrors for Space & Astronomical Systems
Ophthalmic, Intro-ocular & Contact lenses for Medical Sectors

Contact Lenses

Polymer optics for Ophthalmic

IOL Lens

Ultra Precision Mechanical Components

Air Bearing elements.
Hydrostatic & Hydrodynamic Bearing Elements.
High Precision Mechanical Elements.
Ultra Stiff Ultra Precision Diamond Turning Machine

Salient Features:

- High Stiff Hydrostatic Oil Bearing Slides
- Ultra Precise Aerostatic Spindle
- Natural Granite Bed with Vibration Isolation System and active leveling
- Max Workpiece: Dia 250 mm, Lg: 150mm

Ra: 2nm
Form Accuracy: <0.2 µm
Ultra Stiff Ultra Precision Diamond Turning Machine

Ra: 2nm
Form Accuracy: <0.2 µm
How to Finish Intricate Components?
Salient Features:
- Super finish / deburr ID and OD of components
- Radiusing of sharp edges
- Finishes inaccessible areas & complex internal passages
- Temperature control of abrasive laden polymer media
- Simultaneous processing of multiple passages

Applications:
- Micro/Nano finishing,
- Radiusing
- Deburring

Max. Height of the Component: 250mm
Abrasive Flow Finishing Machine

Centre tube for filter element
Abrasive Flow Finishing Machine

Shuttle valve for Aircraft landing gear actuator
Mass - IH: Projection Microstereolithography (PµSL) System

Sūkshm3D.
Micro rapid prototyping

PMSL SYSTEM DEVELOPED BY CMTI
Mass IH Process - Projection Micro Stereo Lithography

- polymers
- responsive hydrogels
- shape memory polymer
- functional particles

digital microdisplay

UV lamp

projection lens

digital images

polymer resin

3D micro structure
Sukshm 3D Micro fabrication system

Salient Features:

- It enables complex 3D ultra fine solids to be made in a short time by means of spatial light modulation technique.
- A UV-curable resin on is cured at a super-precision resolution by a high-precision digital light exposure mechanism.
- 3-D structures are created by the layer-by-layer forming method, under which 3-D ultra-fine solids are formed automatically by repeated light exposure and resin coating.
- Ultra-fine Features down to 10um level can be fabricated
- Layer thickness can be optimized to 5um level so that staircase effect can be eliminated with continuous exposer of UV projection

Applications:
- Polymer based 3D Microfabrication for various applications in MEMS, Jewellery, Biomedical industries.
- Fabrication of complex 3D Micro components
- MEMS sensors, actuators, and micro bellows
- Micro fluidic channels and micro fluidic devices
- Bio medical Implants like coronary stents & scaffolds
- Micro moulds and lenses for optics industry
- Micro mixers and micro pumps
Fabrication of Complex 3D Micro Components

Micro Rotor - Compressor

Micro Sensor Component

Micro Turbine

Micro Spring
Fabrication of Microneedle Electrodes

Microneedle Array Based Biopotential Electrodes

developed at CMTI

Micro Needle Electrodes for Biopotential Acquisition

Micro Needle Electrodes for Painless Drug Delivery
Despite the development and progression of metallic stents, many concerns still remain because of their permanent nature. Thus, the concept of bio absorbable stents has emerged as an alternative to permanent metal stents.

“The dream has always been to find a temporary solution for a temporary problem, giving blood vessels a chance to bounce back to their natural state”.

Ref: http://emag.medicalexpo.com/article-long/8671/
Microstereolithography (PμSL) technology can fabricate three-dimensional (3D) tissue engineered scaffolds with controlled biochemical and mechanical microarchitectures.
Ceramic MSL

- Alumina 75% by weight mixed with Polymer (HDDA)
- 3D parts made by MSL
- Polymer melted away by heating
- Green ceramic part is sintered at 1600 deg C
- Shrinkage is about 20%
- Scattering of radiation by ceramics is also an issue
- Curing depth and width gets reduced due to scattering

Ceramic Micro Parts

Issues: Scattering, Shrinkage, high viscosity

Thread Measurement System

**Salient Features:**

- Non-contact method of external thread measurement to check for dimensional tolerances.
- High speed thread
- Can be used for automating in manufacturing lines.
- User friendly thread measurement system requiring minimum human intervention.
- Records measurement results for statistical analysis.

- Measurement Range: Upto 30mm
- Measurement Accuracy: +/- 10 µm
GUI of the System displaying the measurement of a thread gauge
3D SCANNER

Salient Features:

• Short measuring times.
• Actual and nominal comparison with CAD data.
• Portable as it can be mounted on a tripod/robot.
• Automated registration using rotary table and markers.

Applications

• Dimensional measurements
• Reverse Engineering
• Automated Inspection Tasks

• Measurement Area: 267*205*150 mm³
• Accuracy: 150 µm
• Fastest Measurement Time: 4 secs
3D Scanner - Point cloud captured

(a) Tyre Mold  
(b) Lower human jaw bone model  
(c) Turbine  
(d) A small locating component  
(e) Lattice Mirror Housing
ULTRA STIFF ULTRA PRECISION HYDROSTATIC SLIDE

Salient Features:
• Hydrostatic oil Bearing gives infinite life
• True motion, zero stick-slip, zero backlash & Maximum positioning accuracy
• High stiffness for Heavy loads & excellent geometric performance
• High Dampening effect from oil film for vibration from machining process
• Direct drive with Integrated Linear motor with low cogging force
• Ultra precision Linear Glass Scale for position feedback

Applications:
• Ideally suited for development of Ultra Precision Machines

Nano Slide way HS 200

Model & Type
HS 200; Fully constrained oil hydrostatic, box way slide

Travel
200 mm (8 Inch)

Load Capacity & Stiffness
1000Kg (10,000 N)
1000N/µm

Drive System
Brushless DC Linear Motor

Feedback Resolution
32 picometer

Straightness
Horizontal : 0.2 µm over full travel
Vertical : 0.4 µm over full travel
Thermal Error Compensation for Machine Tool Applications

Machine tool thermal distortion can account for 75% of the total machining error.

Salient Features:
• RTD based Temperature Sensors
• Recursive Neural Network based Algorithm
• CNC Interface module
• Real Time Compensation
• Upto 80% error compensation contributed by thermal distortion
• Low Cost solution
• Can work with all general purpose CNC controllers
Machine Health Management System (MHMS)- Machine Fault Diagnostic Module

**Salient Features:**

- *Machine tool vibration measurement*
- *Data acquisition through MEMS Accelerometer*
- *Signal Conditioning and Analysis*
- *Fault diagnosis for Unbalance, Misalignment, Mechanical looseness and Bearing faults*
- *Fault display on LCD Display Screen*
Maximum / Minimum work-piece dia: 150 mm / 8.5 mm

Centerless Grinding Machine
GN 3050

Facing and Taper Boring Machine (FTB -320)
(Ø2m to Ø3.2m)

For Facing & horizontal bores of Ø675mm & Length of 1100mm

Line Boring Machine (LBM)

Finish Turning Machine

Key Stone Piston Ring Grinding Machine (GKPR)

Sphere Lapping Attachment for CNC Lathe
Modalities for Technology Transfer

- Calling for Expression of interest
- Conducting Pre application conference
- Inviting Request for Qualification {Direct or through e-tendering (forward auction)}
- Evaluating Requests and selection of firms
Modalities for Technology Transfer

- Technology transfer is done on non-exclusive basis
- In certain cases, Technology Transfer is done on exclusive basis with lock in period
- License fee is different for both
Modalities for Technology Transfer

Technology transfer involves:
- Licence fee
- Royalty
What do we offer?

- Blueprint of drawings
- Bill of Materials
- Technological process for critical parts
- Bought out items
- Vendor’s list
- Testing Protocols
- Machineries and Infrastructure required
- Data base of process receipe
- Hand holding
Looking forward to have our Technologies in your factories

Thank You
Connecting Man an Machine for Smart Factory

Dr. Kaustubh Nande
Director – Marketing
MSC Software Indo-Pacific
June 2019
Global leader in **sensor**, **software**, and **autonomous** technologies committed to

**empowering an autonomous future**
Leading a revolution
From automation to autonomy

Autonomy is the ultimate form of putting data to work

Efficiency  Automation  Autonomy

Industry 1.0----------------------------------------Industry 4.0

MECHANISATION  MASS PRODUCTION  AUTOMATED PROCESSES  HYPER-CONNECTIVITY
The road to autonomy
Our core capabilities
Smart Factories

that learn and adapt quickly to changing conditions in real time, pursuing perfect quality with optimised design, requiring fewer inputs and producing zero waste.

Did you know?

Each year, Hexagon technology touches:

- 75% of cars produced
- 90% of aircraft produced
- 85% of smart phones produced

We have expertise in and connect all stages of the manufacturing lifecycle:

- **DESIGN AND ENGINEERING (CAE)**
  - Optimise designs and ensure manufacturability
- **PRODUCTION (CAD/CAM)**
  - Deliver on design intent and product quality with minimal waste
- **METROLOGY HARDWARE/SOFTWARE**
  - Capture real-world data for positioning and inspection

SUSTAINABLE VALUE CREATION
- Fewer inputs
- Zero waste
- Perfect quality

PRIMARY APPLICATIONS
- Automotive
- Aerospace
- Electronics
- Medical
- Heavy industry
- Power & energy
The Hexagon Digital Thread: Design to Manufacturing to Quality
Ecosystem for Smarter Manufacturing
Industrial Metrology Applications: World Leader in Quality Measurement
Production Software: World’s #1 CAM provider

- CADCAM to address metal, sheet metal and woodworking industries
- MES for die/mold processes, small scale ERP tools, machine simulation technologies
- Direct offices in 13 countries, development teams in 7 countries, 700+ employees, 140 resellers in 45 countries
- Strong relationships with all the largest machine tools OEMs
• **Presence in 23** Countries
• R&D in **10** Countries
• **90% of top 1000** manufacturing co.s use MSC Solutions
• Part of the US$ 4.5B Hexagon AB
Associated with India since 1983
MSC’s Virtual Factory Ecosystem

- Casting
  Interface to leading third party products
- Metal Forming
- Machining
- Joining & Assembling
- Coating
- Changing Material Properties
- Additive Manufacturing

- Sheet Metal Forming
- Bulk Metal Forming
- Welding / RSP
- Mechanical Joining
- Heat Treatment, Carburization
- Additive Manufacturing
Challenges faced by Manufacturing Industry

Connected Plant Floor to Improve Operational Efficiency
Manufacturers are missing out on a critical opportunity: Leveraging real-time data on cycle times, quality yields by machines, production run, utilization and other metrics to improve Operational Efficiency of the plant.

Preventive maintenance without affecting throughput
Keeping equipment functioning is an essential part of running a manufacturing facility. By collecting real-time data, and comparing with failure scenarios, it is possible to predict the appropriate time frames that the machines in the factory should be maintained.

Connected Quality for Final Inspection
Process of quality assurance, quality control, and QC inspections need to be optimized to increase productivity and lower costs

Better supply chain visibility
It is essential to integrate all the business applications including ERP, CRM, PLM with MES systems for a better visibility of supply chain

Customer-facing self-service applications
An organization’s customers typically consist of end-customers, partners (or service providers), and sub-contractors, or any combination of these. These customers have different needs, concerns and requirements for working with and interacting with manufacturers.

References
10 greatest Manufacturing Challenges for CIOs
Top five challenges facing Manufacturing Industry
Six challenges facing Modern Manufacturing Companies
DATA CREATION

DAWN OF TIME  PRINTING PRESS  INTERNET  IoT

DATA USAGE

INTERNET OF THINGS
Introducing Xalt

One of our major R&D initiatives is a technology framework called Xalt, which will eventually underpin all of our solutions – making them faster, easier to use, more connected, and autonomously intelligent.

Xalt framework:
- Artificial intelligence
- Edge computing
- Mobility
- Advanced visualisation
- Enterprise integration
Autonomous Connected Ecosystems with

SENSORS

VIRTUALIZATION

PROCESS FEEDBACK

STREAMING

SENSOR & DATA FUSION

PATTERNS

EXTRACTION

PROCESS MODELS / OUTPUT

MODELS / INPUT

EDGE

MOBILITY

AI

5G

Cyber-security / Blockchain

VIZ

ENTERPRISE VIZUALIZATION

VIRTUALIZATION

STREAMING

UI / UX AI powered CLOUD

DIGITAL SIMULATION

SOFTWARE

GUIDE

OUTPUT

TECHNOLOGY

INPUT
Digital Transformation with Xalt

Infinite Connectivity for Disconnected Data

CLOUD ENABLEMENT
Connecting B2B with an orchestrated microservice framework and cloud analytics for big, fast data.

EDGE CONNECTIVITY
Processes, combines, and analyses IoT and sensor data at the edge of the network and puts it to work with AI.

ENTERPRISE INTEGRATION
Plug-in enterprise integration for legacy connections, databases, and IT systems, equipped with middleware for messaging, file, system, and database connectivity and transformation.

MOBILITY
Secure and nimble framework that is native iOS- and Android-ready with zero client footprint and network-optimized for visualization of multiple georeferenced 3D & 2D data sets

UBIQUITOUS A.I.
Multiple AI data sources including imagery, video, and big data for applications such as predictive maintenance, change, and anomaly detection.

VISUALIZATION
Visualizes 2D/3D data, including point clouds, and is optimized for all mainstream OS, mobile, and web platforms. Augmented reality applications are validated on HoloLens, Daqri, and Oculus, and can process enormous datasets at high speeds.

Security without Rigidity: Xalt is HIPAA and PCI-compliant, is SOC2 certified, and has passed the United States Department of Defense regulatory process.
Addressing the Complex Real-life Challenges in Manufacturing – not just Connectivity

THE BIG DATA DISCONNECT
Organizations have limited visibility to at-source data

QUALITY / COST INVERSION
Produce more at higher quality; deliver it faster at lower costs

4.0 MODELS & MARKETS
Lost revenue due to untapped, data-driven models and channels

PROCESS OPTIMIZATION
Real-time logistics, line uptimes, edge analytics of machinery

SMART QUALITY ASSURANCE
Real-time updates and alerts for on-premises, cloud, and sensor assets

CONNECTED WORKERS
Real-time mobile access to consolidated data (sensors, alerts, and workflows)
Why it’s Different

Leverage Your Existing OS

OPEN CONNECTORS

INTEGRATION

SMART WORKFLOWS

LOW/NO-CODE IMPLEMENTATION

FLEXIBLE DEPLOYMENT

DATA ACCESSIBILITY
Smart Factory: Areas of Focus

ASSETS

PROCESS

TOOLING & ASSEMBLY

DATA FLOW

SUPPLY CHAIN

OPERATIONS
Connected Worker
Innovating Work in the Field
Connected Worker Solutions

AUTOMATED MAINTENANCE + SERVICE WORK-ORDERS

ACCURATE TIME PLANNING + PRIORITY ESCALATIONS

TOOL + EQUIPMENT TRACKING

SUPPLY + INVENTORY LOOK-UP AND REQUISITIONS
Smart Factory
Sensor Fusion with User Enablement
# Smart Factory

## MANUFACTURING

<table>
<thead>
<tr>
<th>TRANSPORTATION</th>
<th>METAL + MACHINERY</th>
</tr>
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<tbody>
<tr>
<td>Body + Finished Good MFG</td>
<td>Packaging Machinery</td>
</tr>
<tr>
<td>- Motor Vehicle + Truck</td>
<td>- Door + Window</td>
</tr>
<tr>
<td>- Heavy Duty Vehicle</td>
<td>- Elevator + Convey</td>
</tr>
<tr>
<td>- Specialty Vehicle</td>
<td>- Material Handling</td>
</tr>
<tr>
<td>- Aerospace</td>
<td>- HVAC +Industrial Refrigeration</td>
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</table>

## PLANT OPERATIONS

<table>
<thead>
<tr>
<th>ELECTRICAL</th>
<th>MECHANICAL</th>
<th>UTILITY SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Contracting Of:</td>
<td>Installation Of:</td>
<td>Construction Of:</td>
</tr>
<tr>
<td>- Electrical Site Prep</td>
<td>- HVAC System</td>
<td>- Oil + Gas Pipelines</td>
</tr>
<tr>
<td>- Commercial Bldgs</td>
<td>- Plumbing + Piping</td>
<td>- Power + Comm. Lines</td>
</tr>
<tr>
<td>- Electrical Finishing</td>
<td>- Drywall + Structural</td>
<td>- Water + Sewage Systems</td>
</tr>
<tr>
<td>- 100 Employees+</td>
<td>- Elevator+Equipment</td>
<td></td>
</tr>
</tbody>
</table>

## Quality Inspections

- Inspection Plans
- Times Tests
- Shared File Specs
- Rework WOs
- Production to Delivery Tracking

## Field Service Suite

- Workorder Mgmt
- Time Allocation
- Supply Reqs
- Inventory
- Mileage Tracking

## Maintenance

- Workorder Mgmt
- Time Allocation
- Supply Reqs
- Inventory
- Emergent Alerting

## Time Planning

- Jobsite HR
- Timesheets
- Payrate plan
- Project time
- Budgeting

## Material Requisitions

- Inventory
- prefab Reqs
- Equipment Rentals
- Supplier Orders

## Tool Tracking

- Asset Mgmt: Tools
- Equipment
- Rentals
- Maintenance Schedules

## Project Reporting + Analysis

- Job Status
- Daily Site Reporting
- Project Budget
- Deadline Tracking

---

*Confidential*
1. Confirm power source installed, secured, and available for testing.

3D visualisation allows workers to lay piping and instrumentation diagram data over built structures.
**Xalt Framework**

- **Massive Streamed Data Sets**
- **Cloud Orchestration**
- **Big Data**

**Hexagon Devices & Applications**

- **Data Acquisition**
  - Temperature
  - Geolocation
  - Metrics
  - Notification
  - Status

- **Edge Orchestration**

- **Connector Gateway**
  - SQL
  - SAP
  - Web Services
  - Other

- **iOS, Android, Browser, Hexagon Devices & Applications, Apps, Visualisation and Data Acquisition**
Connections to Business Applications

- CRM
- ERP
- SCM
- HR
- Mfg.
- PLM
- Others..
Xalt | Integration provides interfaces to connect multiple software applications and a highly configurable no-code business rules engine to solve enterprise-level integration challenges.

It’s the glue that holds solutions together
Asset Management

Minimize Downtime. Maximize Efficiency.

- System Health
- Asset Utilization Charting
- Facility Environment Tracking
- "OEE"
- System Notifications
- HMI Service Connection
Factory Monitoring and Load Balancing

Scope
- Manage and see Assets in Smartphones
- Receive Notifications on CMM Started, Busy, Idle, Crash, Error
- Master complexity of setups in OEM environment
- Autodiscover assets
- Manage loads based on availability
Towards Predictive Maintenance

SQ Health Concept

Stepwise approach:

• **Step 1**: Rules-based notifications on pre-defined thresholds

• **Step 2**: Condition monitoring on parameters based on statistical methods

• **Step 3**: Predictive maintenance with ML algorithms trained on historical telemetry (machine, environment), failure/service events and process data
Data-Driven Customer Intelligence

- Observer logs usage data of different devices
- Mine this data for Business Insights
- Leverage AC’s Advanced Analytics Platform SIMPALA
  - Usage Analytics module available
  - State-of-the-art data mining and machine learning tools

1) Detect Clusters
2) Map to Personas
3) Understanding and Decision Making
In-Plant Logistics, Monitoring and Detection
Logistics Management

Physical Raw Material Flow

- Tractors & Implements
- Harvester Machines
- Trucks & Tranships
- Industry

Real Time Management

- Managerial Dashboards
- Monitoring Control
- Routing & Tracking
- Warning & Notifications
- Process Optimization

3G/4G WiFi

T7/5 Board Computer

- Operation monitoring
- Telemetry record
- Workflow automation
- onBoard Navigation
- Auto steering
- Precision agriculture
- Remote support/update

Cloud Servers

- AgrOn Platform
- IoT Services
- Optimization Server
- Edge Frontier Server

Legacy Systems

Control Room

Managerial Dashboards
Monitoring Control
Routing & Tracking
Warning & Notifications
Process Optimization

AgrOn Platform
IoT Services
Optimization Server
Edge Frontier Server

Legacy Systems
Integrated Real-time Sales & Operations Dashboard

Infor LX

Read Only Access

XALT API GATEWAY

XALT CONNECTORS

AUX Database

QUOTA

Financial Admin

CLOUD API

SSL

salesforce

Financial Admin

Infor LX

Xalt

Xalt

Xalt
Hexagon Digital Thread from Design to Production to Quality

- Function and manufacturing driven design
- Virtual manufacturing (engineering)
- Preparation for printing/process planning (CAM)
- Tactile and optical measurement, inline inspection, Ct scan
- Fixed and mobile 3D measurement for reverse engineering
- Material data management
  - Test data, Virtual data, Production data
- Process data management and analytics
Capturing the End to End Additive Manufacturing Process Chain

Design space-Model
Topology-optimization
Active bonnet-function
Supporting structure optimization
Distortion and residual stress optimization
Manufacture LAM
Testing
Smart Factory Solutions APAC Concept

**Design**
- CAD
- Computer Aided Engineering (CAE)

**Programming**
- AM/CAM
- MSC
- NCSIMUL

**Production**
- CNC
- CMM, Arms, Laser Trackers, AICON, Tesa, WLS, Vision, Calipri

**Metrology**
- SMART QUALITY
- NC Gage, 3D Form, PC DMIS, NC
- "Real-time" data, "LIVE" monitoring & alert, statistical analysis & report

**Data Analysis**
- SFx Asset Management, Pulse, NC Simul Monitor
- Equipment & Environmental Status

**Simulation**
- SIMULATION
  - I++ SIM
  - PC DMIS, Quindos, Inspire, SpatialAnalyzer, METUS

**IMPROVE DESIGN**
- Work Order with QR Code
- SCAN

**Equipment & Environmental Status**
Hexagon Demo Centre Layout - WIP

- Arms
- Vision
- Tesa Equipment (Height Gauge, bluetooth micrometers & calipers)
- TV screen (for SA & Inspire)

6 x TVs for SF Dashboard

Prod Software | Assets Mgt / Pulse | SimuFact / F&G
NC SIMUL | Q-DAS / eMMA | NC Gage / 3D Form

Workstation with QR Code Reader & Handphone

- Laser-Tracker,
- AICON Stereoscan Neo
- Calipri

- 2 x “to-be-assembled” parts
- 1 x Assembled part (for Flush & Gap and welding analysis)
- Complex Part
Conclusion: Completing the Digital Thread with Optimized Design and Processes
Thank you.
Precision and Smart Metrology

K. Niranjan Reddy
Scientist - E & Head – UPE
CMTI, Bangalore.
If you measure

“Do it with Utmost Care”

and

“Remember the Measuring Errors”

- Anonymous
The Science of Precision Measurement

“METRO” & “LOGY” are Greek Words

Meaning

“Measurement” and “Science”

Respectively
Metrology Started in Ancient Egypt in 2750 BC

First Unit of Length Was Cubit

Cubit - Length of the Reigning Pharaoh’s Forearm
• Started in 1775 with Wilkinson machining a \( \phi 1800 \) mm bore to 1 mm accuracy

• Today conventional precision machining is being carried out to dimensional accuracies of 1 \( \mu m \) on 100 mm length
Dimensional Accuracies since 1900

Accuracy in microns

IT Grades

Year

Central Manufacturing Technology Institute   |   www.cmti-india.net
What is 1 μm

1nm = 1/1000 μm

Human hair φ 50 μm
What is 1 arc sec

1 arc sec

10 meters

Human hair \( \phi \ 50 \ \mu m \)
The Goal of Metrology

- **Accept good products**
- **Reject bad products**
- **Better to reject few good ones than to accept a few bad ones**
Classification of Metrology

- Dimensional Metrology
- Surface Metrology
- Co-Ordinate Metrology
- Mass Metrology
- Force Metrology

and So on .....
BASIC TERMINOLOGIES
Basic Terminologies

RESOLUTION (of a displaying device)

Smallest value that can be indicated by the displaying device.

or

Smallest difference between indications of a displaying device that can be meaningfully distinguished.
**ACCURACY**

Closeness of agreement between the result of measurement and the true value of the measurand.

**PRECISION**

Closeness of agreement between the results of successive measurements of the same value of a quantity carried out under identical conditions at short intervals of time.

(Precision is also called Repeatability)
Graphic Distinction Between Accuracy and Precision

- Precise but not Accurate
- Accurate but not Precise
- Precise and Accurate
**REPRODUCIBILITY**

Closeness of agreement between corrected results of measurements of the same value of a quantity when the measurements are made under different conditions.

**RELIABILITY**

The ability of an item to perform a required function under stated conditions for a stated period of time.
TRACEABILITY

The concept of establishing valid calibration of a measuring standard or instrument by step-by-step comparison with better standards up to an accepted national or international standard.
Material measure or physical property which defines or reproduces the unit of measurement of a base or derived quantity.
Types of Measurement Standard

- **FUNDAMENTAL OR ABSOLUTE STANDARD**
- **INTERNATIONAL STANDARD**
- **NATIONAL OR PRIMARY STANDARD**
- **REFERENCE STANDARD**
- **SECONDARY STANDARD**
- **WORKING OR STANDARD**
<table>
<thead>
<tr>
<th>Hierarchy of Traceability</th>
</tr>
</thead>
</table>
| **Primary Standard of Length (Metre)**  
  Established by Interferometry |
| **Secondary Standard of Length**  
  Verified by Interferometry |
| **Grade “00” Slip gauges Calibration Grade**  
  Verified by Interferometry |
| **Grade “0” & “1” Slip gauges**  
  Verified by high magnification comparator |
| **Grade “2” Slip gauges**  
  Verified by high magnification comparator |
| **Work piece**  
  Verified by suitable gauging practice |

The metre is defined as the length of the path travelled by light in a vacuum in \( \frac{1}{299.792.458} \) second.
Length Traceability at CMTI

1. SI Unit ‘Metre’
   - NPL - India
     - Grade ‘K’ Slip gauges Reference Standard
       - Grade ‘K’ Slip gauges Sec Standard
       - Grade ‘K’ & ‘0’ Slip gauges
   - Mahr (DAKKS) - Germany
     - Grade ‘K’ Slip gauges (Special set for GBC) Reference Standard
     - Gauge Block Comparator
     - Grade ‘0’ Slip gauges Sec Standard
     - Grade ‘1’ & ‘2’ Slip gauges
   - DKD (DAKKS) - Germany
     - Step Gauge Reference Standard
     - Step Gauge Secondary Standard
     - Step Gauge / Caliper Checker / Check Master
   - Metrology Equipment/ Machine Tools
Factors affecting the Accuracy of Measurements

- Factors affecting the Standard
- Factors affecting the Work-piece
- Factors affecting the Measuring Instruments
- Factors affecting the Person
- Factors affecting the Environment
Factors affecting the Accuracy of Measurements

Environmental Effects:

- Room Temperature
- Part Temperature Stabilization
- Temperature Variation
- Humidity
- Vibration Level
- Dust Level
- Air Flow
- Lighting
NABL Accredited Dimensional Metrology Lab

Lab conforms to ISO/ IEC 17025:2005

Measurement of Dimension, Form, Surface Texture and Gear Parameters

“India’s one of the kind metrology lab that is housed 6m below ground”
Dimensional Metrology at CMTI

Ultra Precision Co-ordinate Measuring Machine

Gauge Block Interferometer

Co-ordinate Measuring Machine
Surface Metrology at CMTI

Form profiler

Roughness Tester

Flatness interferometer

Optical Profiler
Trends of Accuracy/ Uncertainty in Length Measurement

Increasing Tolerance Requirements

Large Parts with high Requirements’
(e.g. Drive Components of Wind Energy Systems)

Coordinate-Measuring Machines

Theodolite, Lasertracker, Laserradar
Multilateration

Increasing Miniaturization/
Micro metrology

“Measuring Length“

“Measuring Uncertainty“
Current Status: In the country most of these artefacts (>90%) are being imported
High Precision Optical Standard Glass Scales

**Technical Data**

Graduation Pitch : 0.1 mm
Graduation thickness : 12 µm
Grating Accuracy : < 2 µm

<table>
<thead>
<tr>
<th>Range</th>
<th>L</th>
<th>W</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-150 mm</td>
<td>175 mm</td>
<td>20 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>0-10 mm</td>
<td>75 mm</td>
<td>20 mm</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

In-house facility used:
1. Femtosecond laser micromachining system
2. Confocal Microscope
3. Ultra Precision CMM

Angular Standard Glass Scale

**Technical Data**

Graduation Pitch : 1°
Graduation thickness : 4 µm
Grating Accuracy : < 2 µm
Transformative Forces Reshaping the Future of Metrology

Future of Metrology

- Augmented Reality
- Simulation
- Industrial Internet
- Enterprise Integration
- Inline Inspection
- Cyber Security
- Additive Manufacturing
- Big Data
The need for Smart Metrology

Correct Decisions

Reliable Information

Reliable Data

Smart metrology

Zero-defect products
Smart Metrology Challenges

**Product flow**
- Measurement time
- Accessibility of features
- Motion and handling

**Environment**
- Temperature
- Humidity
- Vibrations, contamination

**Diversity**
- Multiple features per product
- Variation between products

**Data handling**
- Task-specific uncertainty,
- Numerical accuracy and Data integrity
- Data fusion from multiple sensors
Factors to consider in adapting Smart Metrology
Inline Metrology—Market Size and Forecasts

Speed, accuracy, and flexibility are key attributes that enable optical scanners to replace traditional CMMs.

Global Inline Metrology Market Revenue by Key Technologies: 2014 and 2020

- CMMs: CAGR = 4.8%
- Optical Metrology: CAGR = 11.0%

2014
2020
Mega Shifts

- Dedicated Fixtures
- Modular Fixtures
- Laboratory Inspection
- Inline Inspection

New Mega Shifts

Increased Penetration of Optical Metrology
Smart Metrology Lab

- Manual Inspection Data
- CMM Data
- Wireless Measuring Instruments Data
- Cloud / Server
- Auto Ballooning
- Inspection Reports
- Quality Control
Smart Metrology Lab

Smart Inspection
- Automatic generation of Inspection Data sheet
- Wireless exchange of inspection data

Smart Data Management
- Integration across
  - Inline
  - Manual
  - CMM Inspection
- Real Time Data Visualisation

Smart Quality Management
- Improved Traceability
- Statistical Process control data (Cp,Cpk)
- Customized Inspection reports
Smart Inspection

Smart Inspection Facility encompassing

– Smart Measuring Instruments
– Smart Quality Monitoring
– Smart Process Monitoring

Smart Inspection Lab

A smart inspection and data management application for digital metrology is setup. The application would collect, store, present digital data from Smart Bluetooth enabled instruments and data from other instruments/equipments/gauges and CMM. Data analytics such as $C_p$, $C_{pk}$ are also performed to provide process capability information.
SMART Automated Inspection System Developed by CMTI
Auto-Correction Feedback

Multi Gauging System for Sabot
Multi Gauging System for Penetrator
Multi Gauging System for Tail Piece

SABOT  PENETRATOR  TAIL PIECE

Highlights:
• Automated Measurement of Internal Thread Parameters, Form Errors and Dimensions
• 18 Parameters measured and documented in just over 3 minutes

The system was developed for comparing manufactured dimensions of the components with that of the designed dimensions, record the deviations and indicate whether the component can be accepted, rejected or needs rework.

➢ Automatic gauging significantly cuts down the inspection time
➢ Eliminates human measurement error
➢ Measured data is stored and accessed from the PC for statistical analysis.
➢ Online correction for the dimensional variation by automatically feeding the result of inspection to CNC system
Multi Sensor Implementations

Parallel Sensor Implementation on a Co-ordinate Measuring Machine

Changeable Sensor Implementation on Surface Texture Measuring Device
Automated Integrations

Faster metrology due to the automated integration of a CMM into material flow by Robot loading.
Measurement of X-offset / Tool Radius as well as automatic quick correction for it from direct measurement of a production asphere.
Smart Metrology Cell
Digitization of Industrial Measurement Throughout the Supply Chain

Revenues from ERP software will surpass the hardware revenues over the next 5-8 years.

- Inspect the manufactured components
- Share the quality inspection data with the prospective buyer
- If the OEM is satisfied with the quality inspection data, then the supplier can ship the components to OEM.
- Integrate RFID/Sensors along with shipment carriage to monitor the components during transportation
- Permanent monitoring throughout the product’s life cycle
- Centralized global data for future references

Permanent monitoring will help manufacturers design effective root cause analysis, corrective and preventive strategies, and help manufacturers achieve the utopian vision of ‘Zero errors in Manufacturing’.
Success is a new dimension.

One stop solution for a complete range of dimensional, form, gear and surface roughness measurement & calibration accredited by NABL.

From Ultra precision CMMs to Gauge block interferometer, Flatness interferometer to Nano surface optical profiler, our calibration services guarantee your success.

Thank you
Smart Machine tool and Intelligent Machining

Gopi Krishna S, Scientist C
Smart Manufacturing, Precision Machine tools & Aggregates
Central Manufacturing Technology Institute, Bengaluru
Outline

1. Introduction
2. Features of a smart machine tool
3. Introduction to Intelligent machining
4. Development of an Intelligent Ultraprecision Machine Tool
5. Intelligent Machining – CMTI initiatives
Machining processes evolved around Sensing, process model, knowledge base and process control is intelligent machining.

Smart machine is an intelligent device that uses machine-to-machine (M2M) communication and are able to make decisions and solve problems without human intervention.

An Smart machine tool takes the CAD data, the materials and the set-up plans as inputs and can take autonomous decisions and produce accurate machined parts with quality, machine condition and productivity data as outputs

Development of technology for smart machine tools and intelligent machining is one of focus area of CMTI activities

Improvement in accuracy of products, along with productivity and ease of operation is our targets for technology development in this domain
Main Features of a smart machine tool

1. Adaptation to Changing conditions
2. Open Architecture CNC and sensor interface
3. Extensive Information processing capability
4. Real time compensation of Geometrical & Thermo-elastic displacement errors
5. Sensor based machine condition monitoring, Self Diagnostics
6. Tool condition monitoring
Main Features of a smart machine tool

7. Vibration and chatter control

8. Sensor based Process monitoring

9. Models for machining processes, Integration of sensory input with stored models and process optimization/Control

10. On Machine Metrology and automatic handling of work piece accuracy

11. Provision for sharing & storing knowledge, IOT enabled
Concept of an Intelligent machine tool

- Designed performance, work material, accuracy required, workpiece geometry, Depth entry and exit

- Database

- Supervision

- CL Data Generation

- Machine Drive

- Cutting Process

- Post-process Measurement

- OPERATOR

- Setup

- LEVEL 1

- LEVEL 2 (Cutting Force, Temperature, ....)

- LEVEL 3 (ON/OFF-line improvement with component measurement)

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What is Intelligent Machining

Machining processes
- Metal cutting
- Grinding

Sensors
Process Models

Intelligent Machining

Central Manufacturing Technology Institute
Software Structure of Intelligent Machining

Data from the sensors

Filtering

Information
Features which condense important signal information

Learning

Knowledge:
Tool wear state,
Workpiece surface quality,
Process control
Benefit from Smart machine tools & Intelligent Machining

1. Enhanced efficiency and productivity

2. Improvement in Machine Accuracy

3. Improvement in Machining (Part) Accuracy

4. Improved Reliability, Safety and ease in operation
Development of an Intelligent Ultra Precision Turning Machine
Intelligent Ultra Precision Turning Machine (iUPTM)

A state-of-the-art smart machine with intelligent features, developed by CMTI, for producing non-ferrous, IR and polymer components with optical quality. IUPTM, a world-class, next generation machine tool with built-in intelligence.

Applications: Electro-optics, Space, Defense, Ophthalmic Industries, Photonics

Intelligent Machine Diagnostics
- Spindle & Slide Health Monitoring
- On Machine Spindle balancing
- Sensor fault detection
- Tool condition monitoring

Intelligent Ultra Precision Turning Machine (iUPTM) developed at CMTI

Intelligent Machine error compensation
Real-time Positioning, Geometrical & Thermo elastic error compensation taking feedback from sensors mounted on machine

Open architecture Motion Control
Can integrate user developed control algorithms

Diamond Turned Mirrors on CMTI’s iUPTM for industrial applications

Remote monitoring, diagnostics & control through internet

Intelligent Machining & Prognostics
Surface error predictions for intelligent machining
The Thermal induced displacement Errors can be reduced from 50 micrometres to 3 micrometres with the compensation system.
Improvement in Machining accuracy with Real Time thermal error compensation

Problem Statement: The radius used to go out of specification after machining of 5 to 6 components.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius (mm)</td>
<td>3.288 ± 0.001</td>
</tr>
<tr>
<td>Form (µm)</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Spherical profile component machined in DTM

Radius Measurement after thermal error compensation

Nanoshape

UPCMM

Central Manufacturing Technology Institute
Online Health Monitoring Of Machine Tool Spindle

Features:

- Autonomous, in-situ spindle health monitoring system based on sensor feedback
- Online spindle problem identification using frequency analysis.
- HMI provides “a basic window for machine operators” and another window for “advanced diagnostics” with alarms.
Tool Condition Monitoring in Ultra precision Machining

[Diagram showing the process of signal monitoring, cutting forces, signal processing, decision making, and data processing]

TOOL CONDITION MONITORING IN ULTRAPRECISION MACHINING

- Cutting Speed
- Feed
- Depth of cut
- Force
- Flank wear
- Tool wear
- Tool is sharp

Graph showing force over time.
On-Machine Dynamic Balancing

Balancing of Rotors
Micro Engineering and Nano Technology,
Central Manufacturing Technology Institute,
Bangalore, India 560022

Initial Unbalance induced vibration (mm/sec): 1
Initial Phase Angle (Degrees): 135

Trial Mass (gms): 5

Vibration with trial mass (mm/sec): 7
Phase Angle (Degrees): 45

Required balance weight (gms): 36.3553
Phase Angle (degrees): 0.0099

Calculate
Cancel
Optical Tool Set Station (OpToSS):

- Tool Radius Measurement
- Tool Position offset (X & Z)
- Tool Height Setting (within 6µm)
- Tool Inspection (Damage & Wear)
- Light Intensity Control for Diamond & CBN Tools

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>≤ 5 µm</td>
</tr>
<tr>
<td><strong>Kinematic mount</strong></td>
<td>≤ 1.6 µm</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>0.8 µm</td>
</tr>
<tr>
<td><strong>Approx. Weight</strong></td>
<td>2.5 Kg</td>
</tr>
</tbody>
</table>

*(Ergonomically designed for ease of handling and mounting)*
Optical Tool Set Station (OpToSS)
IOT Enabled “SMART” Metal Cutting Machine - empowering a Legacy Machine @CMTI

**Smart features**

Sensor modules

- **Temperature**: Machine thermal plot
- **Vibration**: Machine health
- **Evaluate TcP**: (tool center point) drift
- **Pressure**: Spindle coolant pressure
- **Energy**: Downtime of the machine
- **Vision**: In-situ inspection / Quality

**Outcome**

- Generate diagnosis reports / action plan
- Classify reports based on severity
- Enable deep dive information for better process understanding
- Establish data base for further analytics

**Outputs**

- IOT enabled connected machine
- Remote access of machine health and process data
- Real time Machine health monitoring
- Energy monitoring
- Better process monitoring
- Reduced machine down time
A IoT enabled Control GUI has been developed to control the 3D printer in a closed loop. The following features have been implemented.

- Cloud based 3D printing by uploading G-code via Any internet connected device, i.e. Mobile Phones & Tablets.
- Cloud based closed loop monitoring of process parameters & Temperature signatures of subsystems of 3D printer.
- A complete live fabrication process can be viewed online via IOT process monitoring camera.
PREDICTION OF SURFACE FINISH IN DIAMOND TURNING PROCESS
**Prediction of Surface roughness-MRA**

- **Independent variables:**
  - **Cutting conditions:**
    - Speed (S)
    - Feed(f)
    - Depth of Cut (doc)
  - **Vibration from Process:**
    - Vibration in tangential cutting force direction, Vx
    - Vibration in feed direction, Vy
    - Vibration in thrust cutting force direction, Vz

- **Dependent variable:** Surface finish
Comparison of measured and estimated values of surface roughness
Thank you
Smart Sensors & Controls

V. Shanmugaraj
Central Manufacturing Technology Institute (CMTI)
Bangalore
Smart Sensors & Controls

Internet of Things (IoT)

Sensors → Controller → Cloud

(Data Acquisition and Analytics)
Smart Sensors & Controls

Smart Manufacturing (IIoT)
Smart Sensors & Controls

– A Transducer is a device that can convert energy from one form to another

– A Sensor is a device that can detect a physical quantity and convert the data into an electrical signal.

– Sensors are also a type of Transducer
Smart Sensors & Controls

Sensors

– Macro (Conventional)
– Micro (MEMS – Micro Electro Mechanical Systems)
Smart Sensors & Controls

Sensors
– Temperature (upto 10Hz)
– Pressure
– Flow
– Force
– Torque
– Accelerometers (upto 20 KHz)
– Load Cells
– Acoustic (upto 1 MHz)
– Displacement
– Velocity
– RFID
– Gyroscopes
Smart Sensors & Controls

Transduction Principle

– Change in Voltage
– Change in Current
– Change in Resistance
– Change in Capacitance
– Change in Impedance
Output

– Machine status monitoring
– Higher Productivity
– Lower down time of the machine
– Preventive maintenance
– Better utilization of Resources
Smart Sensors & Controls

Temperature Sensors
  – RTDs (Resistive Temperature Detecting)
  – Thermistors
  – Thermo-couples

– Factors
  • Temperature Range
  • Sensitivity
Pressure Sensors

- **Absolute** – A Sensor that Measures Input Pressure in Relation to a Zero Pressure – Altitude Measurement
- **Differential** – A Sensor that Is Designed to Accept Simultaneously Two Independent Pressure Sources. The Output Is Proportional to the Difference Between the Two Sources – Airspeed Measurement
Smart Sensors & Controls

Flow Sensors

– Variable Area (rotameters)
– Rotating Vane (paddle & turbine)
– Positive Displacement
– Differential Pressure
– Vortex Shedding
– Coriolis Mass
– Ultrasonic
Smart Sensors & Controls

Force Sensors
  – Piezo electric
  – Strain Gauge

Torque Sensors
  – Strain Gauge
Smart Sensors & Controls

Accelerometers

– Piezo Resistive
– Piezo Electric
– Strain Gauge
– Inductive
Smart Sensors & Controls

Load Cells
  – Tensile
  – Compression
  – Bending Beam
  – Strain Gauge

Displacement Sensors
  – Capacitive
  – Eddy Current
THANK YOU