Coordinate Measuring Machines

Kalevi Aaltonen, Aalto University
Why coordinate measuring machine is an excellent investment…

Money talks; efficiency and productivity are the key issues… cost cut down is a continuous effort
Coordinate Measuring Machines

Coordinate measuring machine rationalizes difficult quality control tasks
Coordinate Measuring Machines

• HAND HELD MEASURING DEVICE ARE UNPRODUCTIVE AND INACCURATE

• ACCURACY 0.01…0.2 mm

• CALIBRATION RESERVES VALUABLE MEASURING CAPACITY

• CMM AS PRIMARY CALIBRATION NORMAL?
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THE VERY FIRST CMM
ZEISS UMM 500

• YEAR 1973
• ACCURACY 0.5 MICROMETERS
• COMPUTER CONTROL AND PROGRAMMING
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COORDINATE MEASURING MACHINES HAVE DEVELOPED RAPIDLY TO SOPHISTICATED AND ACCURATE PRODUCTION EQUIPMENT
LOW COST CMM IS HAND OPERATED; BUT THE MACHINE IS STILL VERY ACCURATE AND VERSATILE
DIFFERENT CUSTOMER NEEDS
– DIFFERENT CMM STRUCTURES
GANTRY TYPE CMM HAS WIDE MEASURING SPACE AND BIG DIMENSIONS
HAND OPERATED OR NC-CONTROLLED?
Measuring machines

TRADITIONAL CMM TOUCH PROBE AND PROBE MAGAZINE
Measuring machines

OPTICAL LIGHT DIODE PROBE OF CMM
Measuring machines

LASER INTERFEROMETER PROBE OF CMM
Measuring machines

MULTISCOPE CMM
Measuring machines

SHOP FLOOR LEVEL CMM WITH MODEST ACCURACY AND LOW PRICE
Measuring machines

MACHINING CENTER TYPE FIXTURES RATIONALIZE CMM USAGE AND CUTS DOWN THE MEASURING COSTS.
Measuring machines

CMM MEASURING PROBES ARE EXPENSIVE SPECIAL DEVICES
Measuring machines

CMM USER CAN TURN AND TILT THE PROBES FOR EXTREME MEASURING TASKS
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CMM HAVE STOLEN DUTIES AND WORKLOAD FROM CONVENTIONAL AND SPECIAL MEASURING MACHINES EQ. GEAR MEASURING MACHINES
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CMM SOFTWARE IS USER FRIENDLY AND ILLUSTRATIVE
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3D PRODUCT DATA FROM DESIGN SYSTEMS IS THE BACKBONE TO PROGRAMME CMM

PROGRAMMES ARE MODULAR AND VERSATILE

GEOMETRY INTERFACE UTILIZES STANDARD FILE TRANSFER OPTIONS
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WELL-KNOWN WINDOWS USER INTERFACE
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THE MOST IMPORTANT FACTORS TO MEASURING ACCURACY:

- machine operator (30–50 %) most important
- machine (5–20 %) little affect
- workpiece (10–30 %) most difficult to handle
- environment (5–20%)
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CMM technical specification does not anymore rely on word measuring uncertainty and abbreviation U

In standard ISO 10360-2 only the measuring capability is described
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Standard ISO 10360-2 uses the expression MPE (Maximum Permissible Error).

In ISO –standard the CMM testing is done with gauge block measurements and repeatability procedures by measuring a calibration sphere.
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CMM CALIBRATION WITH GAUGE BLOCKS
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USING ACCURATE GLASS SPHERE CMM ACCURACY IS TESTED AND CALIBRATED
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ISO-standard has two concepts for MPE: length measuring error (E) and repeatability error (P).

MPEE = measuring the length:
5 different lengths in 7 places and 3 repetition gives 105 calibration measurement results.
Not a single measurement may exceed the machine supplier’s notification.
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MPEP = 3D- repeatability error:
25 measuring points from calibration sphere (diameter 10 – 50 mm).

According to measurement results a Gauss or Least Squares sphere is calculated. Rdial maximum – minimum deviation may not exceed the machine supplier’s repeatability notification.
CMM service and maintenance, verification and testing, calibration and measuring accuracy are all different concepts and technical terms.
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CMM CALIBRATION DEVICE
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CMM CALIBRATION WITH SPHERE ROD
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CMM CALIBRATION AT MIKES
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PRECISION MEASUREMENT WITH CMM AND
DEVIATION GRAPH AT MIKES
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Contact touch-trigger probe

Scanning analogue probe
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MEASURING PROBE TIPS ARE HARD AND WEAR RESISTANT MATERIALS (RUBY AND SAPPHIRE)

… AND RATHER EXPENSIVE 😊
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THE PROBES MUST BE CALIBRATED IN PROCESS MEASUREMENT POSITION
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SCANNING PROBE
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A ROTARY MOTION PROBE
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PROBES ARE CHANGEABLE
MODERN PROBES ARE RATHER SMALL
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COMPLICATED PARTS AND ACCURATE GEOMETRICAL TOLERANCES ARE EASY TO MEASURE WITH CMM
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FLATTNESS MEASUREMENT WITH TOUCH PROBE IN CMM
Coordinate Measuring Machines

DIVERSE PROBES – EFFECTIVE MEASURING APPLICATIONS

Aalto University
School of Engineering
Coordinate Measuring Machines

CMM MEASURING OF TURBINE BLADE
<table>
<thead>
<tr>
<th>TOLERANCE</th>
<th>Distance or Diameter [mm]</th>
<th>10</th>
<th>100</th>
<th>300</th>
<th>600</th>
<th>1000</th>
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<td>±0.003mm</td>
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<td>0.3+L/100</td>
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<tr>
<td>±0.005mm</td>
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<td>0.5+L/900</td>
<td>0.4+L/100</td>
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<tr>
<td>±0.007mm</td>
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<td>0.6+L/900</td>
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<tr>
<td>±0.010mm</td>
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<td>1.0+L/400</td>
<td>0.8+L/500</td>
<td>0.6+L/750</td>
<td>0.4+L/100</td>
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<td>1.2+L/300</td>
<td>0.8+L/450</td>
<td>0.5+L/600</td>
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<td>1.6+L/250</td>
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<td>0.8+L/800</td>
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<tr>
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<td>2.6+L/250</td>
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<td>4.3+L/150</td>
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<td>7.0+L/100</td>
<td>6.0+L/150</td>
<td>4.0+L/150</td>
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<td>0.200mm</td>
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</table>
0.007 mm ROUNDNESS TOLERANCE
0.7 MICROMETER MEASUREMENT UNCERTAINTY

<table>
<thead>
<tr>
<th>R [μm]</th>
<th>Form Tolerance [μm]</th>
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<td>5.0</td>
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</table>
Mitutoyo Crysta Apex 9106
905 x 1005 x 605 mm, $\text{MPE}_E = (1.7 + 0.3L/100) \, \mu m$
CMM PH10 and MCosmos2-software machine installed and calibrated
Price: 85 000€

When measuring 100 mm $\text{MPE}_E = 2.0 \, \mu m$
Mitutoyo Legex 9106
905 x 1005 x 605 mm, $MPE_E = (0.48+0.1L/100) \, \mu m$
CMM with scanning probe MPP-100 and MCosmos3-software installed and calibrated
Price: 320 000€

When measuring 100 mm $MPE_E = 0.58 \, \mu m$
QUALITY CONTROL OF 3D SURFACES REQUIRES 3D CMM MEASUREMENTS
INTERNAL SURFACES ARE EASY TO MEASURE USING CMM
INDEXABLE MEASURING PROBE
DIVERSIFY QUALITY CONTROL OPPORTUNITIES IN CMM
HIGH ACCURACY DIMENSIONAL MEASUREMENTS GO HAND IN HAND WITH EXCELLENT SURFACE ROUGHNESS
WHO HAS THE NERVE TO CONTROL COMPLICATED COMPONENTS BY HAND MEASUREMENT DEVICES?
GEAR MEASUREMENT WITH CMM GIVES A LOT OF MEASURING DATA IN VERY UNDERSTANDABLE FORM; EASY TO AUTOMATE
DIFFICULT 3D GEOMETRIES ARE IMPOSSIBLE TO CONTROL AND MEASURE WITHOUT CMM
THIN WALL COMPONENTS ARE VERY CHALLENGING TO CONTROL AND MEASURE EVEN WITH CMM
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Coordinate Measuring Machines
Coordinate Measuring Machines

- Scanning probe systems
- Measuring probe heads
- Touch-trigger probe systems
- Optical probe systems
Benefits of Coordinate Measuring Machines

• A
• B
• C
Benefits of Coordinate Measuring Machines

1. SHORT MEASURING TIMES

- 95% TIME SAVING COMPARED TO CONVENTIONAL MEASURING METHODS
- MORE ACCURATE MEASUREMENTS PRODUCTION BATCH
- PROGRAMMING RATIONALIZE MEASUREMENTS => SUPPORTS MEASURING PLANS
CMM MEASURING INSTRUCTIONS

1. PREPARING THE PART (CLEANING, REMOVING SCRAPS, EVALUATING THE SURFACES)
2. STABILIZE THE TEMPERATURE; TIMING
3. FIXTURING (PICTURE, DRAWING)
4. MEASURING PROBE SELECTION
5. PROBE CALIBRATION
6. ORIENTATION OF THE WORK PIECE
CMM MEASURING INSTRUCTIONS

7. MEASURING POINTS, TEMPERATURE CORRECTION
8. RESULTS AND STATISTICAL CALCULATION
9. ANALYZING THE GEOMETRICAL TOLERANCES
10. DEFINING THE MEASUREMENT ACCURACY AND UNCERTAINTY
CMM MEASURING INSTRUCTIONS

11. APPENDIX:
- SET UP DRAWING AND PICTURE
- PICTURE OF THE PROBES
- FIXTURING PICTURE
- THE NAME OF THE MEASURING PROGRAMME AND FILE LOCATION
- NC-PROGRAMME PRINT OUT
- UNCERTAINTY CALCULATIONS
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2. FEW PRODUCTION BRAKE

- REAL TIME MEASUREMENT RESULTS AND MEASUREMENT PROTOCOLS
- ON LINE PROCESS CONTROL BY MEASURING RESULTS
- TREND FOLLOW-UP
- OFF LINE MEASUREMENTS – EFFECTIVE MACHINING
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3. SHORT LEAD TIME

• PALETS AND FIXTURES
• AUTOMATED PROBE CHANGE
• COORDINATE CALCULATIONS INSTEAD OF PART ORIENTATION
• PROGRAMME LIBRARIES
• NO CONTINUOUS CALIBRATION
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4. MANAGEMENT OF URGENT ORDERS

- SHORT SET UP TIMES
- TESTED PROGRAMMES
- ON LINE MEASUREMENT RESULTS
5. OPTIMIZED PRODUCTION COSTS

- UTILIZATION OF THE WHOLE TOLERANCE ZONE
- MAXIMUM MATERIAL PRINCIPLE
- FACTS INSTEAD OF FICTION; GEOMETRICAL TOLERANCES EASY TO VERIFY
- LESS SCRAP AND REPAIR WORK
- CONTROL OF SUBCONTRACTING
6. SAVINGS IN PERSONNEL

• MEASURING AUTOMATION REDUCES MANPOWER
• SPECIAL MEASURING KNOW HOW COMPENSATED WITH CMM
• MACHINIST MAKES THE MEASUREMENTS – NO INSPECTORS NEEDED
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7. LOW MEASURING COSTS

- HIGH EFFIENCY (NC CONTROL)
- QUICK MEASUREMENT
- 3 SIFTS AVAILABLE; UNMANNED MEASUREMENTS
- REPLACEMENT OF MANY MANUAL MEASURING DEVICES
- FLEXIBLE MEASUREMENTS
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8. IMPOSSIBLE MEASUREMENTS

- THIN PLASTIC COMPONENTS
- ABSTRACT MEASUREMENT ELEMENTS
- MEASUREMENT OF SCULPTURED 3D SURFACES
- MICRO MACHINED SMALL PARTS
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9. IMPROVES COMPANY IMAGE

- Part of the modern quality system
- Part of the measurement calibration chain
- Requires new know how; attracts personnel
- Attracts customers
- Reminds the competitors
- High class technical reports
Measuring machines

EXCELLENT COURSEBOOK
I HIGHLY RECOMMEND
LESSONS TO LEARN:

- automated production – automated measuring
- CMM rationalize quality control
- coordinate measuring machines are the most important devices in the modern factory
- money talks – CMM investments must be profitable
- company quality image is important – CMM is the best salesman
- geometrical tolerances require CMM
- subcontracting quality control without CMM is guesswork

Vita, si scias uti, longa est, Seneca
(Life, if well lived, is long enough)
Acta est fabula. Plaudite!

(Play is over. Applaud!)

(emperor Augustus)