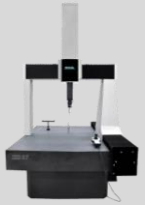
High Quality
Machining Control Software

Robust, scalable, error-proof environment

Summary of benefits

- A novel approach to planning and analysis of metrological testing
- Validation of measuring and machining capability with a low risk of errors
- Precise quantification of errors for instruments, appraisers, and methods
- The right fit in a high value inspection process
- Smart plans with no restrictions on the number of elements in a metrology set
- The power to reduce the cost of poor quality
- The ability to identify and eliminate sources of variation in real time
- Confident capability decisions for high-mix low-volume production



MICRONITE DPM

Digital Process Management

Metrology in high-precision machining

Excerpts

Unlocking the potential of machining excellence

By Dr. Stephen P. Birman

September, 2022

AN OPPORTUNITY TO BENEFIT FROM MICRONITE TECHNOLOGY

Uniquely designed for metrological evaluation of measurement and machining process, MICRONITE offers flexible design of unscripted sampling plans. cross-reference convergence of system elements, and critical to quality visual analytics.

A single metrology plan may include all probable causes affecting accuracy (shifts), variation and capability of individual system elements and special groups. Wide-scope data acquisition and comprehensive analysis provide deep insights into sources of errors and have a decisive effect on the results of inspection.

With easy-to-use MICRONITE metrology software, the machine shop can quickly evaluate individual and combined capabilities of gages, operators, and inspection methods. Instead of being frozen by regulatory standards, engineers can quickly determine the best way forward for ensuring high data quality.

MEASUREMENT ACCURACY AND PRECISION ON THE MICRONITE METROLOGY PLATFORM

In-screen design of metrology plan; Samples are elements of measurement and machining control system.

Estimates of accuracy, precision, and capability. Multiple choices in each column.

Color-coded charts of averages, ranges, and sigma-defined variation

Color-coded charts of averages and estimates of process control window

#	Notes	Shift N	R 90	PP	Ppk	Averages and Variation (LSL – USL)	Averages and Alert Limits (LSL – USL)
1	Bore Gage QA, 3 rdgs around/along, Part #3, Inspector R.	-6	34	1.79	1.59		
2	Bore Gage QA, 3 rdgs around/along, Part #6, Inspector R.	-15	27	2.23	1.57		
3	Bore Gage QA, 3 rdgs around/along, Part #9, Inspector R.	-19	36	1.61	1.01		
4	Bore Gage Floor, 3 rdgs around/along, Part #3, Inspector R.	-8	45	1.45	1.22		
5	Bore Gage Floor, 3 rdgs around/along, Part #3, Operator J..	1	44	1.40	1.38		

MICRONITE METROLOGY ANALYTICS

The user selects most meaningful measures

MICRONITE allows every machine shop to solve its own issues with efficiency of inspection process and acceptable level of machining process capability.

Measures of accuracy	Shift R, N, PA, M
Measures of variation	Range %, R 90, 3 to 6 STD
	CP R, CP s, CP 90
	% Tol est, % Variation
Indexes of measurement and process capability	Cpk R, Cpk s, Cpk 90
	PP, Ppk
Pre-Control limits (Est)	PSL (Stop), PWL(Warning)
Lower Permissible Tolerance	LPT sv, LPT 6s

Measurement and machining capability analytics empowers preventive quality control. Innovative methodology validates short-run process capability in minutes.

MICRONITE is ensuring protection of data accuracy

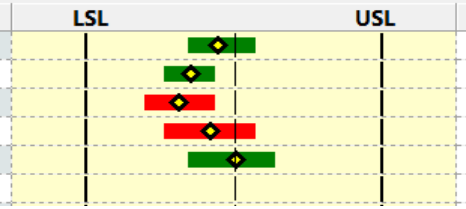
THE NEXT CHAPTER OF METROLOGY IN MEASUREMENT AND MACHINING PROCESS

Sampling scheme on demand

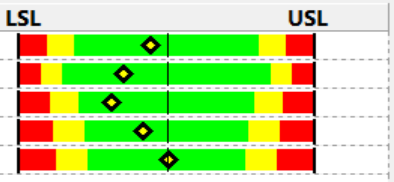
Selected statistical parameters

Charts of averages/ranges

#	Notes	Shift N	R 90	PP	Ppk
1	Bore Gage QA, 3 rdgs around/along, Part #3, Inspector R.	-6	34	1.79	1.59
2	Bore Gage QA, 3 rdgs around/along, Part #6, Inspector R.	-15	27	2.23	1.57
3	Bore Gage QA, 3 rdgs around/along, Part #9, Inspector R.	-19	36	1.61	1.01
4	Bore Gage Floor, 3 rdgs around/along, Part #3, Inspector R.	-8	45	1.45	1.22
5	Bore Gage Floor, 3 rdgs around/along, Part #3, Operator J..	1	44	1.40	1.38
6					
7					
8					
9					
10					
11					
12					



Averages and Alert Limits



Process warning and stop limits can be assigned for process control charts

IN-SCREEN DATA CAPTURE AND METROLOGICAL ANALYSIS

User-defined sampling scheme can include measuring instrument(s), observer(s), fixture(s), CNC machines, around/along, effects of tool wear, thermal, and others.

Variation criteria for charts

Abs. | Variation: Expert | Actual | 3 Sigma

Acceptance: CP | Cpk | PP | Ppk 1.33 | CP / Cpk / Auto | None

Color-coded acceptance criteria for averages and variation

Data is captured by wired/wireless gages, CMM, or Vision System
Capability to use a matrix of 12 rows by 12 columns

Sort | Ind.Grid | Abs.Gage

#	1	2	3	4	5	6
1	0.54621	0.54628	0.54624	0.54632	0.54634	0.54621
2	0.54621	0.54616	0.54616		0.54622	0.54626
3	0.54616	0.54613	0.54612	0.54626	0.54626	0.5462

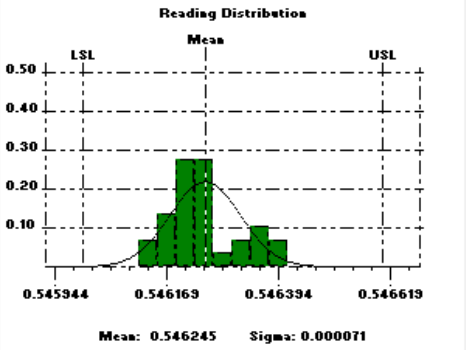
Data grid.

In-screen transformation of metrology scheme and statistical analysis

Histogram | Tolerance analysis | Columns stats | Columns | Instructions | Metrology Samples

#	Notes
1	Bore Gage QA, 3 rdgs around/along, Part #3, Inspector R.
2	Bore Gage QA, 3 rdgs around/along, Part #6, Inspector R.
3	Bore Gage QA, 3 rdgs around/along, Part #9, Inspector R.
4	Bore Gage Floor, 3 rdgs around/along, Part #3, Inspector R.
5	Bore Gage Floor, 3 rdgs around/along, Part #3, Operator J..

Unlimited options for re-organization and grouping of metrology elements



Matrix of samples and groups

Statistics of metrology matrix

Charts of metrology matrix

Zero-defect process window

#	Shift N	R 90	PP	Ppk	PWL	PSL
A	-6	38	1.79	1.59	19	10
B	-15	30	2.23	1.57	15	8
C	-19	41	1.61	1.01	21	11
D	-7	53	1.66	1.43	20	11
E	1	50	1.40	1.38	24	13
F	-4	64	1.52	1.39	22	12
G	-9	76	1.42	1.15	24	12

User-marked conversion of numerically defined samples into alphabetically constructed interactive metrology matrix

MICRONITE IS STRENGTHENING THE GAME IT INVENTED

PP | Ppk 1.33 | CP / Cpk / Auto | None

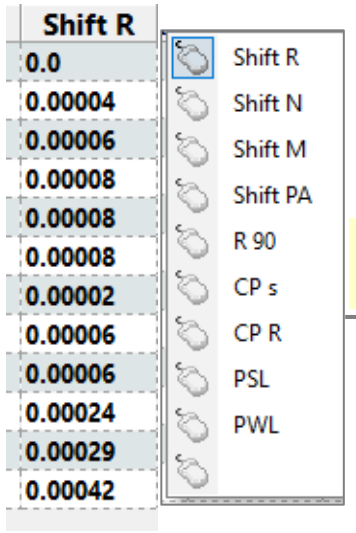
Sort | Ind.Grid | Abs.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5	6
1	0.54621	0.54628	0.54624	0.54632	0.54634	0.54621

A powerful metrology analytics platform

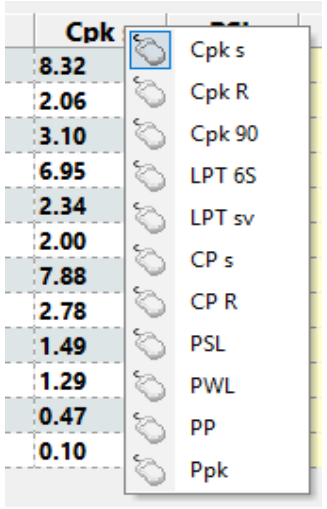
The user can select one of 16 statistical parameters which are placed in 4 columns

Options for column #1



Shift from reference is selected

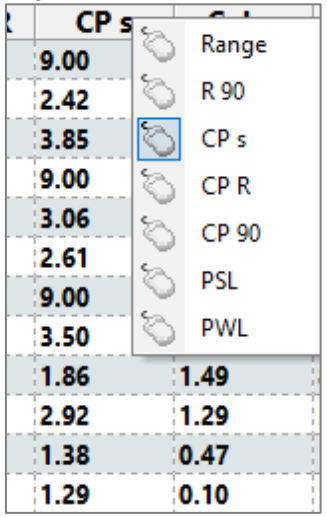
Options for column #3



Cpk is selected

Shift R	CP s	Cpk s	PSL
0.0	9.00	8.32	1
0.00004	2.42	2.06	6
0.00006	3.85	3.10	4
0.00008	9.00	6.95	1
0.00008	3.06	2.34	5
0.00008	2.61	2.00	6
0.00002	9.00	7.88	1
0.00006	3.50	2.78	5
0.00006	1.86	1.49	8
0.00024	2.92	1.29	5
0.00029	1.38	0.47	11
0.00042	1.29	0.10	12

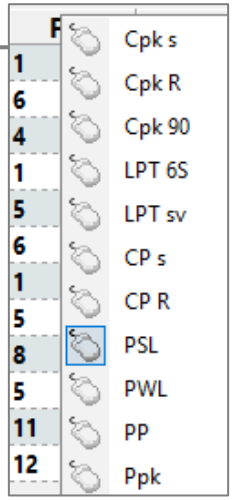
Options for column #2



CPs is selected

Process STOP limits (PSL) are selected

Options for column #4



Metrology insights are represented by 7 groups of estimates (1) accuracy (Shift R, Shift N, Shift M, and Shift PA), (2) sample variation (Range, Range 90), (3) indexes CP (CPs, CP R, CP 90), (4) indexes Cpk (Cpk s, Cpk R, Cpk 90), (5) indexes PP and Ppk, (6) Estimated process stop (PSL) and process warning (WSL) limits and (7) estimated Lower Permissible Tolerance (LPT 6S, LPT sv)

CRITICAL CAUSES OF SHIFT AND VARIATION IN THE SPOTLIGHT

With MICRONITE, the machine shop combines multiple sources of metrology data, including gages, quality experts, operators, and inspection processes to analyze and quickly deploy insights into process control routines. From suited for particular purpose sampling design to creating single and grouped metrology units the user determines the effect of root causes to solve measurement accuracy challenges. It helps create proper recommendations for actions. Instead of being frozen by regulatory standards, a machine shop can quickly determine the best way forward for improvement of data quality.

8550/0.48500 Tol 0.00050 mm	Metro
	No
Inspector, QA gage, 10 random pcs / 120 pcs	
Inspector, QA gage, 10 consec. pcs / 120 pcs	
Inspector, QA gage, pieces #1 #2, same spot / 120 pcs	
Inspector, QA gage, pieces #1 #2, around / 120 pcs	

PRODUCT VARIATION
PROCESS CAPABILITY
GAGE REPEATABILITY
ROUNDNESS

8550/0.48500 Tol 0.00050 mm	Metrolc
	Note
Inspector, QA gage, piece #1, same spot, 5 rdgs	
Inspector, QA gage, piece #2, same spot, 5 rdgs	
Inspector, Production gage, piece #1, same spot, 5 rdgs	
Inspector, Production gage, piece #2, same spot, 5 rdgs	
Operator K., Production gage, piece #1, same spot, 5 rdgs	
Operator K., Production gage, piece #2, same spot, 5 rdgs	

QA VS.PRODUCTION GAGE
INSPECTOR AND OPERATOR
GAGE ACCURACY
GAGE'S REPEATABILITY
REPRODUCIBILITY

0.32100/0.32000 Tol 0.00100 in
Operator Jack, part 1, floor gage, same spot
Operator Steve, part 1, floor gage, same spot
Operator Kevin, part 1, floor gage, same spot
Inspector John, part 1, floor gage, same spot
Operator Jack, 6 consec. parts, floor gage
Operator Steve, 6 consec. parts, floor gage
Operator Kevin, 6 consec. parts, floor gage
Inspector John, 6 consec. parts, floor gage
Operator Jack, 6 consec. parts, QA gage
Operator Steve, 6 consec. parts, QA gage
Operator Kevin, 6 consec. parts, QA gage
Inspector John, 6 consec. parts, QA gage

INSPECTOR QA GAGE
INSPECTOR FLOOR GAGE
QA VS FLOOR GAGE
INSPECTOR AND 3 OPERATORS
PROCESS REPEATABILITY
ROUNDNESS

Notes
6 random pcs / 260 lot, Production D. indicator, Inspector T.
6 consec. pcs, Production D. indicator, Inspector T.
6 rdgs around, piece #1, Production D. indicator, Inspector T.
6 rdgs around, piece #2, Production D. indicator, Inspector T.
6 rdgs, same spot, piece #1, Prod. indicator, Inspector T.
6 rdgs, same spot, piece #2, Prod. indicator, Inspector T.
6 random pcs / 260 lot, Production D. indicator, Operator B.
6 consec. pcs, Production D. indicator, IOperator B.
6 random pcs / 260 lot, QA D. indicator, Inspector T.
6 consec. pcs, QA D. indicator, Inspector T.
6 rdgs, same spot, piece #1, QA D. indicator, Inspector T.
6 rdgs, same spot, piece #1, QA D. indicator, Operator B

PRODUCT VARIATION QA GAGE
PRODUCT VARIATION FLOOR GAGE
PROCESS CAPABILITY
QA GAGE REPEATABILITY
FLOOR GAGE ACCURACY
INSPECTOR AND OPERATOR

ISSUES

Measurement System Analysis (R&R) does not offer practical procedures for validation of accuracy and precision of small or large amount of characteristics measured by Vision System. MICRONITE's Advanced metrology system provides rapid and reliable estimation of accuracy, variation and other metrological properties of any amount of tight-tolerance characteristics measured by Vision System.

Substantial measurement errors are found in a wide range of tolerances, all types of dimensional characteristics, and all brands of Vision Systems

Vision System is used as Go/No-Go device. Process dynamics and tool wear are not controlled by Vision System.

Conventionally, decision to eliminate a characteristic from measurement by Vision System takes relatively long time and is not always correct. MICRONITE eases this decision and reduces the discovery time to 10 – 15 minutes.

Root causes of measurement terrors are not systematically examined and corrective actions are not automatically triggered

Hidden measurement errors can have detrimental effect on quality and process control decisions

There is a gap between claims of manufacturers about accuracy & repeatability of Vision System and actual part-based results of metrological studies

Users of Vision Systems are surprised and sometimes shocked by MICRONITE discoveries

The AIAG MSA (GR&R)
"Because many software packages currently give these nonsense ratios as part of any "measurement system analysis," you will need to identify these fallacious numbers on the output in order to avoid being misled by them. *So what can you learn from the AIAG gauge R&R study? Virtually nothing that is true, correct, or useful!* You have taken the time and gone to the trouble to collect good data, and then you have wasted the information contained in those data by performing a hopelessly flawed analysis."
Dr. Donald Wheeler

MICRONITE METROLOGY TURNS DATA INTO QUALITY SAVINGS

Establish most efficient measurement system control

Efficiently and effectively manage the entire inspection system implementing user-friendly productive control of measurement abilities of precision gages, CMMs and Vision Systems

Up to 12 inspection methods are concurrently tested

Designed for metrological control of inspection methods, the software offers unrestricted sampling schemes within 12x12 matrix with in-screen estimation of accuracy, precision, and measurement capability

Focus on critical causes prevents measurement errors

Leverage the deep metrology knowledge obtained in multi-source studies and routine tests to discover critical causes of errors and compensate / remove measurement errors

Super-precision metrology for tight tolerances

Unique design of replicated single-element studies provides elimination of statistical errors in estimation of measurement accuracy and precision applied to tolerances down to 0.0001”

Connect metrology with online & offline inspection

Quality-critical integration of measurement accuracy control with real-time process control and offline sampling provides timely alerts and prevention of hidden problems otherwise uncovered

Centralized measurement and process metrology

A common platform for digital integration of measurement and process metrology comprises historical data with high-precision estimates of measurement, machine, and process control errors

BRINGING SUPERPRECISION TO MACHINING

MICRONITE

Metrology in measurement process

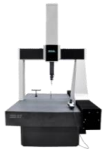
- Assessment and acceptance of measuring process in tolerance ranges down to 0.0001”
- Diagnostic of operational inspection processes involving all probable causes of poor data quality
- Engineering metrology in accuracy and precision of CMM and Vision System

Metrology in machining process

- Solution of complex machining tasks involving measuring and production equipment
- Diagnostic of all probable causes of poor data quality for tight and extremely tight tolerances
- Engineering metrology in accuracy and precision of CMM and Vision System

Metrology in process capability

- Using small sets of data for rapid assessment of process robustness
- Combining measurement accuracy and variation with capability of cutting tool to hold tolerance



MICRONITE provides the reliable metrology assurance for machining processes. The easy-to-use software enables machine shops to produce high-precision components with minimal variation due to tightly controlled measurement accuracy.

MICRONITE empowers measurement and machining statistics

MICRONITE provides a comprehensive, scalable analytics environment that meets diverse needs across shop floor operations and engineering departments

List of parameters

Shift R
Shift N
Shift PA
Shift M
Range
R 90
% Tol est
%, 1 to 3 s
PSL. PWL
CP R, CP s
CP 90
Cpk R
Cpk s
Cpk 90
PP, Ppk
LPT sv
LPT 6s

Technology	Parameters	Description	Goal/ Application	Importance	Source
Measurement and machining process metrology	Accuracy Measurement accuracy Machine accuracy Offset accuracy	Shift R - from reference	Gages, CMMs, Vision Systems, Observers, inspection methods	Key importance	MICRONITE
		Shift N - from nominal			
		Shift PA - from average			
		Shift M - from max value			
	Precision/Repeatability Measurement precision Repeatability Machine precision Offset precision	R, Sample range	All sources of variation	important	General
		R 90, 90% confidence level			MICRONITE
		Spread, Est. % tolerance Spread 1 to 3sigma	One-sided estimate of non-normal distribution	Acceptance / rejection of short-run variation	MICRONITE
	Reproducibility Variation	Spread R 90, 1 to 3 sigma	Group capability	Important	MICRONITE
		Cpk, Cpk 90, PP. Ppk		Advisory /small samples	MICRONITE
Capability of machining process	Measurement capability Process capability Group capability	PSL: Metrology STOP limit Process capability	Capability end zone for tight tolerances	Acceptance / rejection of short-run capability	MICRONITE
		Metrology Warning limit	Capability warning zone		MICRONITE
		CP (R/d2, s)	Standard index	Applied to large samples	General
		CP 90	90% confidence level	Important for short runs	MICRONITE
		Cpk (R/d2, s)	Standard index for open tolerances	Applied to large samples	General
		Cpk 90	90% confidence level	Applied to short runs	MICRONITE
Capability to hold tolerance	Lower Permissible Tolerance	LPT sv (Shift & Variation)	Single and multiple causes	Important	MICRONITE
		LPT 6s (Six Sigma)		Advisory	MICRONITE

SUBJECT TO INVENTION

Method of optimal measurement and machining metrology

A software-implemented method for acquiring, visualizing, and analyzing metrology data for determining optimized inspection process and execution of defect-preventive machining control. The main objective of metrology optimized control is valuation and acceptance of ever shrinking process window.

Software comprises of two major parts: (1) super-precision measurement metrology and (2) integrated measurement and machining process metrology. Composition of data capture schemes reflects which part of metrology system is a target of investigation / acceptance.

Software introduces visual metrology analytics for determining effects of measurement and process variables on accuracy, precision, and capability of inspection process. A user may choose to design metrology tests with multiple causes of shift and variation in an effort to accommodate all parameters affecting the width of process window

Automatic metrology data analysis is used to accept a combination of shift and variation, to alter a process control model, or to dismiss a measuring element causing reject decision. Metrology optimized Inspection processes are used at various steps of operations such as First Article Inspection, process capability validation, real-time process control, and final inspection

Method is intended to be used for any type of measurement equipment and any type of manufacturing equipment separately or in the combination. The correct data acquisition and error-proof analytics will have a dramatic effect on the results of inspection and production.

Next-generation metrology data system and analytics

A MUST-HAVE TOOL FOR HIGH QUALITY MACHINNG

- Measurement metrology plan does not restrict the number of elements in a single set (gage, operator, inspector, fixture, method, etc.)
- Design of metrology plan has three options: (1) in-screen preparation of data entry matrix for single characteristic, (2) metrology plan template for single characteristic, (3) template for simultaneous study of large amounts of characteristics measured by CMM and Vision System
- Statistical metrology estimates are represented by four categories: (1) accuracy (shifts, bias), (2) variation (repeatability, reproducibility), (3) measuring and process capability, and (4) fixed control limits
- High-precision estimation of accuracy, precision and reproducibility can be independently determined for single elements (gage, operator, fixture, method, etc.)
- Contribution of measurement error into sample variation and capability indexes is precisely quantified
- In-screen formation of metrology groups allows to discover and quantify the interactive effect of causes of inaccuracy and imprecision
- Minimization of statistical errors allows to accept accuracy and precision in tolerance ranges down to 0.0001”
- Statistically valid STOP and Warning limits are determined for Pre-Control/SPC charts
- Metrology data and the results of analysis are integrated within the entire process control chain

THE METROLOGY SYSTEM APPLICATIONS

1. Tolerance-based validation and verification of accuracy, precision, and capability of measuring instruments and inspection methods
2. Operational metrology plans for rapid measurement and process capability approval
3. Metrology root cause analysis triggered by excessive variation or non-conformance
4. Integrated metrology and product quality database
5. Validation of short-run process capability across machines and operation
6. Validation of measurement capability of super-precision components

ROUTINELLY, MICRONITE UNVEILS HIDDEN CAUSES OF UNCONTROLLED VARIATION

Primary metrology testing is designed to quantify effects of all probable causes influencing measurement, process and product variation. With no exception, MICRONITE enforces inclusion of Gages, CMMs, Vision Systems, production equipment, and tooling into consolidated data capture and specialized visual analytics. MICRONITE replaces trial-and-error mentality with the solid machining-based data transformation resulting in engineering solutions. In many cases, MICRONITE offers the one and only key to problem resolution.

THE INTEGRATED METHODOLOGY

MICRONITE engineering metrology consists of the following distinct domains:

(1) measurement accuracy and precision,
(2) equipment accuracy and precision
(3) short-term process capability,
(4) multi-variable toolpath capability,
(5) tool wear rate and failure mode
(6) random product variation.

The system provides high-precision metrology analytics including statistical components of measurement system, real-time dynamic process models and offline machining control models

Super-precision measurement and machining process control

METROLOGY OPTIMIZED PROCESS CONTROL

MICRONITE made the leap in metrology innovation. Metrology optimized inspection process is established with assessment of all critical causes leading to a shrinkage of the process variation window. A software-implemented method is developed for acquiring, visualizing, and analyzing a combination of shift and variation coming from measuring and production equipment.

A user may choose to design general and operation-related metrology tests with an effort to accommodate critical parameters affecting the width of the process window. The correct planning, data acquisition and visual metrology analytics have a dramatic effect on the results of inspection.

Uniquely designed for metrological evaluation of measurement and machining process, MICRONITE offers flexible design of unscripted sampling plans, cross-reference convergence of system elements, and critical to quality visual analytics.

A single metrology plan may include all probable causes affecting accuracy (shifts), variation and capability of individual system elements and special groups. Wide-scope data acquisition and comprehensive analysis provide deep insights into sources of errors and have a decisive effect on functionalities of machining control.

Easy-to-use reliable software helps engineers read insights of measurement accuracy and precision much faster than any conventional method. With MICRONITE, the machine shop generates unbiased, accurate inspection data with the power of predictive zero-defect process and quality control.

CREATE A CAPABILITY IMPROVEMENT PROCESS

MICRONITE allows engineers to quickly and efficiently evaluate measurement capability of gages, CMMs and Vision Systems. The system provides automated repetitive steps to discover the level of measurement errors and their origin. Accuracy and repeatability of these instruments for hundreds of characteristics are computed in minutes. Low-risk validation of measurement accuracy and capability of modern CNC equipment drives effective digital transformation.

THE MACHINING CAPABILITY LIFE CYCLE

Tolerance-based validation and verification of accuracy and precision of measuring instruments along with tool and production equipment capability

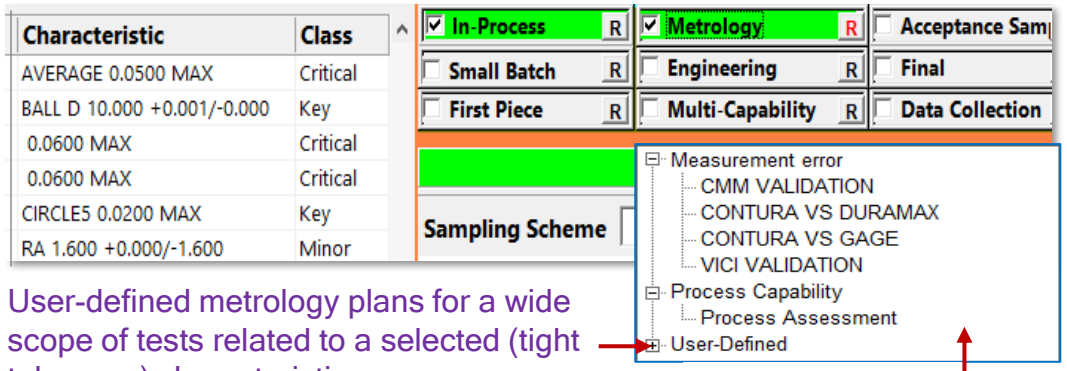
1. Rapid approval of set-up and process capability for incoming operations / jobs
2. Root cause capability analysis triggered by inferior indexes Cpk / Ppk
3. Integrated metrology and product quality database
4. Validation of short-run process capability across machines and operation
5. Validation of measurement and process capability of super-precision components
6. Determination of lower permissible tolerance for measuring instrument and production equipment

Confident planning and simplified data control with greater effectiveness

DEEP METROLOGY KNOWLEDGE OBTAINED BY VERSATALITY AND FLEXIBILITY OF PLANS

MICRONITE manages metrology planning for all types of measurements instruments and machining variables. There are two functions that provide a host of metrology solutions: (1) metrology sets for a single blueprint characteristic and (2) engineering metrology templates for a large amount of characteristics (CMMs and Vision Systems). Versatility of metrology plans is the driving force of measurement accuracy control. Each plan includes a list of prioritized causes of variation for input to the machining control functions.

Metrology is an object of the MICRONITE planning system



User-defined metrology plans for a wide scope of tests related to a selected (tight tolerance) characteristic

Metrology Lab

Engineering

Metrology templates for CMM/Vision System

METROLOGY IN LAYERED ERROR DETECTION

1. Precision of reference measuring instrument and reference inspection method
2. Accuracy, precision and capability data generated by any combination of one or more appraisers, measuring instruments, and methods
3. Accuracy, precision and capability data generated across machines
4. Accuracy, precision and capability data generated by a multi-phase tool wear process
5. Accuracy, precision and capability data generated by CMM and Vision System

OPERATIONAL METROLOGY PLAN

Unscripted metrology plans are focusing on operation capability hierarchy. In designing machining metrology tests considerable efforts should be expanded from measurement accuracy and precision to machine repeatability and to product variation localized by production volumes or phases of tool wear.

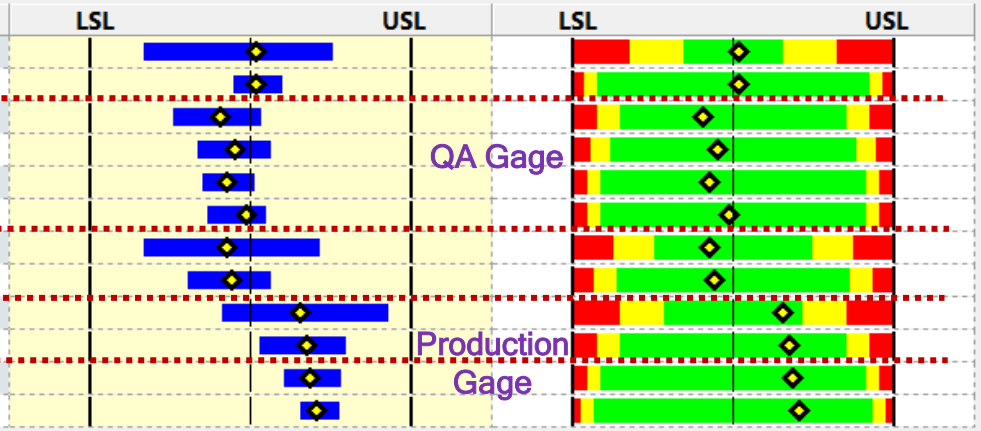
Part #1, 6 rdgs, same spot, QA gage, Inspector K.
Part #1, 6 rdgs, around, QA gage, Inspector K.
Part #1, 6 rdgs, same spot, Floor gage, Inspector K.
Part #1, 6 rdgs, same spot, QA gage, Operator J
Part #1, 6 rdgs, same spot, Floor gage, Operator J
Part #2, 6 rdgs, around, QA gage, Inspector K.
Part #2, 6 rdgs, around, Floor gage, Inspector K.
Part #2, 6 rdgs, around, Floor gage, Operator J.
6 consec. parts, QA gage, Inspecror K.
6 consec. parts, Floor gage, Inspector K.
6 random parts / 250, QA gage, Inspector K
6 random parts / 250, QA gage, Operator J.

Multi-level metrology in a single examination set

IN-SCREEN DATA ENTRY AND ANALYSIS 1

Tolerance 0.001”

	Notes	Shift M	Range	CP s	Cpk s
1	6 random pcs / 50 pcs lot, QA gage, Inspector R	11	58	0.96	0.92
2	6 consec. pcs / 50 pcs lot, QA gage, Inspector R	11	14	4.31	4.15
3	6 rdgs around, Part #1, QA gage, Inspector R	0	26	2.26	1.84
4	6 rdgs around, Part #2, QA gage, Inspector R	5	22	2.83	2.57
5	6 rdgs same spot, Part #1, QA gage, Inspector R	2	16	3.77	3.21
6	6 rdgs same spot, Part #2, QA gage, Inspector R	8	17	3.85	3.74
7	6 random pcs / 50 pcs lot, QA gage, Operator B.	2	54	1.30	1.11
8	6 consec. pcs / 50 pcs lot, QA gage, Operator B.	4	25	2.46	2.18
9	6 random pcs / 50 pcs lot, Production gage, Inspector R	25	51	1.17	0.80
10	6 consec. pcs / 50 pcs lot, Production gage, Inspector R	27	26	2.19	1.42
11	6 rdgs same spot, Part #1, Production gage, Inspector R	28	17	3.82	2.39
12	6 rdgs same spot, Part #1, Production gage, Operator B.	30	11	5.13	2.99



A single set
Gage (s) accuracy and repeatability, gage-to-gage reproducibility, roundness, operator-to-inspector reproducibility, machine repeatability, and product variation

% Abs. Variation Expert Actual 3 Sigma Options for sample spread

Acceptance CP Cpk PP Ppk CP / Cpk / Auto None

Optional values of capability indexes for acceptance decisions

Decisive step in integration of measurement and machining capability

Sort Ind.Grid Abs.Gage Sublot Size 0 Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5	6
1	0.85132	0.85164	0.85162	0.85127	0.85163	0.85163
2	2 6 consec. pcs / 50 pcs lot, QA gage, Inspector R		0.85151	0.85148	0.85156	0.85148
3	3 6 rdgs around, Part #1, QA gage, Inspector R		5145	0.85148	0.85138	0.85131

FINDING CREATIVE WAYS TO EXTRACT MORE VALUE FROM METROLOGY DATA

2

#	Notes
1	6 random pcs / 50 pcs lot, QA gage, Inspector R
2	6 consec. pcs / 50 pcs lot, QA gage, Inspector R
3	6 rdgs around, Part #1, QA gage, Inspector R
4	6 rdgs around, Part #2, QA gage, Inspector R
5	6 rdgs same spot, Part #1, QA gage, Inspector R
10	6 consec. pcs / 50 pcs lot, Production gage, Inspector R
11	6 rdgs same spot, Part #1, Production gage, Inspector R
12	6 rdgs same spot, Part #1, Production gage, Operator B.

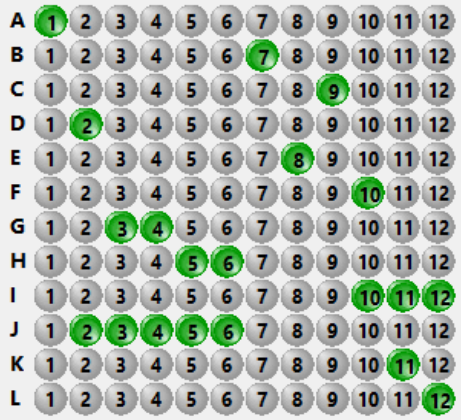
New method for transformation of metrology samples into alphanumeric matrices

The data matrix consists of a maximum of 12 samples with a maximum of 12 measurements in each sample. Samples are elements of the system, such as gages and operators. Metrology groups, consisting of two or more elements can be formed by using the alphanumeric matrix. From a plan for single elements to creating a grouped metrology, the user gets deep insights to solve measurement accuracy challenges.

Transformation of metrology samples into alphanumeric data matrices

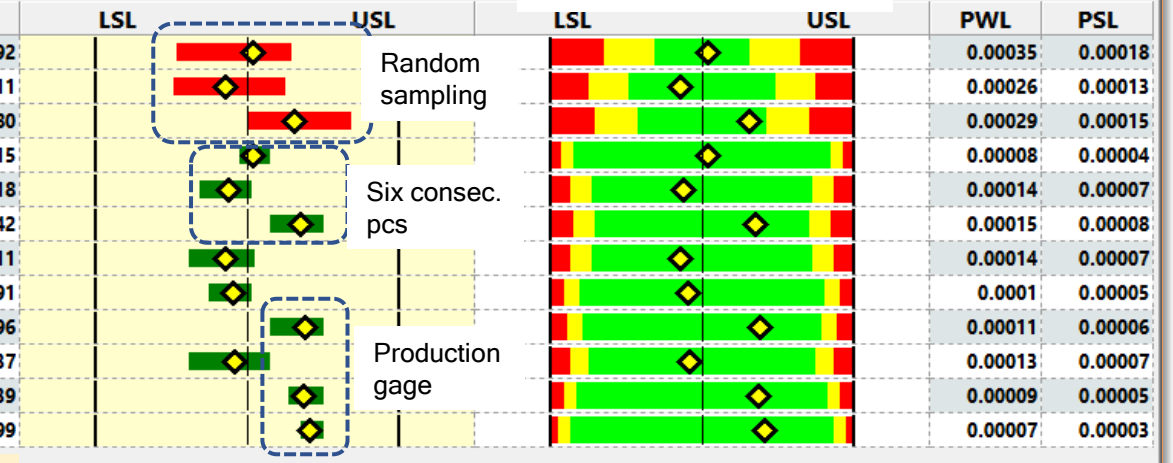
1. Cross-reference of measuring instruments, inspection methods, and appraisers
2. Cross-reference of Gages, CMMs, and Vision Systems
3. Cross-reference of measuring instruments, process capability, and product variation

Matrix of samples and groups



Averages and Variation

#	Shift M	Range	CP s	Cpk s	PWL	PSL
A	0.00009	0.00037	0.96	0.92	0.00035	0.00018
B	0.0	0.00036	1.30	1.11	0.00026	0.00013
C	0.00023	0.00033	1.17	0.80	0.00029	0.00015
D	0.00009	0.00009	4.31	4.15	0.00008	0.00004
E	0.00001	0.00016	2.46	2.18	0.00014	0.00007
F	0.00025	0.00017	2.19	1.42	0.00015	0.00008
G	0.0	0.00021	2.45	2.11	0.00014	0.00007
H	0.00003	0.00013	3.20	2.91	0.0001	0.00005
I	0.00026	0.00017	3.17	1.96	0.00011	0.00006
J	0.00003	0.00026	2.59	2.37	0.00013	0.00007
K	0.00026	0.00011	3.82	2.39	0.00009	0.00005
L	0.00028	0.00007	5.13	2.99	0.00007	0.00003



Zero-defect process control window

Marking 1 to 12 numerical rows within an alphabetical matrix of single and grouped metrology objects

Accuracy, variation, and capability of single and grouped elements of measurement and machining metrology system

Acceptance | CP | Cpk | PP | Ppk | CP / Cpk / Auto | None

0.85139 | 0.85148 | 0.85141

An excellent way of in-screen analysis of shifts and variation

ULTRA-FAST QUANTIFICATION OF CRITICAL CAUSES

3

A. Reference Inspector, QA gage,

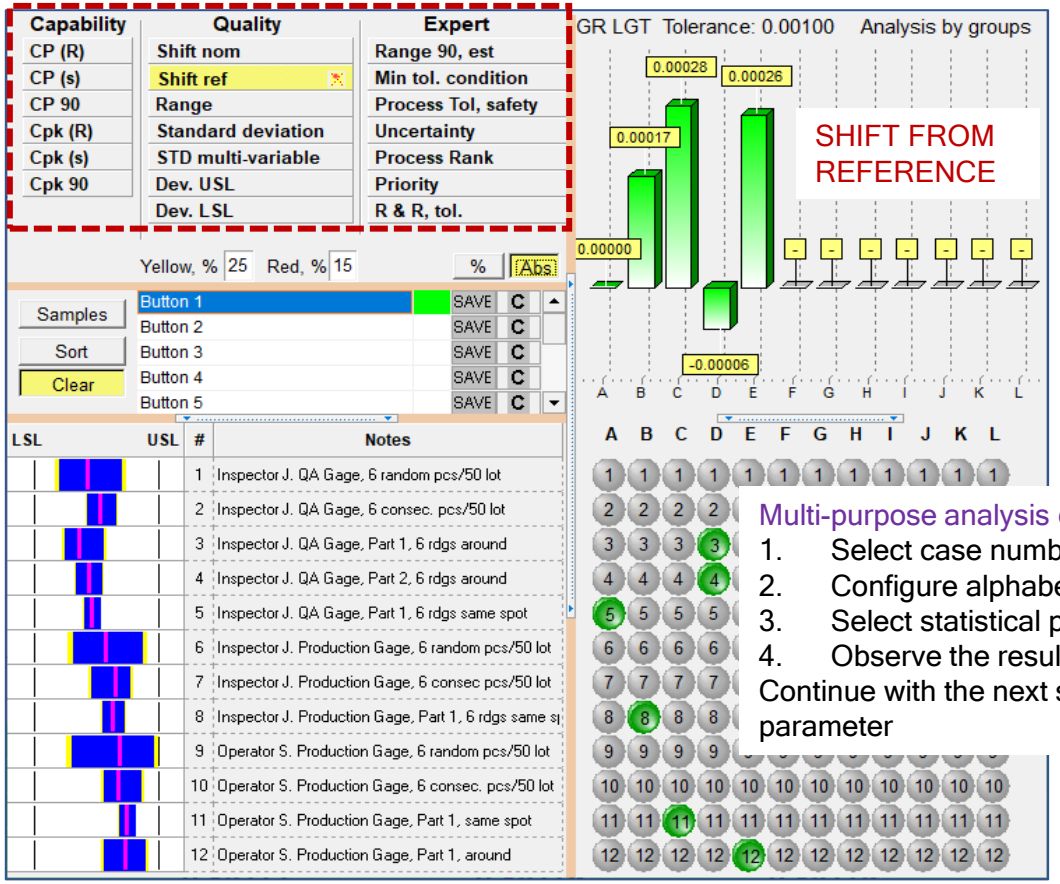
B. Inspector, Production gage, + 0.00017”

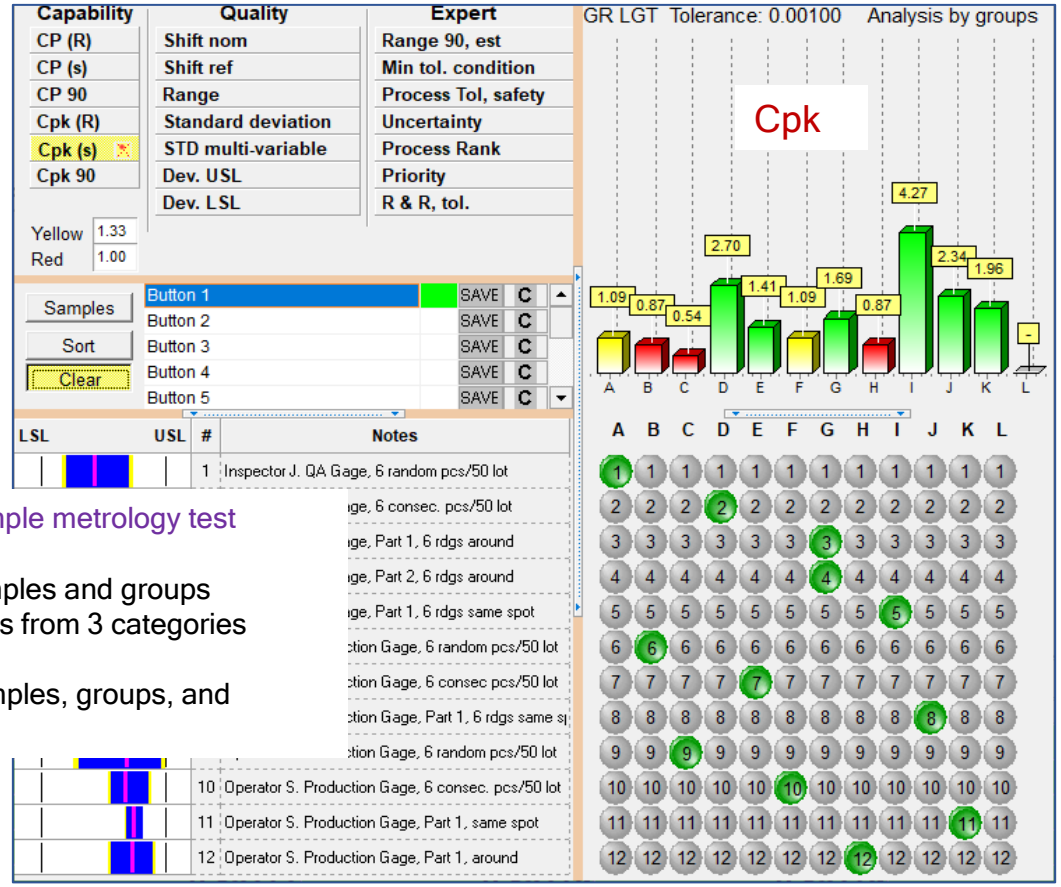
C. Operator, Production gage, + 0.00028”

A, B, C
6 random pcs
Cpk 0.6-0.8

D, E, F
6 rconsec. Pcs
Cpk 1.1 - 2,7

I, J. K
6 rdgs around
Cpk 2.0-4.0





Multi-purpose analysis of 12-sample metrology test

1. Select case number
2. Configure alphabetical samples and groups
3. Select statistical parameters from 3 categories
4. Observe the results

Continue with the next set of samples, groups, and parameter

Comprehensive analytics of measurement and machining process

4

Report Columns: Spread Shifts Tolerance Control Capability Decision Deviation

Category	Shift from ref	Shift from ref...	Range, %	CP (s)	Cpk (s)	Permissible tol. SV
Total capability						
Individual elements						
Reference: Inspector, QA gage, same spot	0.00004	4	8	4.48	4.27	0.00022
Inspector, Production gage, same spot	0.00021	21	11	3.30	2.34	0.00030
Roundness, Inspector, QA gage, 6 rdgs arou	-0.00006	-6	20	2.04	1.69	0.00049
Consecutive 6 pcs, Inspector, QA gage	0.00011	11	15	2.95	2.70	0.00034
Random 6 pieces, Inspector, QA gage	0.00000		33	1.25	1.09	0.00080
Random 6 pieves, Inspector, Productionj gage	0.00001	1	13	2.58	2.34	0.00039
Combination units						
Inspector, QA gage, same spot, around, consec	0.00005	5	40	1.40	1.33	0.00072
Inspector, QA & production gage, all samples	0.00005	5	49	1.29	1.24	0.00077
Operator, Production gage, same spot, around,	0.00025	25	21	1.99	1.09	0.00050

Inspection Set	SAVE
Button 1	SAVE
Button 2	SAVE
Button 3	SAVE
Button 4	SAVE
Button 5	SAVE
Button 6	SAVE
Button 7	SAVE
Button 8	SAVE
Button 9	SAVE
Button 10	SAVE

A	B	C	D	E	F	G	H	I	J	K	L	#	Individual Items
1	1	1	1	1	1	1	1	1	1	1	1	1	Inspector J. QA Gage, 6 random pcs/50 lot
2	2	2	2	2	2	2	2	2	2	2	2	2	Inspector J. QA Gage, 6 consec. pcs/50 lot
3	3	3	3	3	3	3	3	3	3	3	3	3	Inspector J. QA Gage, Part 1, 6 rdgs around
4	4	4	4	4	4	4	4	4	4	4	4	4	Inspector J. QA Gage, Part 2, 6 rdgs around
5	5	5	5	5	5	5	5	5	5	5	5	5	Inspector J. QA Gage, Part 1, 6 rdgs same spot
6	6	6	6	6	6	6	6	6	6	6	6	6	Inspector J. Production Gage, 6 random pcs/50 lot
7	7	7	7	7	7	7	7	7	7	7	7	7	Inspector J. Production Gage, 6 consec pcs/50 lot
8	8	8	8	8	8	8	8	8	8	8	8	8	Inspector J. Production Gage, Part 1, 6 rdgs same spot
9	9	9	9	9	9	9	9	9	9	9	9	9	Operator S. Production Gage, 6 random pcs/50 lot
10	10	10	10	10	10	10	10	10	10	10	10	10	Operator S. Production Gage, 6 consec. pcs/50 lot
11	11	11	11	11	11	11	11	11	11	11	11	11	Operator S. Production Gage, Part 1, same spot
12	12	12	12	12	12	12	12	12	12	12	12	12	Operator S. Production Gage, Part 1, around

ART AND SCIENCE OF METROLOGY DATA CONTROL

Flexible design of metrology report

1. Organization of 3-layer report (category, group, sub-group) using placement of numerical samples into alphanumerical matrix
2. Selection of applied statistical estimates from six columns
3. Each column includes estimates of shift (accuracy), spread (repeatability & reproducibility), capability, and permissible tolerance

Drill down from product variation to process capability and to measurement accuracy - in 30 minutes

MICRONITE allows every machine shop to solve its own issues with efficiency of inspection process and acceptable level of machining process capability. Innovative methodology helps validate in minutes short-run process capability.

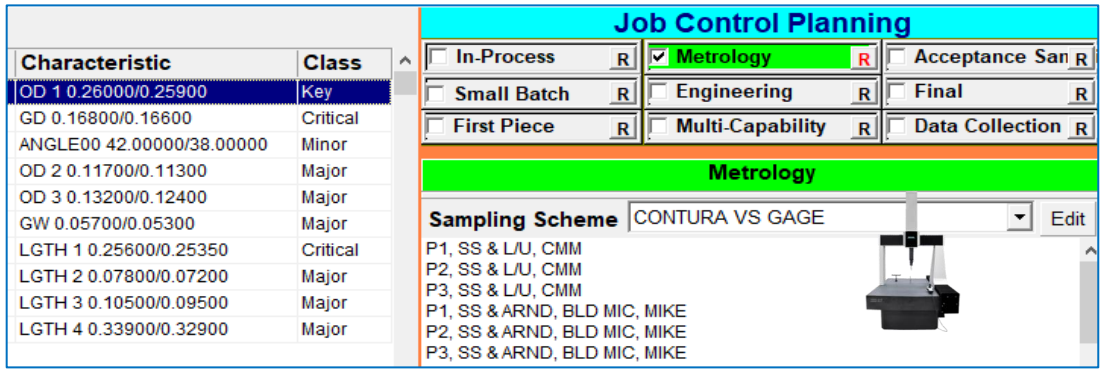
SOLUTIONS FOR CHALLENGING JOBS

Accuracy & shifts
CMM to hand-held gage
CMM to CMM
CMM to Vision System
Vision System to hand-held gage
Vision System to Vision System

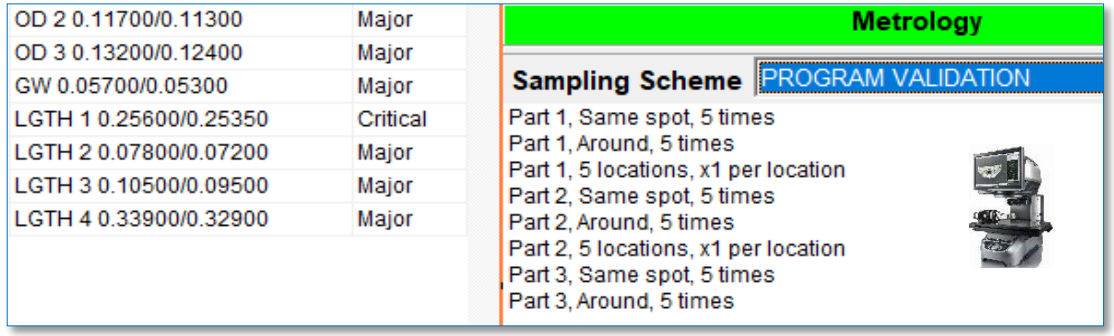
Repeatability & precision
CMM: Load / Unload, multiple readings
CMM: Consecutive pieces, same spot
Vision System: Multiple locations
Vision System: Consec. pcs, same spot

Process repeatability & capability
CMM: 5 to 10 consec. pcs, around/along
CMM: Series of samples with consec. pcs
Vision System: 5 to 10 consec. pcs
Vision System: Series of samples with consec. pcs

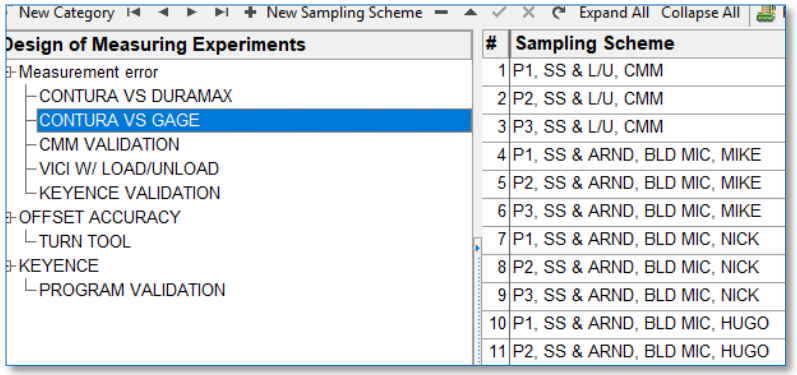
Engineering Capability
CMM: Samples of random/consec. pieces
CMM data by fixtures, pallets, nests, etc.
Vision System: random/consec. pieces
Vision System- Gage: random/consec. pcs
CMM-Vision System-Gage: metrology samples



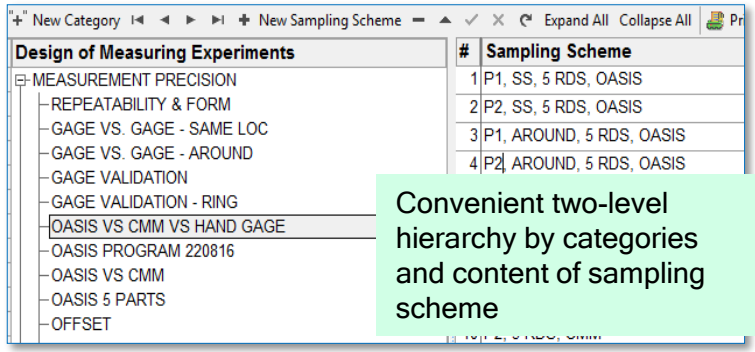
A unique, compactly designed metrology plan



Large amount of CMM/Vision System characteristics - all in one test



User-built templates for analysis and validation of measurements taken by CMMs, Vision Systems, and hand-held gages



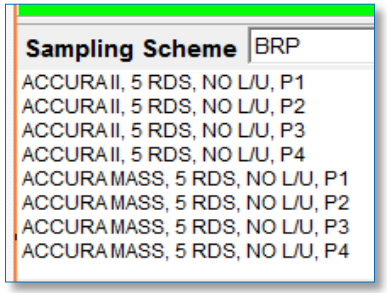
Convenient two-level hierarchy by categories and content of sampling scheme

THE ROLE OF MICRONITE IN EXPANDED METROLOGY INSIGHTS

New metrology models are needed for CMM/Vision to control tight tolerances and extreme machining. There is no general recipe like R&R that fits every application. Our uniquely designed software enables the process metrology team to rapidly conduct root cause analysis.

Design of metrology inspection schemes

Data sets for measurement quality diagnostics and metrological assessment of process capability

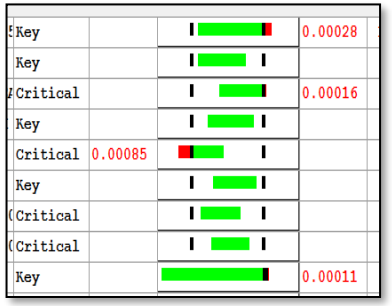


- Repeatability: 1 to 5 parts, 3 to 5 measurements, same spot, load/unload
- Accuracy: 1 to 5 parts with reference point
  - CMM QA Lab
  - Hand-held gage
- Reproducibility: samples of accuracy and repeatability for two and more CMMs

Eight samples in one line for characteristic

Total Quality Assessment

Visual and statistical representation of each characteristic by a full set of metrology samples

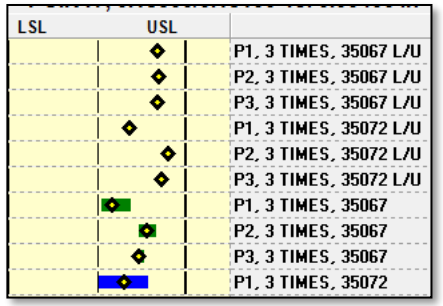


- Population spread charts with actual and predicted spread boundaries
- Filtering by class and statistics
- Finding metrology-critical features
- Sorting by a wide range of valuable distributional and non-distributional measures

From TQA to samples for each characteristic with a click

Metrology analytics by a characteristic

Assessment of shifts, variation, capability, control limits, and Lower Permissible Tolerance



- Charts of ranges and averages
- Charts of process control limits
- Four groups of metrological measures including accuracy, repeatability, reproducibility, capability, and variation
- Convergence of original samples into metrological groups

Smart metrology reports

Hierarchical design of data sets and selection of estimates for CMM certification and error quantification

Range 90	Range, %	Permissible tol. SV	CP (s)
0.00454	13	0.00566	3.89
0.00376	11	0.00463	4.75
0.00358	11	0.00525	4.19
0.00950	27	0.01359	1.62
0.00968	27	0.01408	1.56
0.01003	28	0.01452	1.52

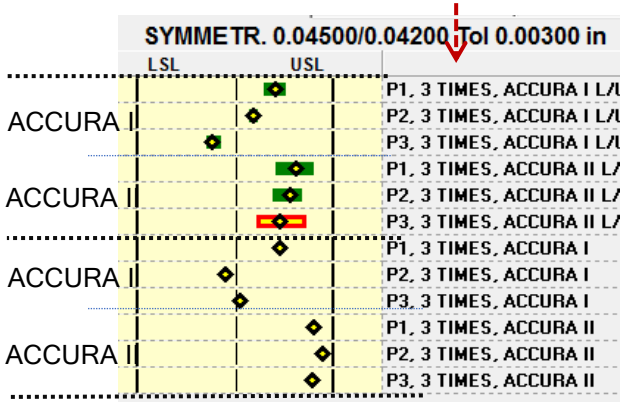
- 3-tier layout of metrology report using a samples' convergence pad
- Statistical assessment of samples groups
- Cause-and-effect analysis
- Validation of instruments, methods, and inspection procedures

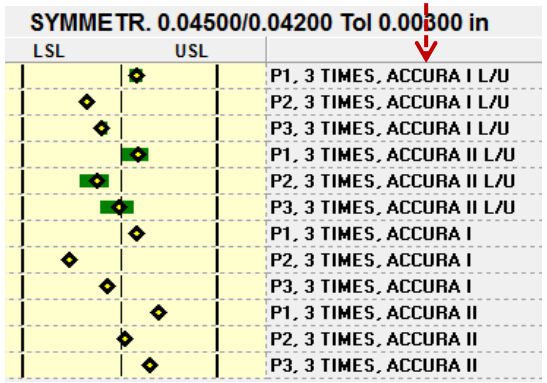
A MICRONITE framework for CMM error detection and prevention

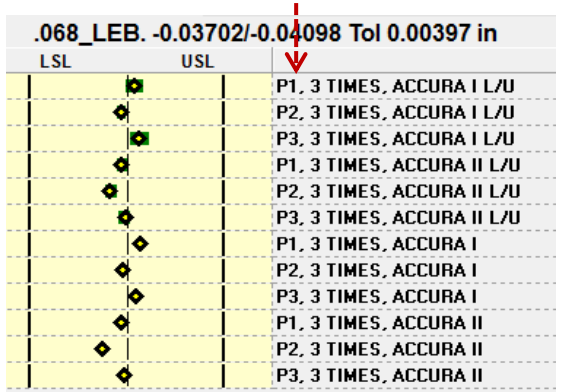
In this example, combined variation is coming from a sample involving 2 CMMs, 3 consecutive parts, and 3 measurements on the same spot with load/unload. Total variation for each characteristic varies from 10% to over 100% of tolerance. Major contributors into total variation are (1) shift between two CMMs, (2) effect of load/unload, (3) process repeatability, and (4) CMM's repeatability. Measurement capability is assessed by MICRONITE capability to hold tolerance (in.)

ACCURA I	Part #1	3 rdgs Load
		3 rdgs Unload
	Part #2	3 rdgs Load
		3 rdgs Unload
	Part #3	3 rdgs Load
		3 rdgs Unload
ACCURA II	Part #1	3 rdgs Load
		3 rdgs Unload
	Part #2	3 rdgs Load
		3 rdgs Unload
	Part # 3	3 rdgs Load
		3 rdgs Unload

Pl	Name	Class	LSL	USL	Tol, %	Capable to hold	Range	LSL	USL	Dev. LSL	Dev. US
Inspection Type : Metrology 98 Items											
Operation : COMPLETE 84 Items											
D	88. .336 - .340 -B- NOTE 6_-1.000_X	Critical			142.40%	0.00142	0.00083	0.3375	0.3385	0.00063	
	27. .042-.045 at 1.5 NOTE 6	Key			107.88%	0.00324	0.00177	0.042	0.045		0.0005
	27. .042-.045 at .700 NOTE 6	Key			87.95%	0.00264	0.00140	0.042	0.045		
	88. .336 - .340 -B- NOTE 6_-.025_X	Critical			72.19%	0.00289	0.00168	0.336	0.34	0.00002	
	84. TP_d.473-.477.Z	Key			65.18%	0.00208	0.00113	-0.033596	-0.030402	0.00009	
	REF d.473-.477 for TP	Critical			62.08%	0.00248	0.00143	0.473	0.477		
	88. .336 - .340 -B- NOTE 6_+1.300_X	Critical			61.69%	0.00247	0.00142	0.336	0.34		
	27. .042-.045 at -C- NOTE 6	Key			53.90%	0.00162	0.00092	0.042	0.045		
	84. TP_d.473-.477	Critical			50.55%	0.00323	0.00188	-0.003194	0.003194		0.0000
	87. TP_d.475_Z	Critical			49.49%	0.00198	0.00113	-0.033999	-0.029999		
	87. .032 BASIC_Left	Critical			47.04%	0.00235	0.00141	0.0295	0.0345		
	56b TP_d.067-.069_L_NOTE 6.Z	Key			42.30%	0.00168	0.00095	-0.040984	-0.037016		
	67b .0390 ± .002_left	Critical			40.94%	0.00164	0.00097	0.037	0.041		
	56a TP_d.067-.069 _R_NOTE 6.Z	Critical			38.99%	0.00158	0.00091	-0.041024	-0.036976		







MICRONITE to the industry: precise multi-dimensional metrology analytics in 15 minutes

KEYENCE

Three consecutive parts are measured in different locations and on same spot. MICRONITE allows to determine metrological properties of Vision System

12-sample Inspection scheme

#	Keyence		
1	Part 1	Same spot	5 times
2	Part 2	Same spot	5 times
3	Part 3	Same spot	5 times
4	Part 1	5 locations	One reading
5	Part 2	5 locations	One reading
6	Part 3	5 locations	One reading
7	Part 1	Around	One reading
8	Part 2	Around	One reading
9	Part 3	Around	One reading
MICROMETER			
10	Part 1	Around	5 readings
11	Part 2	Around	5 readings
12	Part 3	Around	5 readings

MICRONITE quality analytics enables to focus on metrology-vulnerable characteristics

Each line represents statistics of total 12 samples

Predictive statistics

Characteristic	Class	Dev. LSL	LSL	USL	Dev. USL	Insp. pcs	Def	Tolerance	Tol, %	Capable to hold
ACH 60 10 Items										
Items										
1 od 1 0.26000/0.25900	Key				0.00007	60	2	0.001	82.68%	0.00105
2 gd 0.16800/0.16600	Critical					45	0	0.002	45.86%	0.00097
8 lgth 1 0.25600/0.25350	Critical					45	0	0.0025	62.78%	0.00191
4 od 2 0.11700/0.11300	Major					45	0	0.004	16.50%	0.00066
5 od 3 0.13200/0.12400	Major					45	0	0.008	10.78%	0.0005
6 gw 0.05700/0.05300	Major					45	0	0.004	38.96%	0.0012
9 lgth 2 0.07800/0.07200	Major					45	0	0.006	15.43%	0.00083
10 lgth 3 0.10500/0.09500	Major					45	0	0.01	10.78%	0.00084
11 lgth 4 0.33900/0.32900	Major									0.00127
3 angle00 42.00000/38.00000	Minor									0.3961
ACH 62 10 Items										
CH 62 10 Items										
1 od 1 0.26000/0.25900	Key					45	0	0.001	41.61%	0.00055
2 gd 0.16800/0.16600	Critical					45	0	0.002	25.12%	0.00095
8 lgth 1 0.25600/0.25350	Critical				0.00197	45	29	0.0025	140.25%	0.00508
4 od 2 0.11700/0.11300	Major					45	0	0.004	41.22%	0.00122
5 od 3 0.13200/0.12400	Major					45	0	0.008	10.78%	0.00078
6 gw 0.05700/0.05300	Major					45	0	0.004	11.17%	0.00054
9 lgth 2 0.07800/0.07200	Major					45	0	0.006	10.78%	0.00062
10 lgth 3 0.10500/0.09500	Major					45	0	0.01	10.78%	0.00082
11 lgth 4 0.33900/0.32900	Major					45	0	0.01	10.78%	0.00056
3 angle00 42.00000/38.00000	Minor					45	0	4.0	21.35%	0.93576

Machine 60 Part 260238

Machine 62 Part 260238

Control panel TQA (Total Quality Assessment)

Access to visual analytics for each characteristic with a click

From TQA control panel

0.26000/0.25900	Key			0.00007

Averages and Variation | Averages and Alert Limits

#	Notes	Shift M	CP s	Cpk s	PSL
1	Part 1, Same spot, 5 times	0.0	9.00	8.32	0.00001
2	Part 1, Around, 5 times	0.00004	2.42	2.06	0.00006
3	Part 1, 5 locations, x1 per location	0.00006	3.85	3.10	0.00004
4	Part 2, Same spot, 5 times	0.00008	9.00	6.95	0.0
5	Part 2, Around, 5 times	0.00008	3.06	2.34	0.00005
6	Part 2, 5 locations, x1 per location	0.00008	2.61	2.00	0.00006
7	Part 3, Same spot, 5 times	0.00002	9.00	7.88	0.00001
8	Part 3, Around, 5 times	0.00006	3.50	2.78	0.00004
9	Part 3, 5 locations, x1 per location	0.00006	1.86	1.49	0.00008
10	Part 1, Around, MIC, 5 times	0.00024	2.92	1.29	0.00005
11	Part 2, Around, MIC, 5 times	0.00029	1.38	0.47	0.00011
12	Part 3, Around, MIC, 5 times	0.00042	1.29	0.10	0.00012

Critical MICRONITE findings

- MIC vs Keyence is + 0.0003” (30% of tolerance)
- Excellent Keyence repeatability (measurements are taken on the same spot)
- Substantial variation due to part location and part roundness
- Convergence of samples into groups improves statistical evidence of accuracy and precision

% | Abs. | Variation: Expert | Actual | 3 Sigma

Acceptance: CP | Cpk | PP | Ppk | CP / Cpk / Auto | None

Sort | Ind.Grid | Abs.Gage | Sublot Size 100

Data is provided by a measurement device KEYENCE Instructions: KEYENCE

#	1	2	3	4	5
1	0.25954	0.25953	0.25955	0.25954	0.25953

A platform for digital integration of measurement and machining capability

MICRONITE MAKES CONTROL OF ACCURACY AND PRECISION A HIGH PRIORITY

Operational and general metrology data aligned perfectly with commitment to high product quality

MICRONITE Metrology gives answers to hidden errors in process and quality data

Metrology in control of extremely tight tolerances

Analytics for approval of CMM accuracy and precision

Analytics for approval of Vision System accuracy and precision

Metrology in design for reduced inspection plan and lights-out

Accuracy and precision of measuring instruments and inspection methods

MICRONITE

Metrology in high-precision measurement and machining process

Metrology in short-run capability across machines and operations

Metrology in operational Inspection and real-time process control

Central measurement system and capability data repository

Metrology in control plan and predictive model optimization

Solutions to measuring instrument and equipment variation

Metrology in quality of extreme machining

Tool-and-quality accuracy & precision insights

Real-time verification of multi-variable tool capability

Metrology in productivity and cost solutions

High-mix low volume production

High-volume and continuous production

Metrology in approval of process launch

Metrology in process capability by Cpk/Ppk

Users can leverage deep metrology knowledge obtained in multi-source studies and routine tests to discover critical causes of errors and undertake necessary corrective actions

Simplicity of basic metrology studies for short-run machining

Characteristic	Tolerance	Parts	CNC	Instruments	Observers	Sampling	Material
OD	0.0006”	Four	Two	One	One	Part ## 2, 4, 10, 12	Stainless 15-5PH

1

Averages and Variation | Averages and Alert Limits

#	Notes	Shift N	Range	PP	Ppk
1	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 2 and #4, 3 around	12	30	1.18	0.89
2	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 2 and #4, 3 around	-16	23	2.01	1.36
3	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 10 and #12, 3 around	26	20	2.24	1.07
4	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 10 and #12, 3 around	25	13	2.84	1.42
5					

1	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 2 and #4, 3 around
2	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 2 and #4, 3 around
3	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 10 and #12, 3 around
4	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 10 and #12, 3 around

LSL USL LSL USL

Edit Notes

% Abs. Variation Expert Actual 3 Sigma

Acceptance CP Cpk PP Ppk 1.33 CP / Cpk / Auto None

Sort Abs.Grid Ind.Gage Sublot Size 0 Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5	6
1	0.0001	0	0	0.00016	0.00018	0

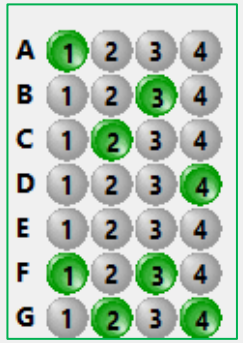
Uncovering basic correlations

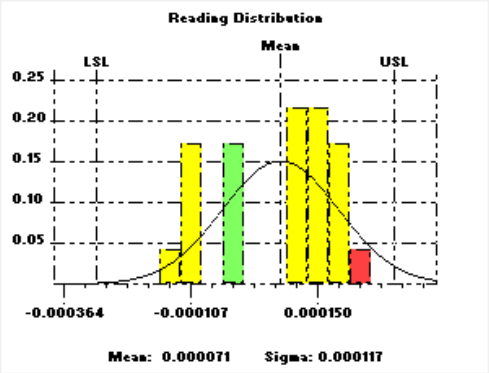
2

Histogram | Tolerance analysis | Columns stats | Columns | Instructions | Metrology Samples | **Metrology Groups** | Statsman

#	Notes
1	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 2 and #4, 3 around
2	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 2 and #4, 3 around
3	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 10 and #12, 3 around
4	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 10 and #12, 3 around
5	
6	
7	
8	
9	
10	
11	
12	

1	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 2 and #4, 3 around
2	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 2 and #4, 3 around
3	Part # 4235, Dia 0.4563" +/- 0.0003"; pcs # 10 and #12, 3 around
4	Part # 7895, Dia 0.5125" +/- 0.0003"; pcs # 10 and #12, 3 around





Matrix of samples and groups

#	Shift N	Range	PP	Ppk	Averages and Variation (LSL – USL)	Averages and Alert Limits (LSL – USL)	PWL	PSL
A	12	30	1.18	0.89			28	15
B	26	20	2.24	1.07			15	8
C	-16	23	2.01	1.36			17	9
D	25	13	2.84	1.42			12	6
E	0	0	0.00	0.00			0	0
F	19	37	1.29	0.79			26	14
G	4	57	0.74	0.67			45	24
H								
I								
J								
K								
L								

C | Abs. | % | Variation | Expert | Actual | 3 Sigma | Acceptance | CP | Cpk | PP | Ppk 1.33 | CP / Cpk / Auto | None

Sort | Abs.Grid | Ind.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5	6
1	0.0001	0	0	0.00016	0.00018	0

Metrology testing for dynamic process capability

1

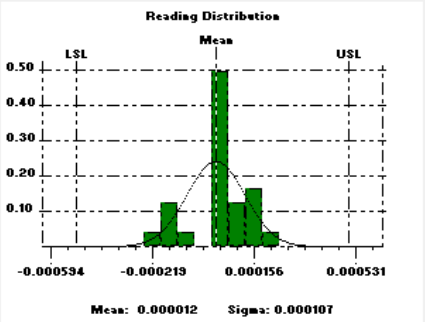
[812] 305.BALL D 0.00000 +0.00050/-0.00050 BALL DIAMETER <Operation> Part:SLINGSHOT - 737124 SHAPER Work Order:STATISTICS

Histogram | Tolerance analysis | Columns stats | Columns | Instructions | Metrology Samples | **Metrology Groups** | Statsman

#	Notes
1	Part # 123452, OD 0.912 +/- 0.0005, pieces # 2,4 6 8, 10; QA gage
2	Part # 737124, OD 0.863, pieces # 2,4 6 8, 10; QA gage
3	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 QA gage
4	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 QA gage
5	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 Floor gage
6	
7	
8	
9	
10	
11	
12	

1	Part # 123452, OD 0.912 +/- 0.0005, pieces # 2,4 6 8, 10; QA gage
2	Part # 737124, OD 0.863, pieces # 2,4 6 8, 10; QA gage
3	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 QA gage
4	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 QA gage
5	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 Floor gage

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5
D	1	2	3	4	5
E	1	2	3	4	5



Matrix of samples and groups

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5
D	1	2	3	4	5
E	1	2	3	4	5
F	1	2	3	4	5
G	1	2	3	4	5
H	1	2	3	4	5
I	1	2	3	4	5
J	1	2	3	4	5
K	1	2	3	4	5
L	1	2	3	4	5

Averages and Variation | Averages and Alert Limits

#	Shift N	R 90	PP	Ppk	PWL	PSL
A	7	56	1.28	1.11	26	14
B	-9	28	2.06	1.69	16	9
C	5	23	2.61	2.37	13	7
D	-2	61	1.58	1.53	21	11
E	0	72	1.45	1.44	23	12
F						
G						
H						
I						
J						
K						
L						

C | Abs. | % | Variation | Expert | Actual | 3 Sigma | Acceptance | CP | Cpk | PP | Ppk 1.33 | CP / Cpk / Auto | None

Sort | Abs.Grid | Ind.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5
1	0.0001	0.00015	0	-0.00012	0.00021
2	0	0	0	-0.00021	0

Five CNC Turning Centers are under MICRONITE scrutiny

Characteristic	Tolerance	Parts	CNC	Instruments	Observers	Sampling	Material
OD	0.001”	Five	Five	Two	One	Part ## 2, 4, 6, 8, 10	4340 Alloy Steel

1

Averages and Variation | Averages and Alert Limits

#	Notes	Shift N	R 90	PP	PP
1	Part # 123452, OD 0.912 +/- 0.0005, pieces # 2,4 6 8, 10; QA gage	10	50	1.28	1.28
2	Part # 737124, OD 0.863, pieces # 2,4 6 8, 10; QA gage	-4	33	1.77	1.77
3	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 QA gage	10	42	1.49	1.49
4	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 QA gage	-9	25	2.06	2.06
5	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 Floor gage	5	20	2.61	2.61
6	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 Floor gage	20	14	4.01	4.01
7	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around QA gage	13	32	2.06	2.06
8	Part # 123452, OD 0.912, pieces # 6, 5 rdgs around QA gage	13	32	1.94	1.94
9	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around QA gage	24	26	2.44	2.44
10	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around Floor gage	28	19	2.68	2.68
11	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around Floor gage	33	20	3.09	3.09
12					

LSL USL LSL USL

1	Part # 123452, OD 0.912 +/- 0.0005, pieces # 2,4 6 8, 10; QA gage
2	Part # 737124, OD 0.863, pieces # 2,4 6 8, 10; QA gage
3	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 QA gage
4	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 QA gage
5	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 Floor gage
6	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 Floor gage
7	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around QA gage
8	Part # 123452, OD 0.912, pieces # 6, 5 rdgs around QA gage
9	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around QA gage
10	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around Floor gage
11	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around Floor gage

Abs. Variation: Expert | Actual | 3 Sigma

Acceptance: CP | Cpk | PP 1.33 | Ppk | CP / Cpk / Auto | None

Sort | Abs.Grid | Ind.Gage | Subplot Size 0

Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5
5	0	0	0.0001	0.00013	0
6	0.00018	0.00016	0.00025	0.00023	0.000

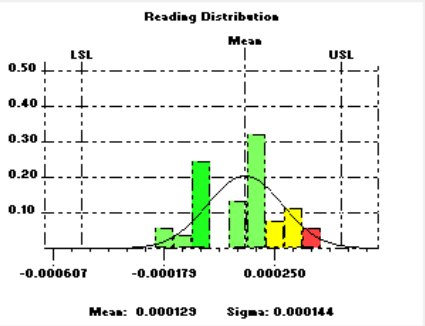
Exploring the total capability potential

2

[812] 305.BALL D 0.00000 +0.00050/-0.00050 BALL DIAMETER <Operation> Part:SLINGSHOT - 737124 SHAPER Work Order:STATISTICS

Histogram | Tolerance analysis | Columns stats | Columns | Instructions | Metrology Samples | **Metrology Groups** | Statsman

#	Notes
1	Part # 123452, OD 0.912 +/- 0.0005, pieces # 2,4 6 8, 10; QA gage
2	Part # 737124, OD 0.863, pieces # 2,4 6 8, 10; QA gage
3	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 QA gage
4	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 QA gage
5	Part # 346745, OD 0.434 pieces # 2,4 6 8, 10 Floor gage
6	Part # 546321, OD 0.524 pieces # 2,4 6 8, 10 Floor gage
7	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around QA gage
8	Part # 123452, OD 0.912, pieces # 6, 5 rdgs around QA gage
9	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around QA gage
10	Part # 123452, OD 0.912, pieces # 2, 5 rdgs around Floor gage
11	Part # 123452, OD 0.912, pieces # 10, 5 rdgs around Floor gage
12	



Matrix of samples and groups

	1	2	3	4	5	6	7	8	9	10	11
A	1	2	3	4	5	6	7	8	9	10	11
B	1	2	3	4	5	6	7	8	9	10	11
C	1	2	3	4	5	6	7	8	9	10	11
D	1	2	3	4	5	6	7	8	9	10	11
E	1	2	3	4	5	6	7	8	9	10	11
F	1	2	3	4	5	6	7	8	9	10	11
G	1	2	3	4	5	6	7	8	9	10	11
H	1	2	3	4	5	6	7	8	9	10	11
I	1	2	3	4	5	6	7	8	9	10	11
J	1	2	3	4	5	6	7	8	9	10	11
K	1	2	3	4	5	6	7	8	9	10	11
L	1	2	3	4	5	6	7	8	9	10	11

Averages and Variation | Averages and Alert Limits

#	Shift N	R 90	PP	Ppk	PWL	PSL
A	-4	38	1.77	1.63	19	10
B	20	16	4.01	2.44	8	4
C	28	21	2.68	1.19	12	7
D	-9	28	2.06	1.69	16	9
E	5	23	2.61	2.37	13	7
F	13	36	2.06	1.54	16	8
G	24	29	2.44	1.29	14	7
H	13	36	1.94	1.43	17	9
I	33	22	3.09	1.05	11	6
J	2	82	1.27	1.22	26	14
K	22	66	1.59	0.89	21	11
L	13	100	1.16	0.86	29	15

C | Abs. | % | Variation | Expert | Actual | 3 Sigma | Acceptance | CP | Cpk | PP 1.33 | Ppk | CP / Cpk / Auto | None

Sort | Abs.Grid | Ind.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

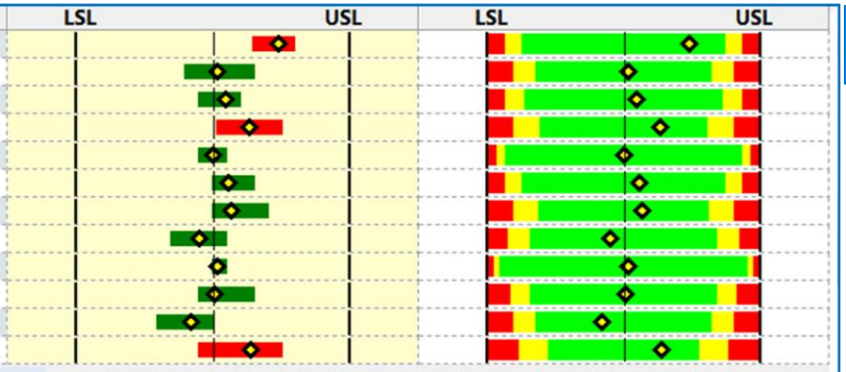
#	1	2	3	4	5
5	0	0	0.0001	0.00013	0
6	0.00018	0.00016	0.00025	0.00023	0.00016

Planting the seeds of factory-wide process capability for short runs

Characteristics	Tolerance	Parts	CNC	Instruments	Observers	Sampling	Material
OD, Groove, Length	0.001”	Four	Four	One	One	Part ## 2, 4, 10, 12	Stainless 410

1

#	Notes	R 90	PSL	PP	Ppk
1	ZG-737125, M9, OD 1.45 +/- .0005, 5 Consec Pcs.	23	7	2.56	1.33
2	ZG-737125, M9, Shoulder Length .578 +/- .0005, 5 Consec Pcs.	38	10	1.83	1.76
3	ZG-737125, M9, Height 5.250 +/- .0005, 5 Consec Pcs.	24	7	2.36	2.12
4	X6014-WP1, M2, OD 1.057 +/- .0005, 5 Consec Pcs.	35	10	1.71	1.25
5	X6014-WP1, M2, Length .475 +/- .0005, 5 Consec Pcs.	15	4	4.71	4.71
6	X6014-WP1, M2, OD 1.665 +/- .0005, 5 Consec Pcs.	23	7	2.56	2.25
7	4601950, M6, Groove Diameter .936 +/-.0005, 5 Consec Pcs.	32	10	1.71	1.47
8	4601950, M6, Length 1.263 +/-.0005, 5 Consec Pcs.	30	8	2.11	1.90
9	4601950, M6, Height 2.652 +/-.0005, 5 Consec Pcs.	8	3	6.09	5.84
10	R44AR-2-1, M21, Width .7490 +/- .0005, 5 Consec Pcs.	31	9	2.03	1.99
11	R44AR-2-1, M21, Depth .542 +/- .0005, 5 Consec Pcs.	31	10	1.83	1.54
12	R44AR-2-1, M21, OD .710 +/- .0005, 5 Consec Pcs.	45	12	1.46	1.05



Estimates of Shifts (accuracy), Ranges, Variation, and Capability

Edit Notes

#	Notes
1	ZG-737125, M9, OD 1.45 +/- .0005, 5 Consec Pcs.
2	ZG-737125, M9, Shoulder Length .578 +/- .0005, 5 Consec Pcs.
3	ZG-737125, M9, Height 5.250 +/- .0005, 5 Consec Pcs.
4	X6014-WP1, M2, OD 1.057 +/- .0005, 5 Consec Pcs.
5	X6014-WP1, M2, Length .475 +/- .0005, 5 Consec Pcs.
6	X6014-WP1, M2, OD 1.665 +/- .0005, 5 Consec Pcs.
7	4601950, M6, Groove Diameter .936 +/-.0005, 5 Consec Pcs.
8	4601950, M6, Length 1.263 +/-.0005, 5 Consec Pcs.
9	4601950, M6, Height 2.652 +/-.0005, 5 Consec Pcs.
10	R44AR-2-1, M21, Width .7490 +/- .0005, 5 Consec Pcs.
11	R44AR-2-1, M21, Depth .542 +/- .0005, 5 Consec Pcs.
12	R44AR-2-1, M21, OD .710 +/- .0005, 5 Consec Pcs.

Expert | Actual | 3 Sigma

Acceptance: CP | Cpk | PP | Ppk 1.33 | CP / Cpk / Auto | None

Variation of five consecutive parts

Setting Ppk Threshold Measurement samples that do not meet this requirement will be displayed in red on the Averages and Variation Chart

Sort | Ind.Grid | Abs.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5
5	0.00005	0	0	-0.00005	0

A novel metrology approach doing validation for all capability needs

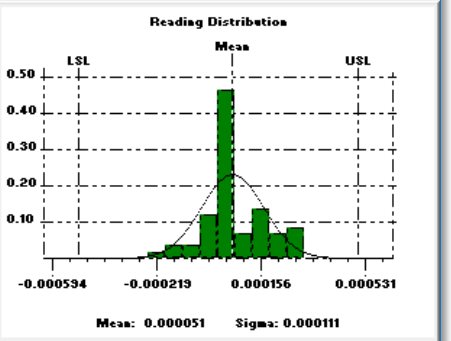
2

Instructions | Metrology Samples | **Metrology Groups** | Statsman

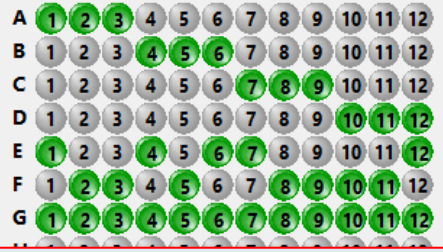
#	Notes
1	ZG-737125, M9, OD 1.45 +/- .0005, 5 Consec Pcs.
2	ZG-737125, M9, Shoulder Length .578 +/- .0005, 5 Consec Pcs.
3	ZG-737125, M9, Height 5.250 +/- .0005, 5 Consec Pcs.
4	X6014-WP1, M2, OD 1.057 +/- .0005, 5 Consec Pcs.
5	X6014-WP1, M2, Length .475 +/- .0005, 5 Consec Pcs.
6	X6014-WP1, M2, OD 1.665 +/- .0005, 5 Consec Pcs.
7	4601950, M6, Groove Diameter .936 +/-.0005, 5 Consec Pcs.
8	4601950, M6, Length 1.263 +/-.0005, 5 Consec Pcs.
9	4601950, M6, Height 2.652 +/-.0005, 5 Consec Pcs.
10	R44AR-2-1, M21, Width .7490 +/- .0005, 5 Consec Pcs.
11	R44AR-2-1, M21, Depth .542 +/- .0005, 5 Consec Pcs.
12	R44AR-2-1, M21, OD .710 +/- .0005, 5 Consec Pcs.

Grouping in a single test
Four CNC
Diameters (20 parts)
Lengths (20 parts)
All 0.001” dimensions

Cumulative short-run process capability is accepted



Matrix of samples and groups



#	R 90	PSL	PP	Ppk	Averages and Variation (LSL – USL)	Averages and Alert Limits (LSL – USL)	PWL	PSL
A	70	13	1.35	1.07			25	13
B	51	9	1.92	1.67			17	9
C	60	9	1.95	1.90			17	9
D	77	14	1.29	1.23			26	14
E	61	11	1.58	1.18			21	11
F	61	8	2.14	2.12			16	8
G	86	12	1.50	1.34			22	12

Transformation of numerical rows into alphabetical representation of single and grouped system elements

Custom layouts allow to assess the effect of single and grouped causes on accuracy, variation, and capability

C | Abs. | % | Variation | Expert | Actual | 3 Sigma | Acceptance | CP | Cpk | PP | Ppk 1.33 | CP / Cpk / Auto | None

Sort | Ind.Grid | Abs.Gage | Sublot Size 0 | Use Gage Connected To Data Channel 1, Gage Port #1 Instructions:

#	1	2	3	4	5
5	0.00005	0	0	-0.00005	0
6	0.00005	0	0	0.00015	0.0001

Measurement and process capability report

3

Report Columns: Spread ▾ Shifts ▾ Tolerance Control ▾ Capability ▾ Decision ▾ Deviation ▾

Category	Range 90	Shift from nom	PP	Ppk
PROCESS CAPABILITY ACROSS MACHINE & PART #				
ZG-737125; Mach 9; .001 Tol; OD / LN / HGHT	0.00062	0.00010	1.35	1.07
X6014-WP1; Mach 2; .001 Tol; OD / LN / OD	0.00045	0.00006	1.92	1.67
4601950; Mach 6; .001 Tol; GD / LN / HGHT	0.00053	0.00001	1.95	1.90
R44AR-2-1; Mach 21; .001 Tol; WDT / DPT / OD	0.00068	0.00002	1.29	1.23
Only Diameters	0.00053	0.00013	1.58	1.18
Only Lengths	0.00054	0.00000	2.14	2.12
Total (all dimensions)	0.00077	0.00005	1.50	1.34

Inspection Set	SAVE
Subset I	SAVE
Subset II	SAVE
Subset III	SAVE
Subset IV	SAVE
Subset V	SAVE
Subset VI	SAVE
Subset VII	SAVE
Subset VIII	SAVE
Subset IX	SAVE
Subset X	SAVE

A	B	C	D	E	F	G	H	I	J	K	L
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10
11	11	11	11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12	12	12	12

#	Individual Items
1	ZG-737125, M9, OD 1.45 +/- .0005, 5 Consec Pcs.
2	ZG-737125, M9, Shoulder Length .578 +/- .0005, 5 Consec P
3	ZG-737125, M9, Height 5.250 +/- .0005, 5 Consec Pcs.
4	X6014-WP1, M2, OD 1.057 +/- .0005, 5 Consec Pcs.
5	X6014-WP1, M2, Length .475 +/- .0005, 5 Consec Pcs.
6	X6014-WP1, M2, OD 1.665 +/- .0005, 5 Consec Pcs.
7	4601950, M6, Groove Diameter .936 +/-.0005, 5 Consec Pcs
8	4601950, M6, Length 1.263 +/-.0005, 5 Consec Pcs.
9	4601950, M6, Height 2.652 +/-.0005, 5 Consec Pcs.
10	R44AR-2-1, M21, Width .7490 +/- .0005, 5 Consec Pcs.
11	R44AR-2-1, M21, Depth .542 +/- .0005, 5 Consec Pcs.
12	R44AR-2-1, M21, OD .710 +/- .0005, 5 Consec Pcs.

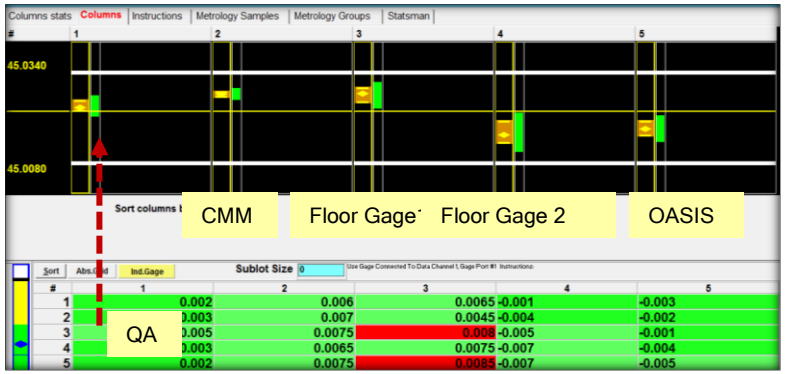
Highpoints of MICRONITE transformation of single set of metrology data

GLOBAL STATISTICS
IN METROLOGY DATA

Tolerance analysis | Columns stats | Columns | Instructions | Metrology Samples | **Metrology Groups** | Statsman

Analysis by columns in the data matrix

Logic and software design make it possible to quantify shifts, repeatability, and variation between 5 devices - in 30 min

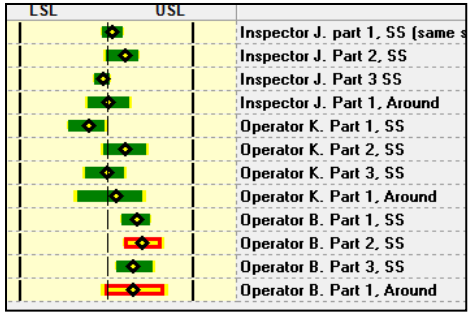


Excellent visual and analytical representation of shifts (bias) and repeatability of single metrology elements

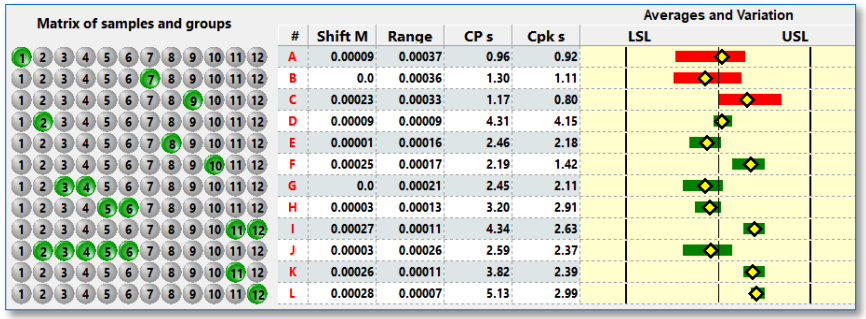
#	1	2	3
Cpk	2.72	3.12	1.26
CP	3.54	6.65	2.74
Average	45.0240	45.0279	45.0280
Min	45.0230	45.0270	45.0255
Max	45.0260	45.0285	45.0295

MICRONITE showcases error discovery to isolate root causes of non-conformance and substantially increase the tolerance range allowable for process variation and tool wear

Metrology of single elements



Transformation of metrology samples into groups

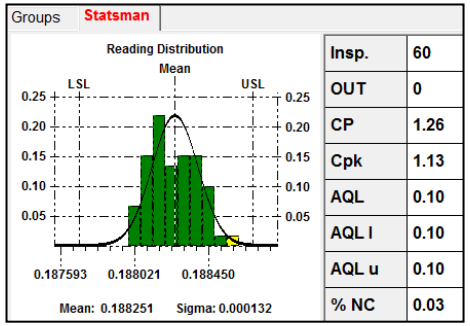


#	Shift M	Range	CP s	Cpk s
A	0.00009	0.00037	0.96	0.92
B	0.0	0.00036	1.30	1.11
C	0.00023	0.00033	1.17	0.80
D	0.00009	0.00009	4.31	4.15
E	0.00001	0.00016	2.46	2.18
F	0.00025	0.00017	2.19	1.42
G	0.0	0.00021	2.45	2.11
H	0.00003	0.00013	3.20	2.91
I	0.00027	0.00011	4.34	2.63
J	0.00003	0.00026	2.59	2.37
K	0.00026	0.00011	3.82	2.39
L	0.00028	0.00007	5.13	2.99

Metrology Statsman

Summary statistics for 3 consecutive parts, 3 observers and form variation

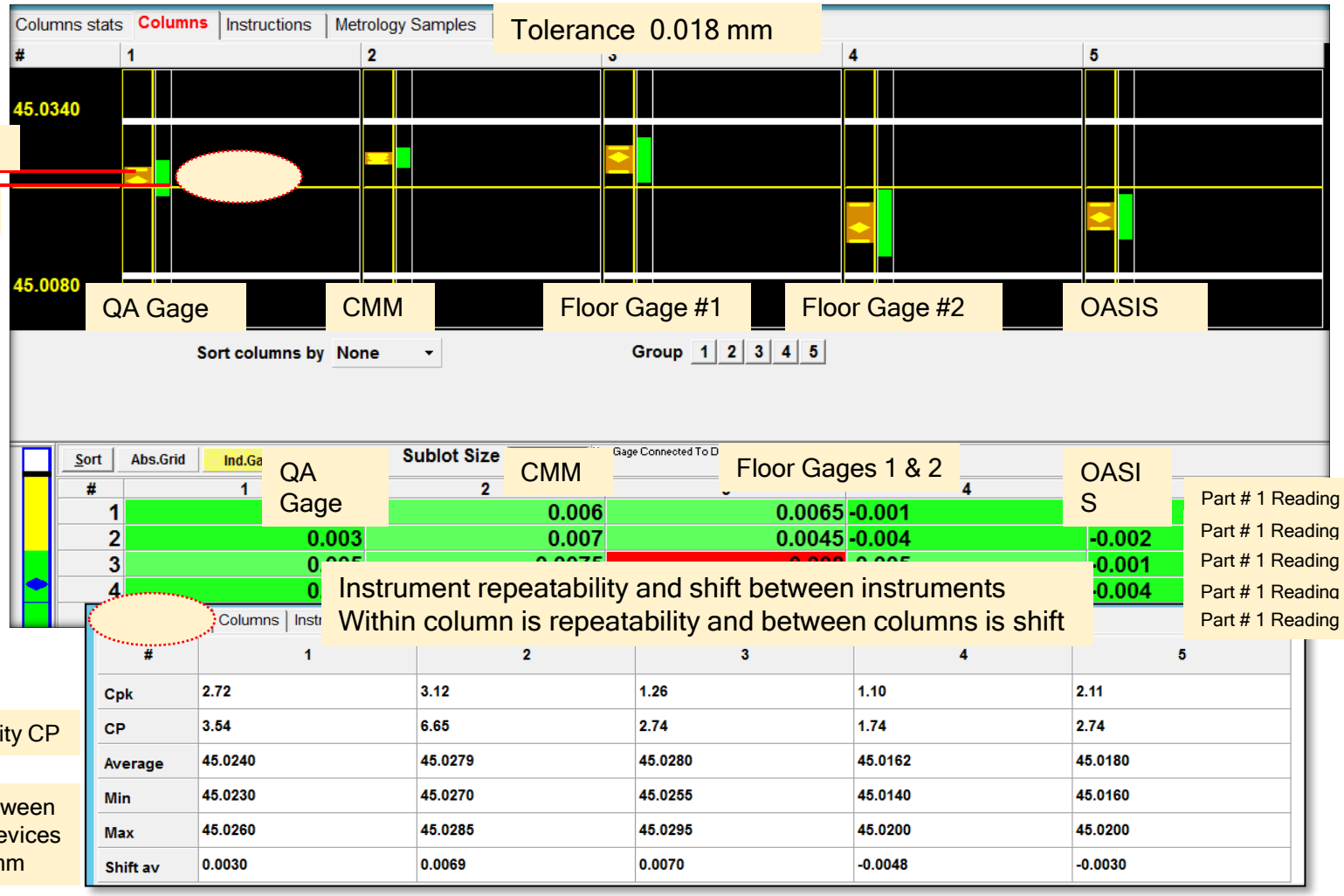
Predicted % to spec	Predicted Min	LSL	USL	Predicted Max	Predicted % to spec	Spec tolerance	Capable to hold
1.90	0.32002			0.32088	11.73	0.00100	0.00086



Visual and analytical MICRONITE metrology delivers exceptional functionality for cost-critical control of key tight-tolerance characteristics. MICRONITE metrology excels continuous process improvement in low- and high-volume machining and grinding.

Precision and accuracy of CMM, Vision System and three gages

A SINGLE SOURCE TO ASSESS MEASURING INSTRUMENTS PERFECTLY



Metrology in measurement and machining process

Issues in control of tight and extremely tight tolerances

- Massive investment and engineering time from prototype to production can be jeopardized by hidden quality-risking inspection error at the end of machining pipeline
- Substantial amount of hidden systematic and random measurement errors can be found on the shop floor and in quality departments
- Metrological issues cannot be solved by existing methodologies and R&R software
- Measurement errors cause big losses in quality and productivity
- Excessive engineering time is needed for detection of metrology problems

MSA
R&R (Repeatability and Reproducibility)

- Logic of metrological studies and statistical references are not applied to strict requirements of modern tight-tolerance machining
- Large statistical errors cannot be avoided due to fixation of sampling schemes and reliance on normality of data distribution
- Very limited options for investigation of multiple root causes left measurement errors hidden

GROUNDBREAKING PRINCIPLES

- Measurement and machining metrology plan does not restrict the number of single elements of the measurement system in a single test (gage, operator, inspector, fixture, method, etc.)
- Machining metrology plan includes all probable causes of measurement, machine, tool, and process variation
- Multi-functional data entry panel helps accurately analyze the effects of root causes on measurement error
- Metrology data matrix allows to evaluate up to 12 groups (columns) and up to 12 single samples (rows)
- Statistical estimates are represented by four categories: accuracy (shifts, bias), variation (repeatability, reproducibility), measurement and process capability, and Stop / Warning process control limits
- High-precision estimation of accuracy, precision, reproducibility, and measurement capability is independently determined for single system elements (gage, operator, fixture, method, etc.)
- In-screen formation of metrology groups allows to discover and quantify interactive causes of errors
- Large number of characteristics can be simultaneously analyzed for CMM and Vision System
- Hierarchical report structure allows to discover main players of cumulative measurement and process variation
- Metrological data control is integrated within the entire process control chain
- Minimization of statistical errors allows to accept accuracy and precision in tolerance ranges down to 0.0001”
- Statistically valid STOP and Warning limits are determined for Pre-Control/SPC charts

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CMM PROCESS METROLOGY	VISION SYSTEM – MICRONITE	VISION PROCESS METROLOGY
ADVANCED MICRONITE SPC	EFFECTIVE CONTROL PLANNING	METROLOGY IN QUALITY
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