

# CONTENT LEVEL 1

- **Target group:** Production metrologists
- **Prerequisites:** None
- **Learning aims:** The seminar lays and consolidates basic knowledge of production metrology for beginners and advanced metrologists. The didactic approach used in the seminar is based on the latest findings. The seminar covers the latest knowledge regarding dimensional tolerancing, programming basics, measurement process planning and the machine and sensor technology used. The enhanced understanding of measuring jobs and influencing parameters enables measuring technicians to reduce measuring uncertainties and thus to make measurement results more reliable and easier to compare. The minimization of costs and waste is supported.
- **Duration of course:** 5 days, depending on previous level of knowledge
- **Completion:** Exam, certificate

## 1-1 Units

SI Units, incl. Definition and History, Base Quantities, Derived Quantities, Prefixes of Units, Angles, Conversion Degrees <-> Radian, Conventional Measuring and Test Equipment

## 1-2 Coordinate Systems

(Mathematical) Drawing Plane, Origin, Cartesian Coordinates, Right-Hand Rule, Translation and Rotation, Polar Coordinates, Cylindrical and Spherical Coordinate System

## 1-3 Coordinate Measuring Machines

History of Coordinate measuring machines, Cantilever/Bridge/Column/Gantry Types, Differences in the Types, Axis Guide, Measuring Computer and Software, Work Holding Fixture, Accuracy of Coordinate Measuring Machines, CAA Correction, Form Measuring Machines

## 1-4 Sensors

Sensor selection, Stylus System, Stylus, optical sensors, Image Processing, Laser Triangulation

## 1-5 Basic definitions

Drawing Entries (Dimensions, Tolerance Symbols), Standard Reference, Differences Nominal Element - Real Element - Extracted Element - Associated Element, Free Form surfaces

## 1-6 Dimensional Tolerance

Dimensional Tolerances, Taylor's Principle, Standards, Symbols and Drawing Entries, Length Dimensions, Angular Dimensions, Limiting Dimensions and Fits, ISO Fitting/Mating System, Common Tolerances

## 1-7 Geometric elements

Standard form elements: Plane/ Cylinder/ Cone/ Sphere/ Line/ Circle/ Point/ Ellipse, Vector, Normal Vector, Minimum Number of Points, Projection



### **1-8 Geometric constructions**

Calculation of characteristics out of two geometrical features (distance, angle), Calculation of features out of two geometrical features (Intersection, Symmetry), Calculation of new features out of some geometrical features (Construction)

### **1-9 Preparing a Measurement on the Coordinate Measuring Machine**

Standardized Temperature, Part Cleaning, Temperature Control, Fixturing, (Avoiding Distortion), Fixturing Systems, CMM and Software Startup

### **1-10 Stylus Selection and Qualification**

Stylus System Selection, Stylus Qualification, Reference Sphere, Reference Stylus, Stylus Sphere Radius Correction, Stylus Tip Bending Correction, Mechanical Filter Effect of the Stylus, Errors of Incorrect Qualification,

### **1-11 Measuring using Coordinate Measuring Machines**

Determining part Coordinate System, Difference to Control Coordinate System, Manual and automatic Alignment, Probing, References, Consequences of Collisions, Number of Probing Points and their Distribution, Influences on measuring result

### **1-12 Evaluation of Measurement and Statistics**

Importance of Statistical Parameters, Outliers, Scattering, Histogram Representation, Compensation Methods, Influences on measuring result

### **1-13 Inspection planning**

Completely defined characteristic, Purpose of the Measurement, Production of workpiece, Function of workpiece, Feature description, Manufacturing Methods and Accuracies, Shape Deviations, Uncertainty Effects, Awareness of Measuring Uncertainty, Inspection planning, Identifying measuring features

### **1-14 Documentation and Quality Management**

Measurement Reports, Quality Control Charts, Cooperation between Design - Production - Testing, Reproducible and Clear Measurement Documentation, Measuring Strategy documentation

## CONTENT LEVEL 2

- **Target group:** Production metrologists
- **Prerequisites:** AUKOM 1 certificate
- **Learning aims:** The Seminar furthers basic knowledge of production metrology for advanced measuring technicians. The didactic approach used in the seminar is based on the latest findings. The content comprises the latest knowledge on the topic, form and positional tolerance, test plan interpretation, programming, monitoring, and the machine and sensor technology used. An enhanced understanding of measuring jobs and influencing parameters enables measuring technicians to reduce measuring uncertainties and thus to make measurement results more reliable and easier to compare. The minimization of costs and waste is supported.
- **Course duration:** 5 days
- **Completion:** Exam, certificate

### **2-1 Overview of the Entire Measuring Process**

Short repetition of the contents of stage 1

### **2-2 Geometric Overview**

Standard Geometric Elements, Surface and Space Points, Punched Hole/Slot, Tetragonal/Hexagonal Hole, Symmetry, Perpendicular, Parallelism, Angle in Space, Coordinate System Transformations

### **2-3 Form and Positional Tolerances**

Introduction to the Form and Positional Tolerances, Symbols and Drawing Entries, Form Tolerances, Reference Designation, Directional, Positional and Runout Tolerances, General Tolerances

### **2-4 Measuring Strategy**

Define Clamping Setups and References (Practical Instructions), Order of Reference and Origin Selection, Iterative Alignment, Alignment According to the 3-2-1 and Best-Fit Methods (3-D Fit), Measuring Element and Auxiliary Elements, Machine Grid Measurements, Contour Measurements, Measurement with Cylinder Surfaces, etc.

### **2-5 Probing Strategy - Tactile**

Number and Distribution of Probing Points, Probing Force and Speed, incl. Material Properties, Stylus Diameter, Special Styli, Scanning

### **2-6 Probing Strategy - Image Processing**

Single-shot measurement, Multi-shot measurement, Edge finder, Contour image processing, Projection optics, Illumination, Filter, Scanning, Auto focus

### **2-7 Probing Strategy - Distance Sensors**

Laser triangulation sensors, Foucault sensor, White light sensor, Light section sensor, Photogrammetry, Fringe protection, Influence on the measuring results



### **2-8 CNC Programming**

Teach-In, Offline Programming, Measuring against CAD Data, Clarity and Self-Explanatory of Variables, Modules and Programs

### **2-9 Measurement of Free Form Surfaces**

Element types in Free Form Surface Metrology, ? Effect of a 3D-Fit, Different Measuring Strategies, Programming Methods for Establishing Measurement Sequences

### **2-10 Evaluation**

Evaluation Criteria: Function-oriented and Manufacturing-oriented Evaluation Methods, Differences in the Association Methods (Gauss, Envelope, Minimum Requirement), Constructions, Graphic and Tabular Evaluation, Measurement Logs

### **2-11 Effects on the Measurement Result**

Effects on the Measurement Result, Reduction of Measurement Uncertainty, Detection and Reduction of Systematic and Random Effects, Temperature Compensation

### **2-12 Documentation**

Principles of Documented and Reproducible Documentation, Graphic Evaluation, Form Plots, Measurement Reports and Their Improvement

### **2-13 Test Equipment Monitoring**

Test Equipment Monitoring, incl. Monitoring Strategies, Test Specimen, Normals, Monitoring and Acceptance Test of Coordinate Measuring Machines, Qualification Chain

### **2-14 Good Measurement Practice**

Good Measurement Practice, Necessity of Cooperation

# CONTENT LEVEL 3

- **Target group:** Production metrologists
- **Prerequisites:** AUKOM 2 certificate, AUKOM GD&T
- **Learning aims:** The seminar offers comprehensive knowledge of production metrology for advanced measuring technicians who work at interfaces with other departments and are obliged to communicate effectively. The didactic approach used in the seminar is based on the latest findings. The content comprises the latest knowledge on function and production-based measuring, filtering, programming, computer tomography, QM and measuring room management. An integrated understanding of measuring jobs and influencing parameters enables experts to communicate confidently with interdepartmental areas and reduce measuring uncertainties, measuring results become more reliable and easier to compare. The minimization of costs and waste is supported.
- **Course duration:** 5 days
- **Completion:** Exam, certificate

## **3-1 Basic Knowledge - Geometry**

Calculation of Angle, Center of Gravity, Distance, Area

## **3-2 Basic Knowledge - Production Technology**

Production Types and Achievable Production Precisions, Shape Deviations and Their Causes, Functionally Adequate Design and Construction Suitable for Production

## **3-3 Basic Knowledge - CAD**

Principles of Construction and Technical Drawing, Principles and Tools of CAD Design, Imaging of Geometry, Model Types, CAD Data Dimensions, CAD Formats, Import of CAD Data, Interfaces

## **3-4 Point Cloud and Computer Tomography**

Development of computer tomography technology, Physical principle, From the radiographic image to the measure, Tomography ?on the image?, Region of interest, Initial sampling of the entire component, Evaluations of the deviations from the nominal geometry, Measurement of sections, Checking the material structure, Radiation spectrum, Beam hardening, Scattered radiation, Cone beam artifact, Noise, Further applications; Additionally: Fringe Projection, Photogrammetry, Tracking

## **3-5 Creation of Measurement Programs**

Precision-Optimized Measuring Sequence, Time-Optimized Measuring Sequence, Travel Path Optimization, Feature-Oriented Measuring, Remote Programming, Safety Points and Planes, Program Loops / Branches/ Modules, Macros, User Interfaces, Program Optimization Loops, If/Then Conditions, DMIS Standard

## **3-6 Digital Filtering and Evaluation**

Software Filters, Gauss Filters, High-Pass, Low-Pass, Waviness, Roughness, Comparison Form Tester - CMM

## **3-7 Monitoring of CMMs**



CMM Monitoring, ISO 10360/VDI 2617, Possibilities to optimize the accuracy of CMMs, Examples, Experience

### **3-8 Measuring Uncertainty and Measuring Process Suitability**

GUM Handbook, Determination of the Measuring Uncertainty, Uncertainty Budgets, PUMA Method, Increasing Measurement Uncertainty, Extended Measurement Uncertainty, Conformity, ISO 14253, Determination of Uncertainty Using Calibrated parts, Use of the Virtual CMM, Measuring Process Suitability according to MSA (GR&R), VDA 5, Comparing the methods

### **3-9 Quality Management**

Quality Management Systems, Quality Management Handbooks, Quality Management Standards, Audit and Certification, Quality Tools, Fixed and Actual Costs, Origin of Errors and Error Elimination, Cost-Conscious Tolerance

### **3-10 Process Monitoring**

Process Monitoring, Statistical Process Control (SPC), cp Values, cpk Values, cm Values, cmk Values, Monitoring Strategies and Quality Control Cards

### **3-11 Aspects of Measuring Room Management**

Measured Data Management, Measuring Room Management, User Qualification, Training Plans and Options for Metrologists