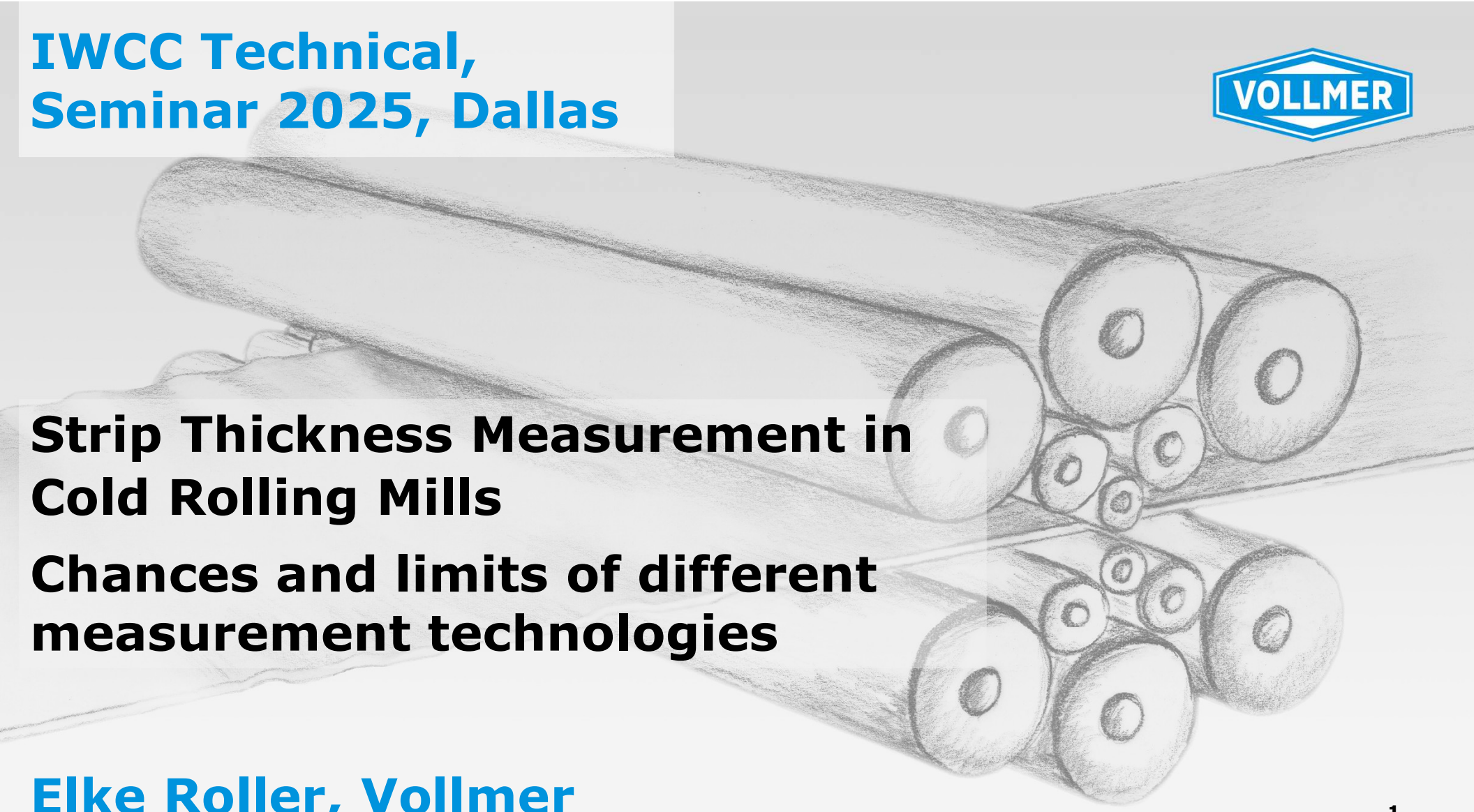
IWCC Technical, Seminar 2025, Dallas



Strip Thickness Measurement in Cold Rolling Mills

Chances and limits of different measurement technologies

Elke Roller, Vollmer

IWCC Legal Disclaimer:

The purpose of this presentation is to guide programs benefiting the copper industry and to provide attendees with information to make independent business decisions.

Thickness gauges technologies for Cold Mills

Different Technologies are established in the market.

Which technology is suitable for which application?

Advantages / Disadvantages

Choice according to which criteria?

Thickness gauges technologies for Cold Mills

Possible reasons to use the same gauge type for various applications:

- Proven technology
- Well known in the company
- Spare parts available
- Operators are trained
- Maintenance team is trained
- No discussions

Thickness gauges technologies for Cold Mills

But, there are good reasons to think about, which technology has which advantages and disadvantages for which use.

Reasons:

- Proven technology sometimes needs very costly accompanying procedures for being proven
- Can costly procedures be reduced or saved with technology change
- How to combine different technologies for avoiding effects for which the only used technology has to be blind

Thickness gauges technologies for Cold Mills

The use in Cold Mills has special challenges and by that we focus only on technologies what are able to work there:

- Steam
- Wetness
- Temperature development from pass to pass
- Varying surfaces from high gloss to matt
- High strip speed
- …

Thickness gauges technologies for Cold Mills

Today we have a look on 4 established thickness gauge technologies for use in Cold Rolling Mills:

Indirect Measuring Methods:

- X-Ray gauges
- Eddy Current gauges

Direct Measuring Methods:

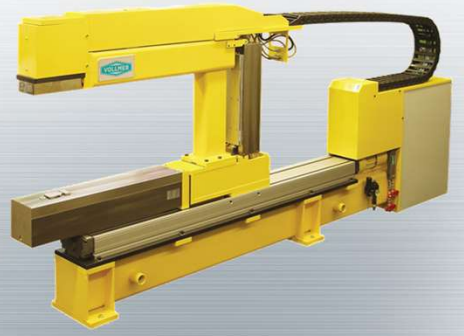
- VTLG Laser gauges
- Contact gauges

Test Equipment Monitoring,
Measuring equipment capability analysis

Capable gauges are the basis for determining process capability
MSA (Measuring System Analysis) determines if gauges are capable for the relevant application

- MSA, method 1:
  accuracy and repeatability,
  50x measurement of e.g. a gauge block,
  Cgk > 1.33 = gauge capable
- MSA, method 3:
  repeatability, reproducibility (R&R)
  Measurement of sample strip or different sheets from the strip

X-Ray gauges

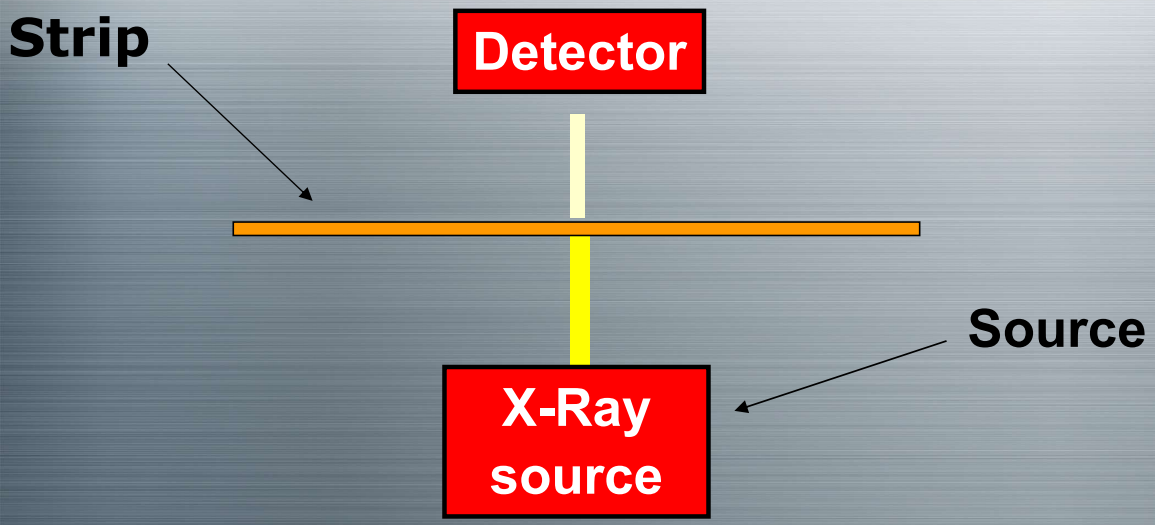


- Usually as driving C-Frames
- X-Ray source in the lower C-frame leg
- Detector above the strip in the upper C-frame leg

X-Ray gauges

Measuring principle:

Radiate through the strip and measure the unabsorbed radiation



The strip thickness is determined by evaluating the measured residual radiation in relation to the alloy analysis previously carried out in the laboratory

X-Ray gauges

Advantages:

- Very sturdy
- Cross-profile possible
- Nearly no influence of wetness
- Nearly no service

Outstanding Advantage:

The Robustness

No matter how dirty, wet and bumpy it gets in the roll stand, the measurement runs smoothly

Disadvantages:

- Depending on the alloy
- Radiation protection necessary
- Expensive wear parts

Outstanding Disadvantage:

The Alloy Dependence

Measurement result depends on the quality of the alloy analysis and also on the uniformity of the alloy over the strip length

X-Ray gauges

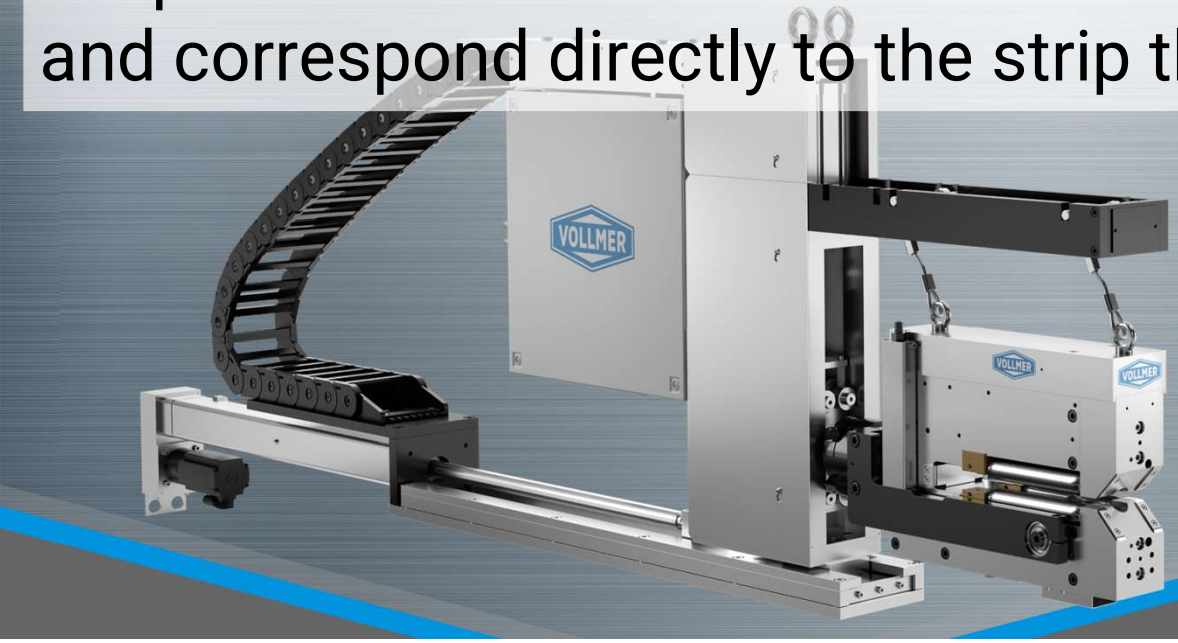
Measurement Accuracy:

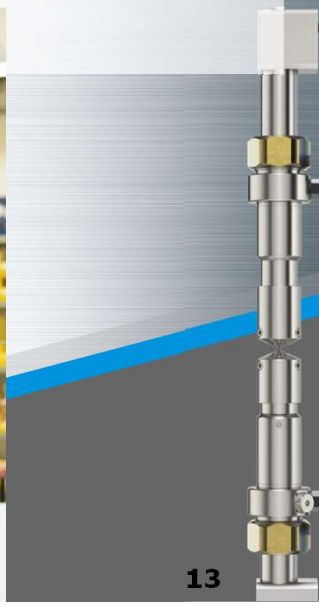
For X-ray gauges the wording “relative accuracy” is used (as the influence of the alloy must be considered in addition)

For strip thickness 0.01 - 4 mm, relative accuracy ± 0.2 - 3 µm (depending on nominal thickness)

Contact Gauges
Measuring principle:

A pair of transducers equipped with diamond tips contacts the strip from above and below. The transducers are installed in C-frames, which are oscillating, rotatable and often in cardanic suspension. The absolute values of the transducers are added and correspond directly to the strip thickness





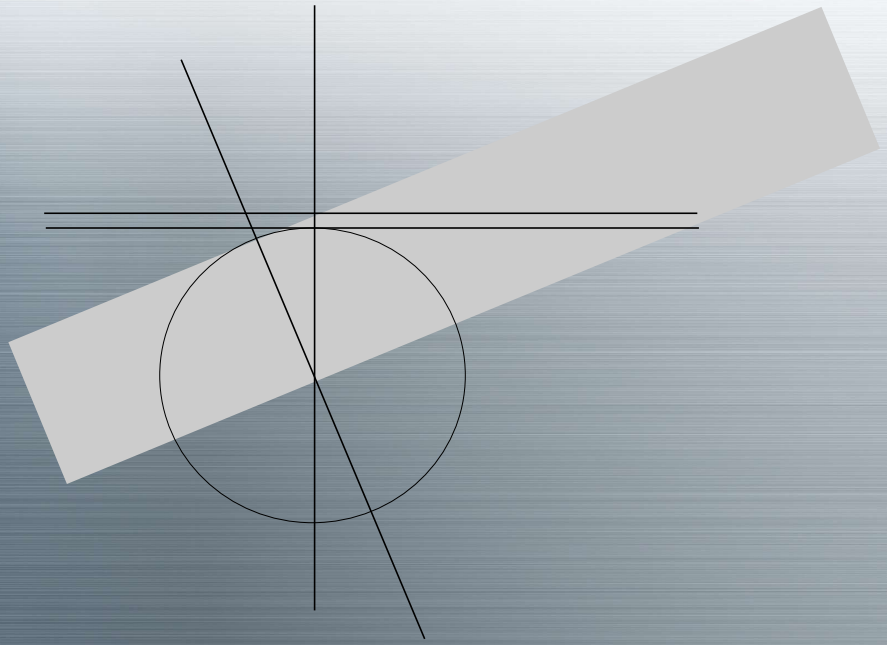
Contact Gauges

Advantages:

- Independent from the alloys
- Compensates strip angles
- Easy to service

Thickness Measurement

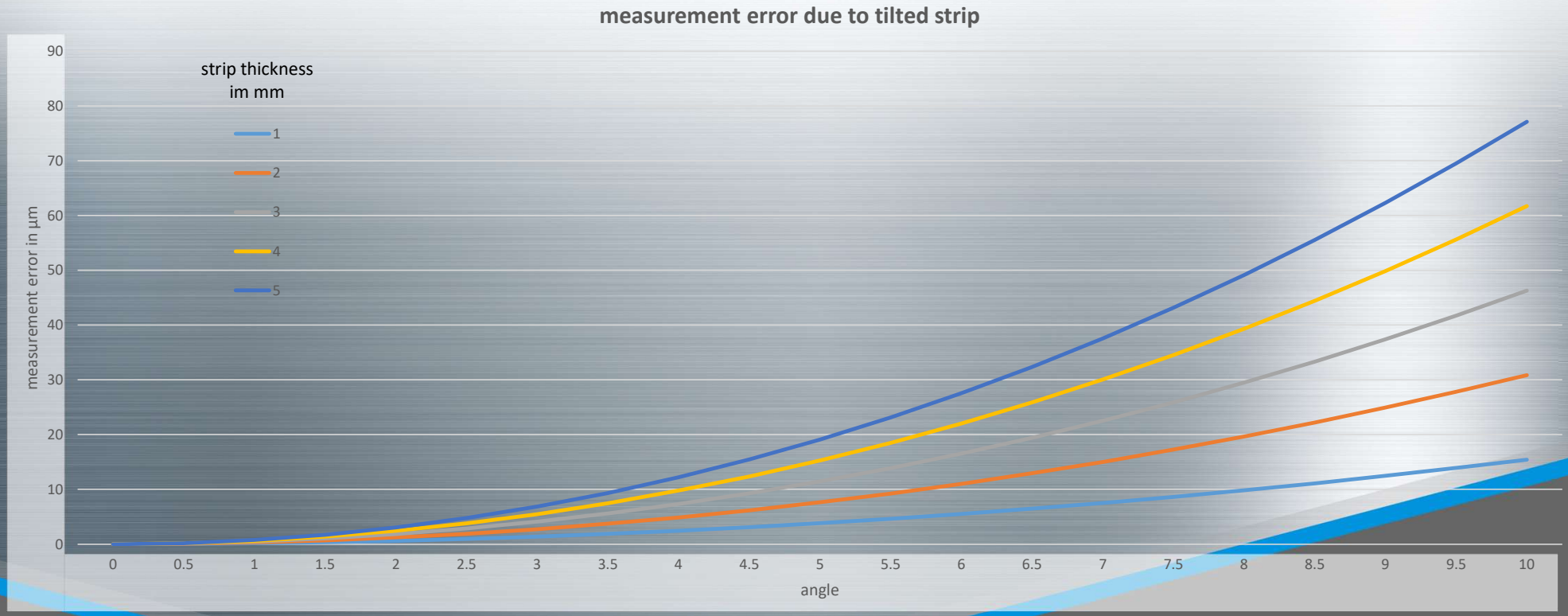
Influence of tilting strip (waves, cross bow, coil set, buckles, … in the measurement axis)



No perpendicular measurement axis results in too thick measurement values

Thickness Measurement

Tilting strip (waves, cross bow, coil set, buckles, … in the measurement axis)



Thickness Measurement

Effects of tilting strip (waves, cross bow, coil set, buckles, … in the measurement axis)

	Strip thick-ness in mm																				
Angle of the Strip		0°	0,5°	1°	1,5°	2°	2,5°	3°	3,5°	4°	4,5°	5°	5,5°	6°	6,5°	7°	7,5°	8°	8,5°	9°	9,5°	10°
Measurement error in µm	1	0,00	0,04	0,15	0,34	0,61	0,95	1,37	1,87	2,44	3,09	3,82	4,63	5,51	6,47	7,51	8,63	9,83	11,11	12,47	13,91	15,43
Measurement error in µm	2	0,00	0,08	0,30	0,69	1,22	1,91	2,74	3,74	4,88	6,18	7,64	9,25	11,02	12,94	15,02	17,26	19,66	22,21	24,93	27,81	30,85
Measurement error in µm	3	0,00	0,11	0,46	1,03	1,83	2,86	4,12	5,61	7,33	9,28	11,46	13,88	16,52	19,41	22,53	25,89	29,48	33,32	37,40	41,72	46,28
Measurement error in µm	4	0,00	0,15	0,61	1,37	2,44	3,81	5,49	7,47	9,77	12,37	15,28	18,50	22,03	25,88	30,04	34,52	39,31	44,42	49,86	55,62	61,71
Measurement error in µm	5	0,00	0,19	0,76	1,71	3,05	4,76	6,86	9,34	12,21	15,46	19,10	23,13	27,54	32,35	37,55	43,14	49,14	55,53	62,33	69,53	77,13

Contact Gauges

Advantages:

- Independent from the alloys
- Compensates strip angles
- Easy to service

Outstanding Advantage:

Compensation of tilting strip

Always perpendicular measurement and by that no influence of coil set, cross bow, waves, buckles …

Disadvantages:

- Maintenance intensive
- No cross profile
- For long running strip addi-tional temp-compensation

Outstanding Disadvantage:

Intensive Maintenance

As the gauges work by contact, some parts wear out and must be regularly checked, maintained, adjusted and, if necessary, replaced

Contact gauges

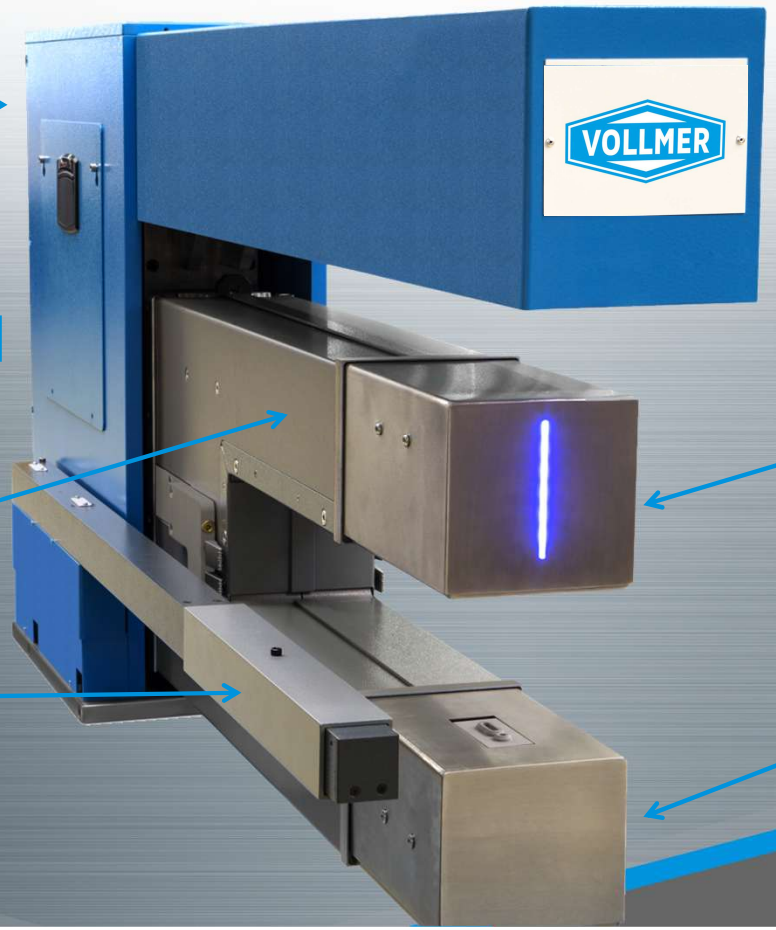
Measurement Accuracy:

Contact gauges work with standard accuracies of ± 0.1% but not better than ± 1 µm

For strip thicknesses 0.01 - 4 mm, measuring accuracy ± 1 to ± 4 µm (depending on nominal thickness)

Special designs for foils achieve ± 0.5 µm

VTLG Laser Gauges



Enclosure with horizontal motorized positioning and vertical motorized positioning

C-Frame

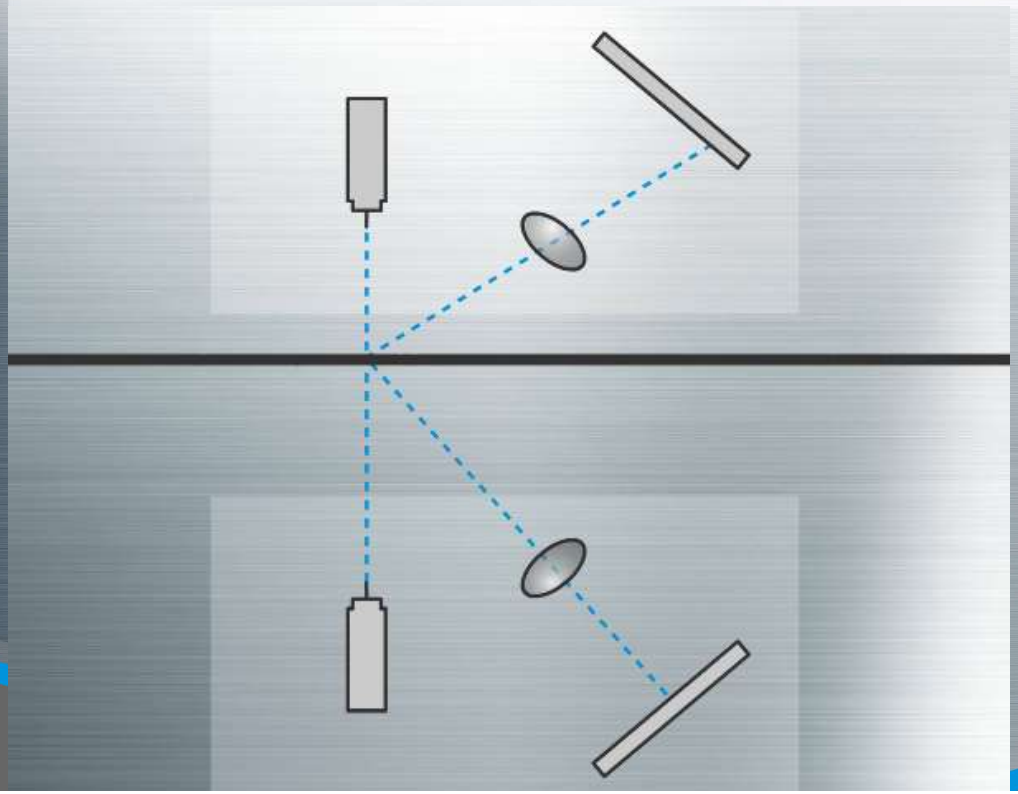
Adjustment Station

Upper laser sensor

Lower laser sensor

VTLG Laser Gauges
Measuring principle:

A pair of laser triangulation sensor scans the strip from above and below



Similar to the contact gauges, the strip thickness is measured by measuring the distance from above and below. What is located between the laser sensors is the strip thickness.

VTLG

- VTLGs are self-calibrating
- Can be used up to 180 °C (356 °F) strip temperature without further measures
- No coil or strip-specific settings required by operators

VTLG Laser Gauges

Advantages:

- Self calibrating
- Independent from alloys and operator
- No wear parts

Outstanding Advantage:

Alloy independent

Self-monitoring of the VTLG ensures stable process

Disadvantages:

- Max. accepted residual moisture 500 mg/m²/side
- Because of still „new“ technology often new proofs and discussions needed

Outstanding Disadvantage:

Stable process required

The self-monitoring of VTLG recognizes arbitrary changes (e.g. wipers open or closed, pass line roll inserted or not)

VTLG Laser Gauges

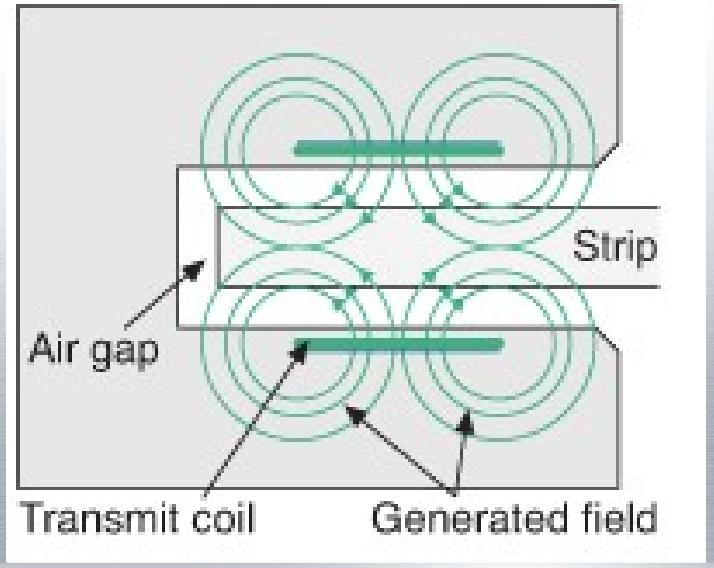
Measurement Accuracy:

VTLGs measure with standard accuracies of ± 1 µm

For strip thicknesses 0.01 - 4 mm, measuring accuracy ± 1 µm

Special design for foils achieves ± 0.5 µm

Eddy Current gauges



Measuring principle:

A constant pulse current, that feeds an electrical coil, generates a pulsed magnetic field around the strip. After each pulse, the induced voltage resulting from the generated magnetic field is measured and the thickness is calculated from this

Eddy Current gauges

Advantages:

- Alloy independent (up to max. 2% Fe)
- No influence by moisture
- Very stable measurement

Outstanding Advantage:

The Stability

As with the x-ray gauges

Disadvantages:

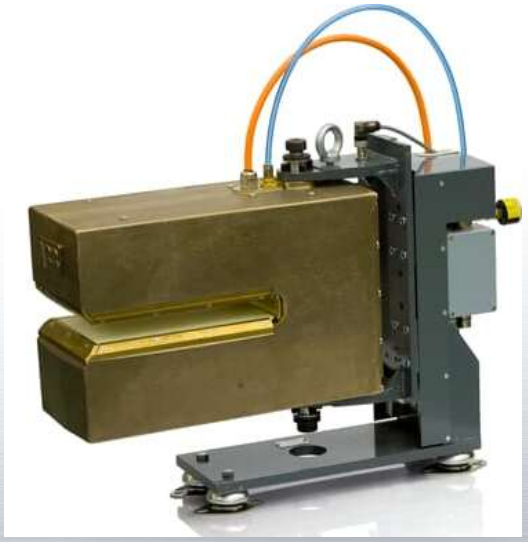
- Very small air gap (10 mm)
- Measurement spot ⌀ 80 mm
- No cross profile
- No use with more than 2% Fe

Outstanding Disadvantage:

Alloy restriction up to max. 2% Fe

Even if the range of alloys initially has less Fe, other alloys may be added over the years of use

Eddy Current gauges



Measurement Accuracy:

Eddy Current gauges work with standard accuracy of ± 0.05 % but not better than ± 2 µm

For strip thicknesses 0.01 - 4 mm, measuring accuracy ± 2 µm

Special designs for foils achieve ± 1 µm

Summary Measurement Accuracy for thickness range 0.1 – 4.0 mm

	Accuracy for strip thickness 0.1 – 4.0 mm	Comments
X-Ray	± 0.2 – 3 µm	Relative accuracy, add. alloy influences
Contact	± 1 – 4 µm	Foil solution ± 0.5 µm
VTLG	± 1 µm	Foil solution ± 0.5 µm
Eddy Current	± 2 µm	Foil solution ± 1 µm

Test Equipment Monitoring
Measuring System Analysis (MSA)

MSA appears to play a more important role in the literature than in day-to-day operation.

But it is common for customers to regularly check the gauges, e.g. with certified gauge blocks.
For monitoring whether the gauges still achieve the basic accuracy that they should have.

Test certificate: VBM , VBS , VBF , VBK

VOLLMER

Customer:	[redacted]				
Project No.:	P21/23708	**Device type:**	VBM 1063	**Service interval:**	½ year
Location:	Winding Line C			**Cost centre:**	350
Inventory No.:	1084	**Measurement equipment No.:**			
Measurem. Parameter:	Thickness	**Measuring range:**	0-8 mm	**Resolution:**	0,0001 mm
Contact measurement with:	Diamond				

Test certificates of the gauge blocks			
Gauge blocks	1	2	3
Gauge block no.	V309.64		
Nominal size	0,8mm		

Test certificates of the gauge block plates			
Gauge block plate	1	2	3
Gauge block plate no.		2548	3598
Nominal size		1mm	1,5mm

Check and adjustment using gauge blocks or gauge block plates									
Test	1			2			3		
Test result before	N +/-	0,002	mm	N +/-	0,003	mm	N +/-	0,004	mm
Test result after	N +/-	0,001	mm	N +/-	0,001	mm	N +/-	0,001	mm
General release at	N +/-	0,004	mm	N +/-	0,004	mm	N +/-	0,004	mm

Maintenance performed according to maintenance report

Inspection criterion	**OK**	**Inspection criterion**	**OK**
1. Measuring head: Guide rollers	/	7. Slide base: PW / HWST / MWST	x
2. Measuring head: C-frame, measurement throat limit	x	8. PN roll control	x
3. KA Suspension	/	9. Vertical guide	x
4. Measuring head: Heating	x	10. C-frame	x
5. Measuring heat: Cooling	x	11. Transducer top/bottom	x
6. Measuring heat: Measuring module „Option"	/	12. Display (VTS, VMF)	x

General release					
Inspect. sticker issured:	X	Next date:	15.07.2025	Inspection acc.	Calibrated gauge blocks by DAkkS

Performed by:	**Remarks:**
H. I DS	
Name and signature service technician:	
10.07.2025 H. TESCHNER	
Date, name, signature	

Prepared: H. Fischer | Reviewed: E. Roller | Released: IMB

Integrated management system | Valid from 12.07.2024 | Page 1 of 1

Document: FB 8.6.01 Revision 3

Test Equipment Monitoring

Gauge blocks,
Calibration plate,
Re-certification
Certificate of a
certified laboratory

Saliger-Gruppe GmbH

Kalibrierschein / Calibration Certificate

DAkkS Deutsche Akkreditierungsstelle D-K-15008-01-00

erstellt durch das Kalibrierlaboratorium
issued by the calibration laboratory

Saliger-Gruppe GmbH
Am Wiesenbusch 4
45966 Gladbeck

als Kalibrierlabor im
as calibration laboratory in the

Deutschen Kalibrierdienst DKD

Kalibrierzeichen *Calibration mark*	
	13265092
	D-K-15008-01-00
	2024-07

Gegenstand *Object*	Parallelendmaßsatz aus Stahl nach DIN ISO 3650
Hersteller *Manufacturer*	-
Typ *Type*	-
Fabrikat/Serien-Nr. *Serial number*	3112023
Kundendaten *Customer*	Friedrich Vollmer Verbandstraße 60b D - 58093 Hagen
Auftragsnummer *Order No.*	2024_131168
Anzahl der Seiten des Kalibrierscheines *Number of pages of the certificate*	3
Datum der Kalibrierung *Date of calibration*	11.07.2024

Dieser Kalibrierschein dokumentiert die metrologische Rückführbarkeit auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multilateralen Übereinkommen der European co-operation for Accreditation (EA) und der International Laboratory Accreditation Cooperation (ILAC) zur gegenseitigen Anerkennung der Kalibrierscheine.
Für die Einhaltung einer angemessenen Frist zur Wiederholung der Kalibrierung ist der Benutzer verantwortlich.

This calibration certificate documents the metrological traceability to national standards, wich realize the units of measurement according to the International System of Units (SI).
The DAkkS is signatory to the multilateral agreements of the European co-opertion for Accreditation (EA) and of the International Laboratory Accreditation Cooperation (ILAC) for the mutual recognition of calibration certificates.
The user is obliged to have the object recalibrated at appropriate intervals.

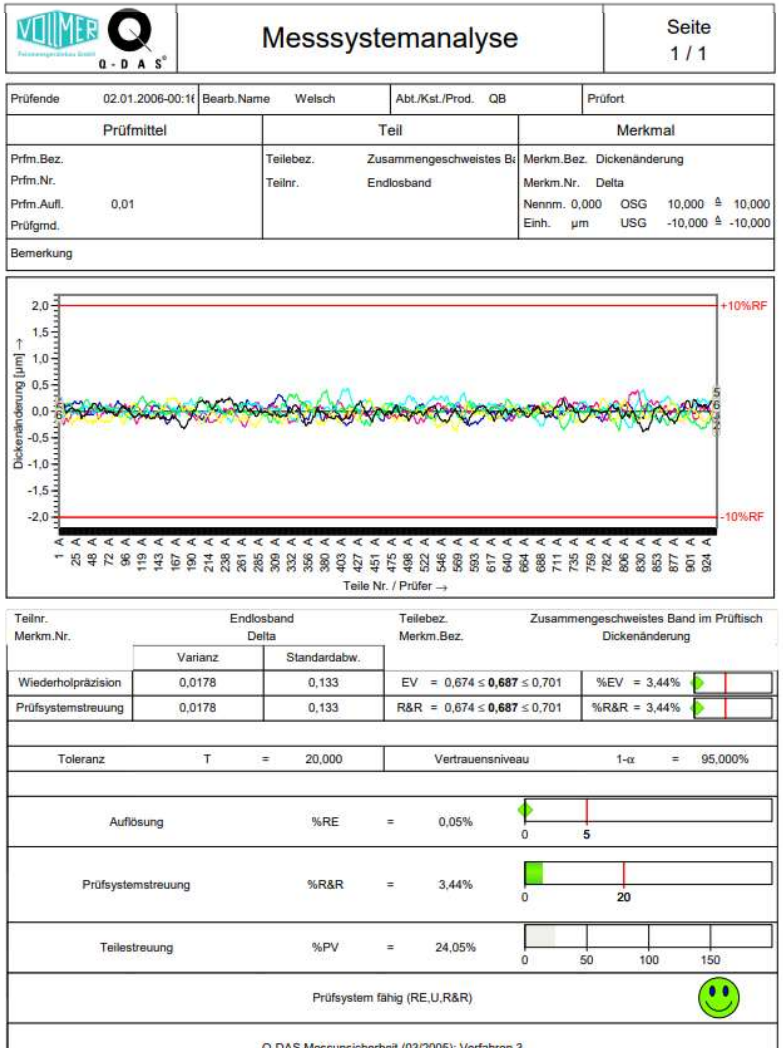
Dieser Kalibrierschein darf nur vollständig und unverändert weiterverbreitet werden. Auszüge oder Änderungen bedürfen der Genehmigung des ausstellenden Kalibrierlaboratoriums. Kalibrierscheine ohne Unterschrift haben keine Gültiggkeit.
This calibration certificate may not be reproduced other than in full except with the permission of the issuing laboratory. Calibration certificates without signature are not valid.

Datum *Date*	Freigabe des Kalibrierscheins durch *Approval of the certificate of calibration by*	Bearbeiter *Person in charge*
11.07.2024	Dr. Watermann, Ramon	Heike Harmel

Saliger-Gruppe GmbH, Am Wiesenbusch 4, 45966 Gladbeck
Telefon 02043/977-0 / Telefax 02043/977-100

Measuring System Analysis (MSA)

Measuring System Analysis (MSA)



Messsystemanalyse

Seite 1 / 1

Prüfende	02.01.2006-00:1(	Bearb.Name	Welsch	Abt./Kst./Prod.	QB	Prüfort	
Prüfmittel		**Teil**		**Merkmal**			
Prfm.Bez.		Teilebez.	Zusammengeschweistes Ba	Merkm.Bez.	Dickenänderung		
Prfm.Nr.		Teilnr.	Endlosband	Merkm.Nr.	Delta		
Prfm.Aufl.	0,01			Nennm.	0,000	OSG	10,000 ≙ 10,000
Prüfgrnd.				Einh.	µm	USG	-10,000 ≙ -10,000
Bemerkung							

Teilnr. / Merkm.Nr.	Endlosband / Delta		Teilebez. / Merkm.Bez.	Zusammengeschweistes Band im Prüftisch / Dickenänderung
	Varianz	Standardabw.		
Wiederholpräzision	0,0178	0,133	EV = 0,674 ≤ **0,687** ≤ 0,701	%EV = 3,44%
Prüfsystemstreuung	0,0178	0,133	R&R = 0,674 ≤ **0,687** ≤ 0,701	%R&R = 3,44%

Toleranz	T	=	20,000	Vertrauensniveau	1-α	=	95,000%

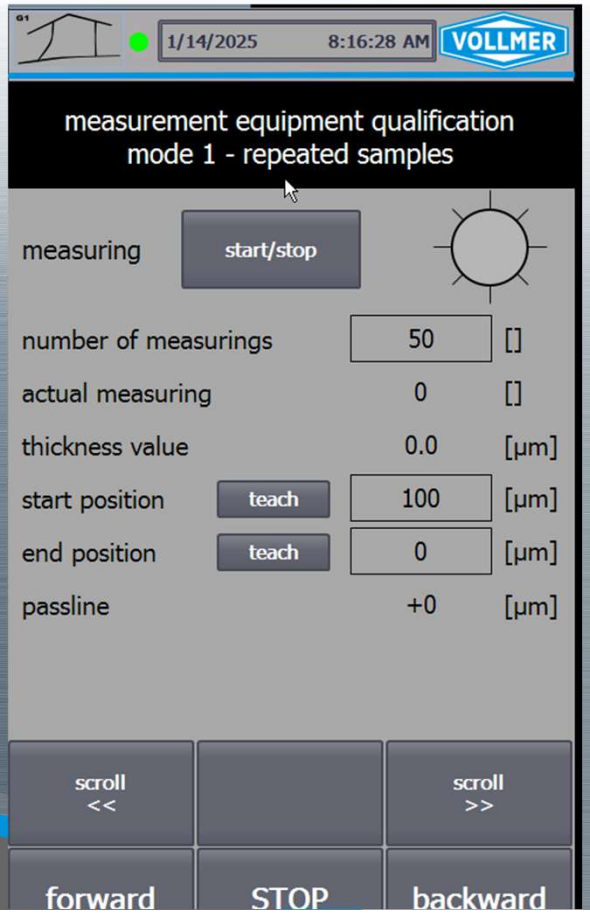
Auflösung	%RE	=	0,05%	0 5
Prüfsystemstreuung	%R&R	=	3,44%	0 20
Teilestreuung	%PV	=	24,05%	0 50 100 150

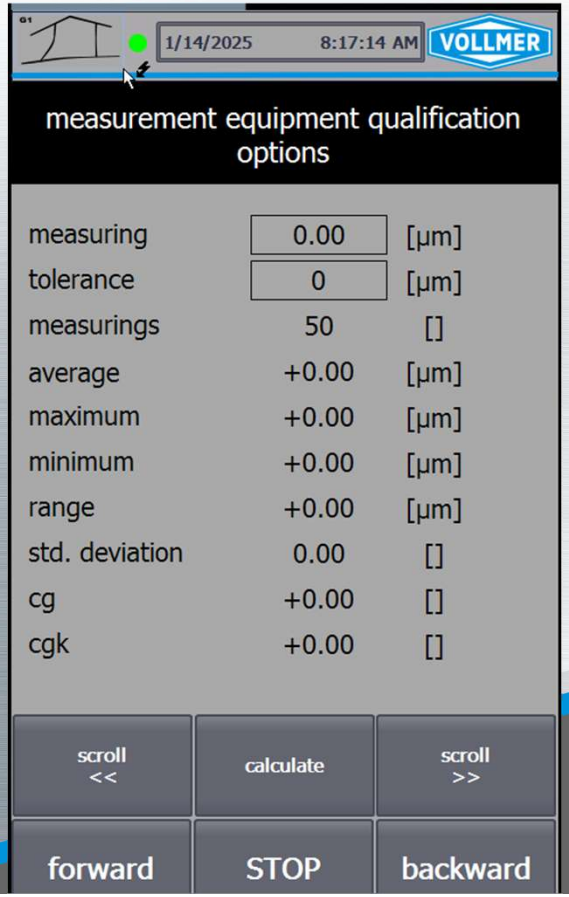
Prüfsystem fähig (RE,U,R&R)

MSA, method 1 and method 3 carried out before delivery for each VTLG

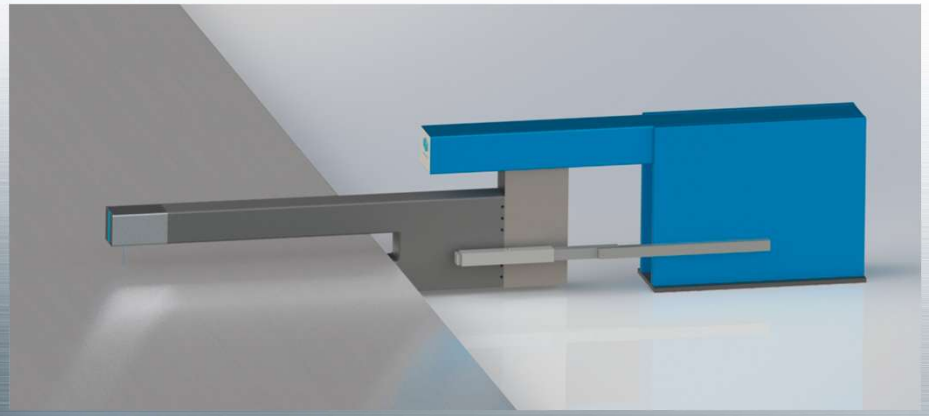
Measuring System Analysis (MSA)

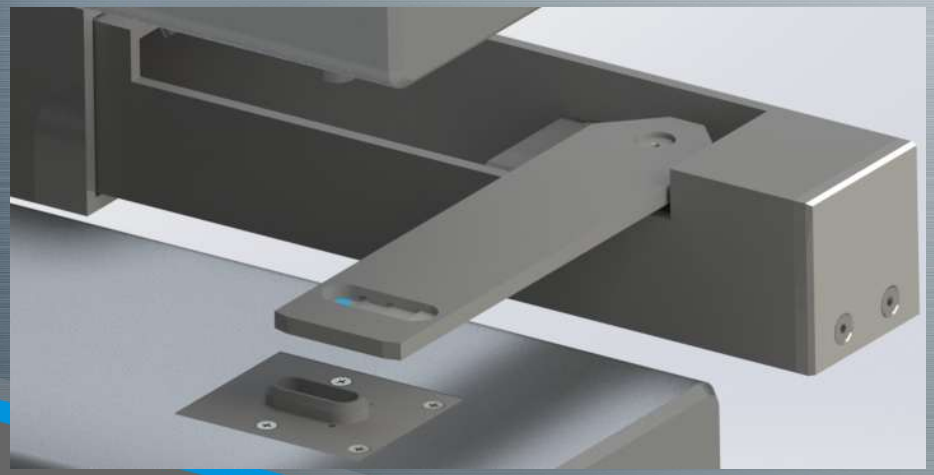
MSA integrated in VTLG standard program

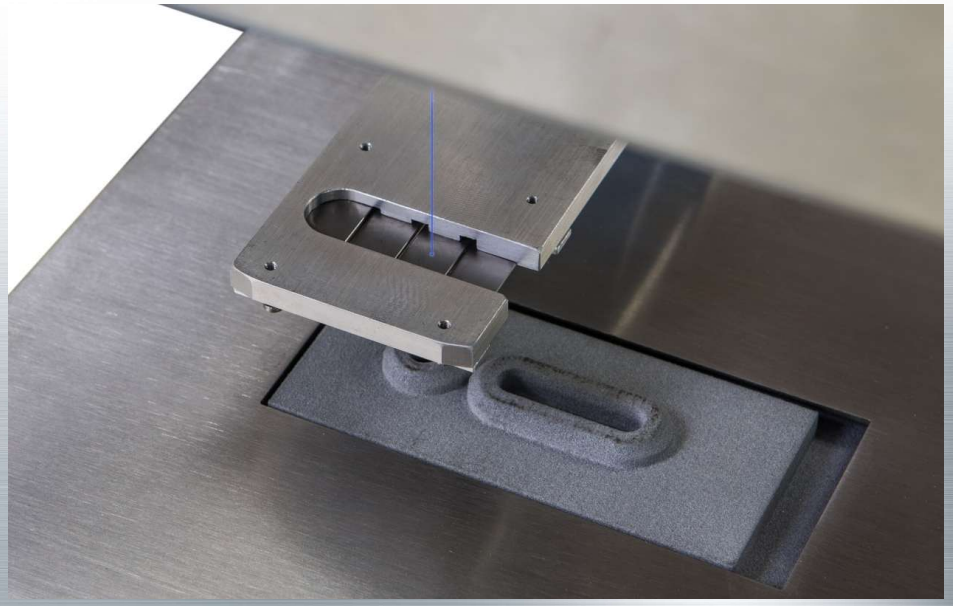




Measuring System Analysis (MSA)







Calibration station in every VTLG with DAkkS-certified gauge blocks

Measuring System Analysis (MSA)

MSA method 1 is as well possible to be carried out e.g. in contact gauges (usually with gauge blocks)

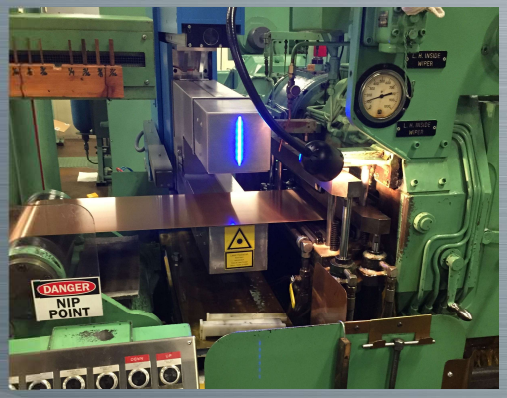
and in x-ray gauges (usually with certified sample sheets from unalloyed metal of pure iron)

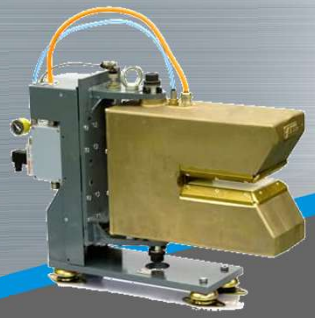
The MSA according to method 3 can be performed individually, depending on the measuring task and process but it is a rarity

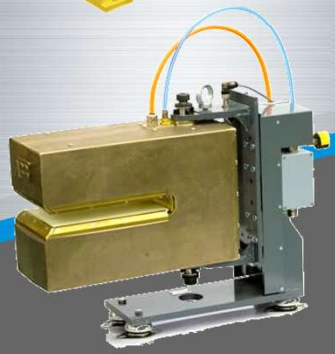
Summary

The 4 different established gauge technologies measure in high accuracy in cold rolling mills

No technology is perfect. Each has its own advantages and disadvantages







Summary

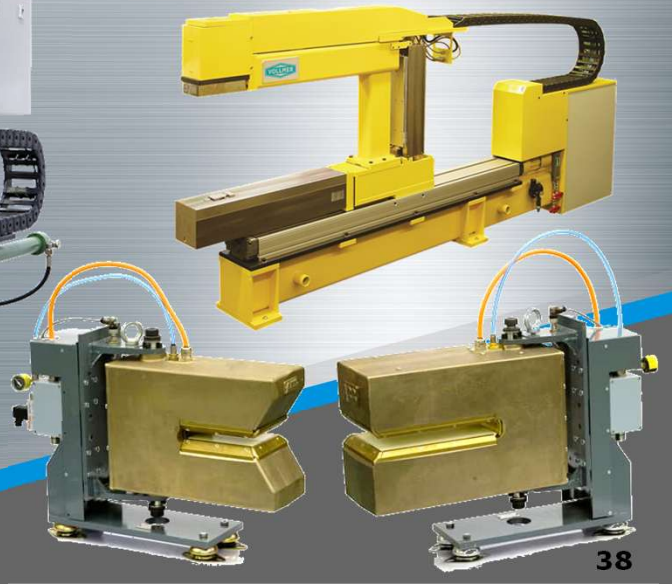
It makes sense to check, which method is suitable for which use.

Depending on the process, there are even sometimes combinations of two technologies in one cold mill e.g. contact gauge for alloy compensation with X-ray gauge

Summary

It can make sense to use different technologies one after the other:

- Break Down Mill with wavy strip: Contact gauge
- Intermediate Mill: VTLG for absolute values
- Foil Mill: X-Ray for highest resolution
- Tension Leveler: VTLG for absolute values and cross profile



Thank you for your attention