Table of Contents

Pre	face			v	
Pre	face	to the 2 ^r	^{1d} Edition	vi	
Pre	face	to the 3 ^r	d Edition	vi	
Tab	Table of Contentsix				
1	Mea	asurement Process Capability			
	1.1	Introduc	tion	1	
		1.1.1 Why Measurement Process Capability?			
	1.2	Historic	al Retrospect and Prospect	7	
	4.0	1.2.1	Development "Measurement Process Capability"	9	
	1.3	Notes If	om the Authors about MSA [1] and VDA 5 [70]	11	
n	1. 4		ving as a Basis for Maggurament Process Canability	16	
Z	Gay		alibration	10	
	2.1	Dial Ga	alibration	10	
	2.3	Capabil	ity Studies for Standard Gages		
3	Defi	nitions a	nd Terms	22	
•	3.1	Process	5		
	3.2	Measur	ement Process	22	
	3.3	Testing		23	
	3.4	Measuring Equipment			
	3.5	Measurement Deviations and Measurement Uncertainty			
		3.5.1	Bias		
		3.5.2	Repeatability	29	
		3.5.3	Linearity		
		3.5.5	Measurement Stability		
4	Influ	encina F	Factors on the Measurement Process	34	
•	4.1 Typical Influencing Factors				
	4.2	Impact	of the Influencing Factors		
	4.3	Evaluat	ion of the Measurement Process	40	
5	Gage Capability as a Measurement Process Capability Study				
	5.1	Basic P	rocedures and Methods	44	
	5.2	Evaluat	ion of Gages	47	
		5.2.1	Uncertainty of the Standard Master / Calibration Master	47	
		5.2.2	Influence of the Resolution	49	
		5.2.3	Evaluation of the Bias	51	
		5.2.4 5.2.5	Study Type 1		
		0.2.0 5.2.6	Study Type 1 for Characteristics with Unilateral Tolerances	80 AA	
		527	Study Type 1 for Several Characteristics		
		5.2.8	Linearity		
	5.3	Evaluat	ion of the Measurement Process	80	



		5.3.1	Range Method (Short Method)	80	
		5.3.2	Study Type 2: %R&R with Operator Influence	82	
		5.3.3	Study Type 3: %R&R without Operator Influence	102	
	5.4	Testing	Measurement Stability	105	
	5.5	Further	Studies	109	
		5.5.1	Study Type 4	109	
		5.5.2	Study Type 5	111	
	5.6	Method	according to CNOMO	114	
6	Сар	abilitv St	tudy of Attribute Measurement Processes	117	
	61	Attribute	e Ganes	117	
	6.2	Attribute	e Gaging or Variable Measuring	118	
	63	Require	ments for Successful Inspections by Attribute	110	
	6.4	Analysia	s of Attribute Measurement Processes "Short Method"	120	
	6.5	Analysis	s of Attribute Measurement Processes Short Method Mathad	120	
	0.0	CE 1	Introduction	120	
		0.5.1		123	
		0.0.2	Evaluating the Effectiveness of an Attribute Measurement System	121	
		0.5.3	Evaluating the Ellectiveness of an Attribute Measurement System	133	
7	Fyte	o.o	easurement I Incertainty	143	
'				. 140	
	7.1		o the Expression of Uncertainty in Measurement	143	
		7.1.1	Basic Principles	143	
		7.1.2	Aim and Purpose of the GUM	144	
		7.1.3	Field of Application	145	
		7.1.4	Contents of the Guide	146	
		7.1.5	Terms and Definitions	147	
	7.2	Determi	ination of Measurement Uncertainties	150	
		7.2.1	Determination of the Standard Uncertainty	151	
		7.2.2	Determination of the Combined Standard Uncertainty	156	
		7.2.3	Determination of the Extended Uncertainty	158	
		7.2.4	Logging of the Uncertainty	161	
		7.2.5	Expression of the Result	162	
	7.3	GUM H	.1 Example: Gage Block Calibration	163	
		7.3.1	Measuring Task	163	
		7.3.2	Standard Uncertainties	164	
	7.4	Calibrat	ion of a Weight for the Nominal Value of 10 kg (S2)	172	
		7.4.1	Measuring Task	172	
		7.4.2	Standard Uncertainties	172	
		7.4.3	Extended Measurement Uncertainty and Complete Measurement Result	1.179	
	7.5	Calibrat	ing a Caliper	181	
		7.5.1	Measuring Task	181	
		7.5.2	Standard Measurement Uncertainty (S10.3-S10.9)	182	
		7.5.3	Extended Measurement Uncertainty and Complete Measurement Result	. 185	
	7.6	GUM In	terpretation for Measurement Processes in Series Production	187	
8	Exte	Extended Measurement Uncertainty according to ISO 22514-7 or VDA 5			
	8.1	VDA 5 F	Flow Chart	188	
		8.1.1	Schematic Approach	189	
		8.1.2	Gage Capability	190	

		8.1.3	Determination of the Standard Uncertainty as per Determination Meth	10d A191			
		8.1.4	Determination of the Standard Uncertainty as per Determination Meth	10d B192			
	8.2	Principa	al Standard Uncertainty Components	194			
		8.2.1	Standard Uncertainty ucal	196			
		8.2.2	Standard Uncertainty of the Resolution uRE	196			
		8.2.3	Standard Uncertainty uBI	197			
		8.2.4	Standard Uncertainty u _{MS} in Case of Standard Gages	198			
		8.2.5	Standard Uncertainty Caused by Equipment Variation at the Reference UEVR	ce Part 199			
		8.2.6	Standard Uncertainty Caused by Equipment Variation at the Object u	_{EVO} 199			
		8.2.7	Standard Uncertainty Caused by the Operator Influence uAV	201			
		8.2.8	Standard Uncertainty Caused by the Test Object uOBJ	201			
		8.2.9	Standard Uncertainty Caused by the Temperature Influence uT	204			
		8.2.10	Standard Uncertainty Caused by Non-linearity uLIN	207			
		8.2.11	Standard Uncertainty Caused by Stability uSTAB	208			
	8.3	Multiple	Consideration of Uncertainty Components	210			
	8.4	Determ	ination of the Extended Measurement Uncertainty	211			
	8.5	Conside	eration of the Extended Measurement Uncertainty at the Specification I	Limits211			
	8.6	VDA 5	Case Studies	213			
		8.6.1	Example: "Linear Measurement Using a Standard Gage"	213			
		8.6.2	Example: "Linear Measurement Using a Particular Gage"	220			
9	Sim	olified D	etermination of the Measurement Uncertainty	227			
Ŭ	0.1		acodura ("All in One" Procedure)	227			
	9.1		Maasuroment Process Canability Study	221			
		9.1.1	Determination of the Extended Measurement Lineartainty	221			
	0.2	9.1.2 Dractics	Determination of the "All in One" Precedure				
	9.Z		Macourement Presses with Linear Material Macoure	231			
		9.2.1	Measurement Process with Linear Material Measure	201			
		9.2.2		200			
10	Spe	cial Cas	es in Measurement Process Capability	236			
	10.1	10.1 What Is a Special Case?					
	10.2 Typical Special Cases						
11	How	to Hand	die Incapable Measurement Processes	238			
	11.4.4. Deservices for Improving Management Processor						
	11.1	FIUCEU	are for improving measurement Processes	200			
12	Турі	cal Que	stions about Measurement Process Capability	241			
	12.1 Questions						
	12.2	12.2 Answers					
13	Capability Studies in Visual Inspections						
10	13.1	13.1 Requirements for Visual Inspections					
	13.2 Antitude Test for Visual Inspectors						
14	Purchase of Gages2						
	14.1 Example for a Measuring Task Description249						
	14.2 Example for a Requirement Specification						
15	Proof of Suitability for Test Software						
	15.1 General Consideration						
	15.2	The Mv	th of "Excel Tables"				
				-			

	15.3	15.3 Gage Capability Test Examples			
16	Appendix			270	
	16.1	Tables		270	
		16.1.1	d2* Table for the Determination of k Factors and Degrees of	of Freedom for	
			t Values	270	
		16.1.2	Capability Limits according to VDA 5	273	
		16.1.3	k Factors	274	
	16.2	Analysis of Variance Models		274	
		16.2.1	Measurement System Analysis – Study Type 2		
		16.2.2	Measurement System Analysis - Study Type 3	279	
17	Refe	rence			
	17.1	Abbrevi	ations		
	17.2 Formulas				
	17.3 Bibliography				
	17.4 Figures				
	17.5 Tables				
18	"Mea	asureme	ent System Capability" Reference Manual		
19	GM	GM PowerTrain Measurement Systems Specification (SP-Q-MSS)			
20	Bosch Booklet 10: Capability of Measurement and Test Processes				
21	Inde	x			