

GTB 500

Measuring of bevel gears
with our single flank inspection machine

GEARTEC.CZ, 2017





BEVEL GEARS

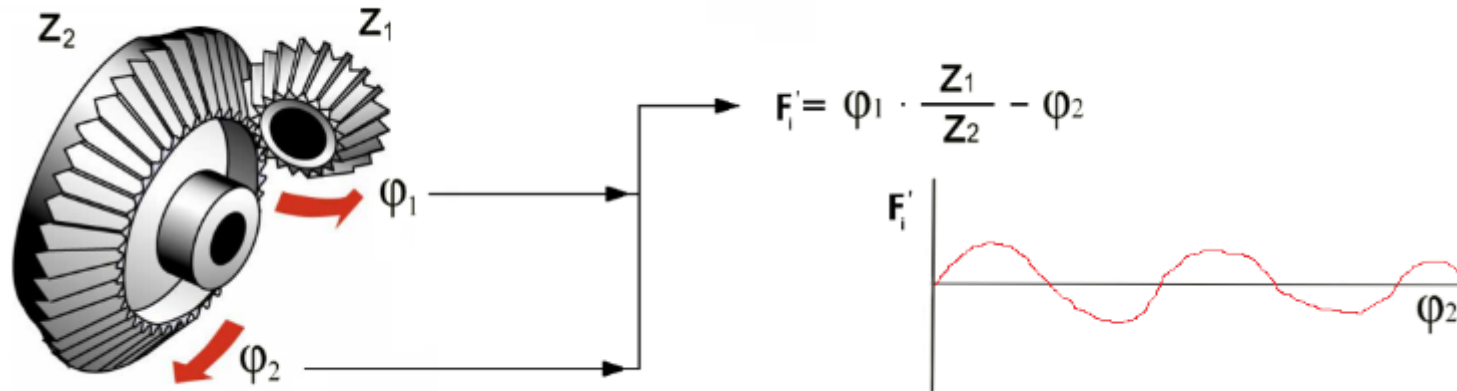
Main requirements in gear production:

- DIN quality
- Defined backlash
- Low noise / high lifetime
- Influence of assembly precision
- Contact pattern, V/H characteristics
- Where error comes from (pinion / wheel)



All these parameters are measured by single flank inspection machine GTB 500

SINGLE FLANK TESTING PRINCIPLE



- Mounting distance during testing is static
- Left and right flanks are tested separately
- Accurate rotary encoder
- Accuracy up to 1 wsec (5 micro rad)
~ 1 μm on radius of 200 mm
- Results in transmission error
- Deviations and tolerances: DIN 3965, AGMA, ISO

MACHINE CAN MEASURE

Standards: DIN 3965, ISO 1328, AGMA 2008

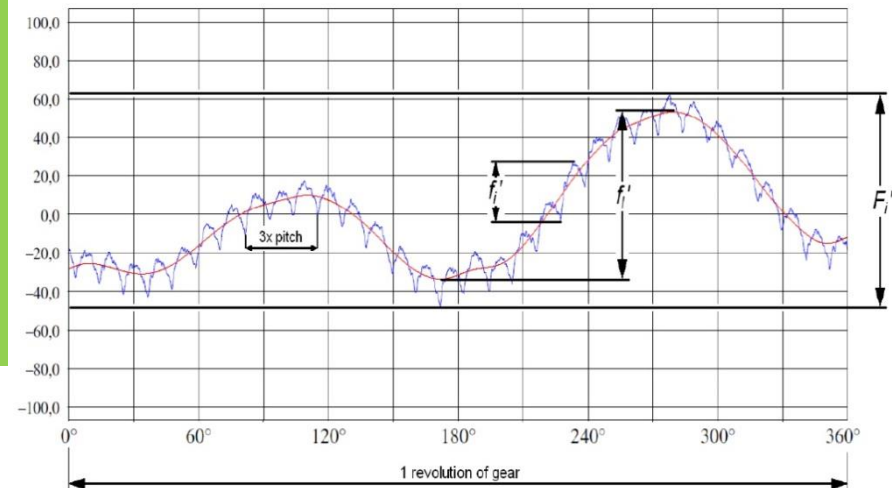
Single flank deviations

- F_i' - Tangential composite deviation
- f_i' - Tooth to tooth composite deviation
- f_l' - Longwave component of tangential composite deviation
- f_k' - Shortwave component of tangential composite deviation
- j - Backlash

- Contact pattern
- V-H Analysis
- FFT Analysis
- Roundness, eccentricity

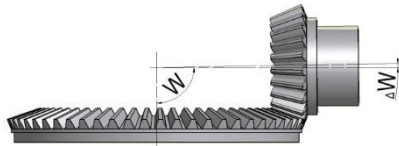
Pitch deviations of pinion and gear

- F_p - Total pitch deviation
- f_{pt} - Adjacent pitch deviation
- f_u - Difference between adjacent pitches
- F_r - Radial run-out

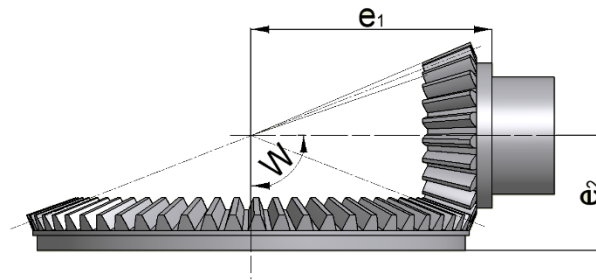


OTHER OPTIONS INFLUENCE OF ASSEMBLY

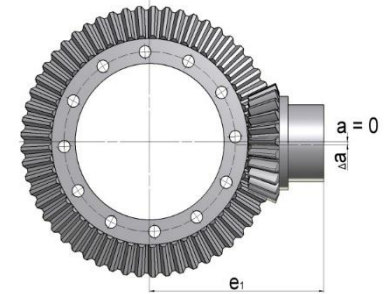
Angular displacement



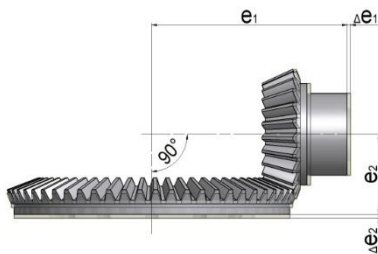
Correct position



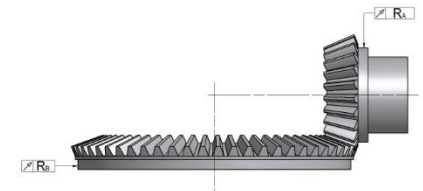
Hypoid offset



Mass displacement



Concentricity



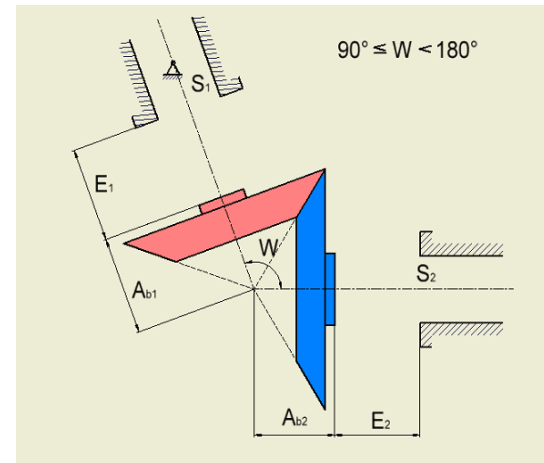
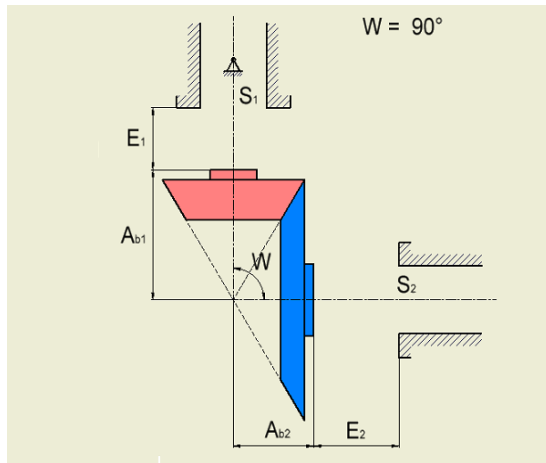
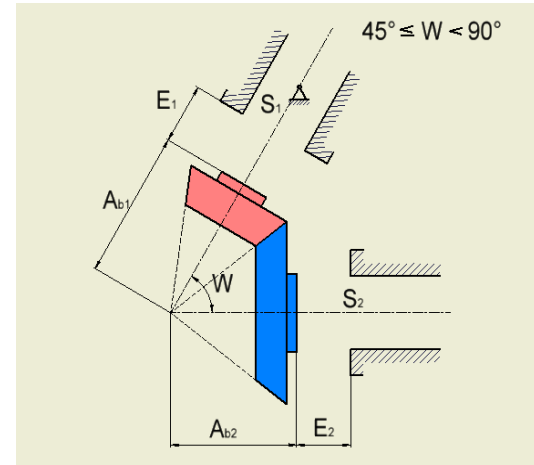
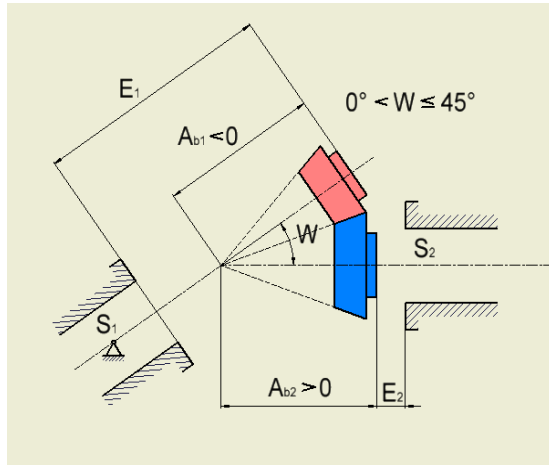
MACHINE VERSIONS

- GTB 500 HW - with hypoid offset and setting of angle between axis
- GTB 500 H - with hypoid offset, fixed angle between axis 90 rad
- GTB 500 W - with hypoid offset 0 – 180 rad , without setting of angle between axis
- GTB 500 - Without hypoid offset
Fixed axis angle 90° for bevel gears
Fixed axis angle 0° for spur gears

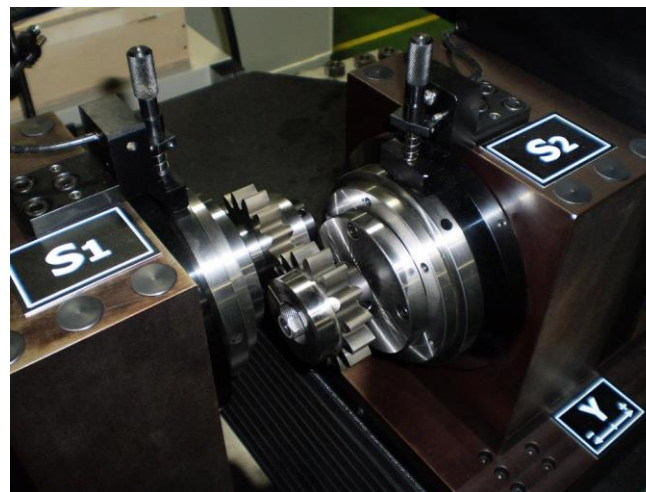
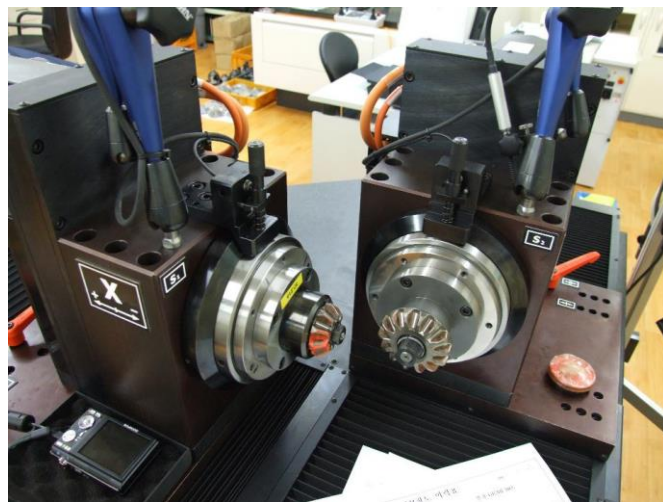
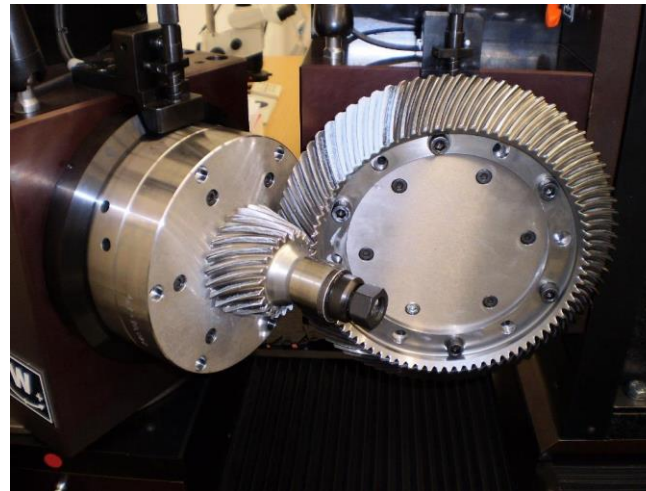
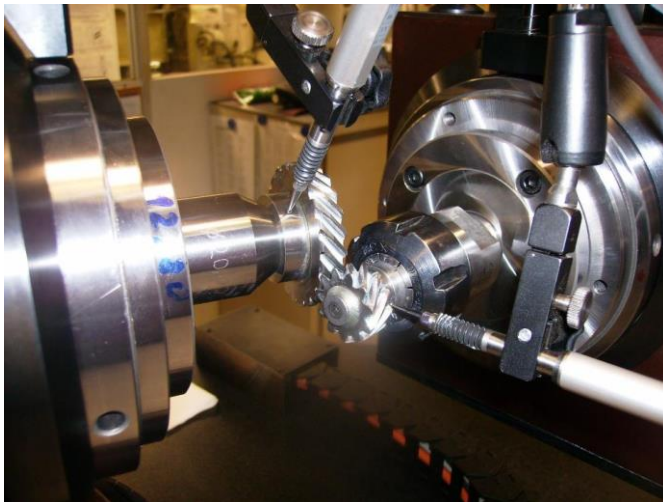
MACHINE PARAMETERS

Parameters	
Diameter, max.	500 mm
Diameter of bore for gear	90 mm
Diameter of bore for pinion	90 mm
Mounting distance of gear, max.	350 mm
Mounting distance of pinion, max.	450 mm
Hypoid offset	± 50 mm
Angle between axis	0 – 180 rad.
Revolutions, max.	100 Rev./min.
Revolutions during measuring, max.	30 Rev./min.
Brake torque, max.	15 (60) Nm
Weight of gear, max.	30 kg
Total weight	1400 kg
Dimesion	1200x1200x1500 mm
Accuracy	DIN 3965 / class 1

PRINCIP OF MEASURING WITH DIFFERENT ANGLES




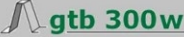
BEVEL GEARS WITH DIFFERENT AXIS ANGLES



INSPECTION REPORTS (HEADER)

Workpiece
data

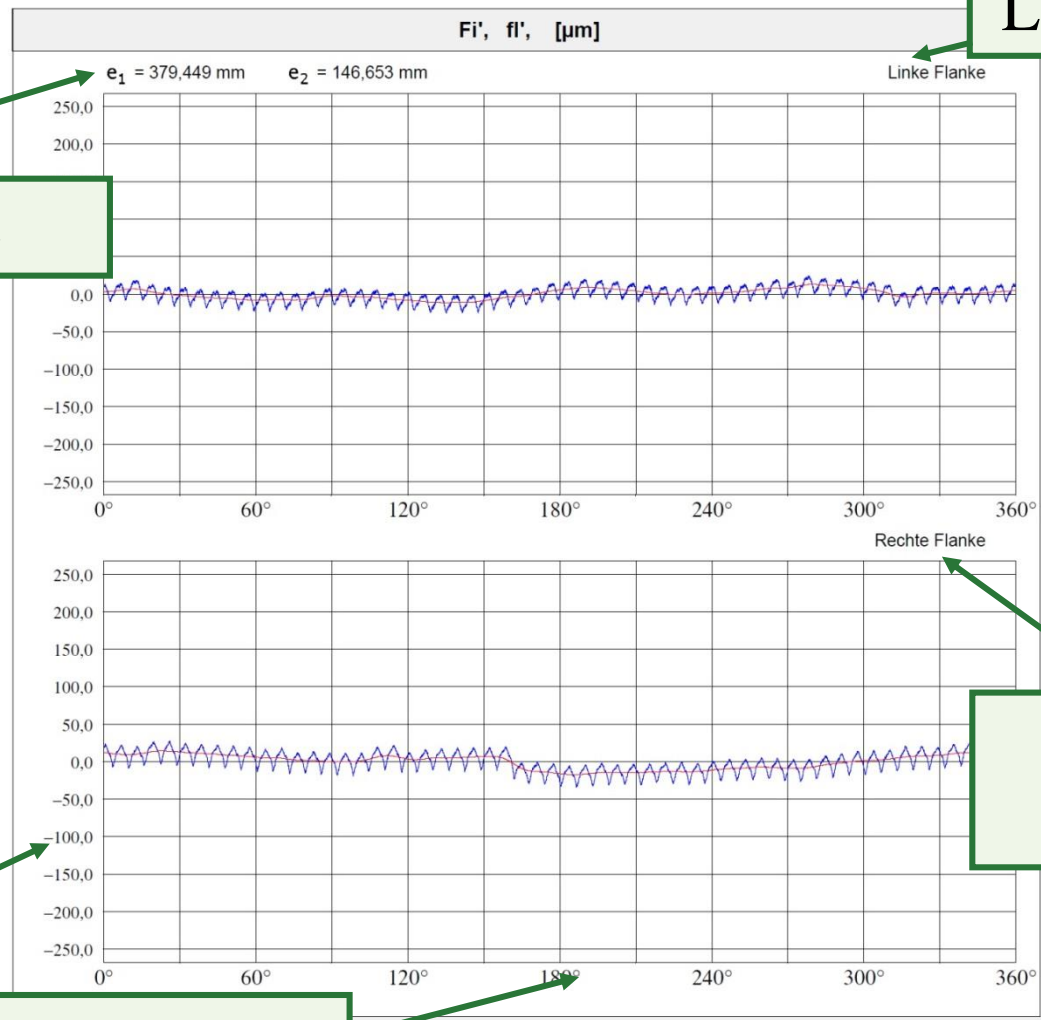
Customer's
logo

Single flank composite measurement, bevel gears						
			Test			
Pinion		Ritzel24	Ring gear		Rad36	Measured points 2000
Number of teeth	z_1	24	Number of teeth	z_2	36	Part No.
Normal module	m_n	3,500	Spiral angle	β_m	35.0000° /R	Contract No.
Pressure angle	α_n	20.0000°	Hypoid offset	a	0,000 mm	Machine No.
Spiral angle	β_m	35.0000° /L	Drawing distance	e_1	170,000 mm	Date 17. 12. 2013 07:38
Load torque		----- Nm	Drawing distance	e_2	88,000 mm	Checked by
Measuring speed		10 rpm	Shaft angle	Σ	90.0000°	Note

LEFT AND RIGHT FLANK

Left flank

Mounting distance



Rolling deviation

Right flank

Angular position

EVALUATION

Allowed values
according to DIN 3965

Left flank

Right flank

Standard: DIN 3965	F-factor 25%	Allowed	Measured f_L	Measured f_R
Total composite deviation	F_i' [μm]	94,0 6	46,5 4	59,7 5
Single flank composite dev.	f_i' [μm]	38,0 6	27,0 5	41,2 7
Mean value	$f_{i,m}'$ [μm]		22,3 5	28,7 6
Max value	$f_{i,max}'$ [μm]		27,0 5	42,7 7
Long wave component	f_l' [μm]	94,0 6	23,0 2	30,9 3
Short wave component	f_k' [μm]	47,0 6	25,2 5	33,6 5
Tooth backlash - normal	j_n [mm]	0,200 ÷ 0,300	0,221	÷ 0,276

Ver. 2.4.7.0

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Measured values

MEASURING APPLICATION – BASIC PARAMETERS

The screenshot shows a software window titled "Measuring parameters" with a blue title bar and standard Windows window controls. The window is divided into several sections for parameter input:

- Name:** "Schulung 1"
- Basic parameters:** Includes tabs for "Basic parameters", "Complementary", "Tolerances", "V/H cycle", "Contact pattern", "Roundness", and "Setup".
- Pinion and Ring gear:** Fields for Drawing No. (717268), Number of teeth ($z_1 = 9$, $z_2 = 13$).
- Module:** Radio buttons for "Normal module" ($m_n = 5,847$) and "Transverse module" (m_t).
- Pressure angle:** $\alpha_n = 22,5000^\circ$
- Face width:** $b = 20,000$ mm
- Hypoid offset:** a mm (with \pm tolerance)
- Spiral angle:** $\beta_m = 0,0000^\circ$
- Pinion spiral hand:** Radio buttons for "L" and "R".
- Distances and Angles:** Drawing distance ($e_1 = 46,228$ mm), Mounting distance ($e_1 = 46,228 \pm 0,010$ mm), Fixture height ($A_{b1} = 43,906$ mm), Shaft angle ($\Sigma = 90,0000^\circ \pm 0,0500^\circ$).
- Backlash:** Radio buttons for "tangential" and "normal", with a field for the backlash value.

At the bottom, there are "Cancel", "Save", and "OK" buttons.

Basic parameters in the measuring application

Measuring software is user-friendly requiring no special PC knowledge. It can communicate in many languages and runs under Microsoft Windows operation system.

All measured results are saved to the databank. Time needed for preparing of measurements is shortened to minimum.

TOLERANCES

Measuring parameters

Basic parameters | Complementary | Tolerances | V/H cycle | Contact pattern | Roundness | Setup

Standard: DIN 3965 ISO 1328 AGMA 17485

Evaluation: [μm] [deg]

Total composite deviation F_i : (358,2 ")

Single flank composite dev. f_i : (162,8 ")

Long wave component f_l : (298,5 ")

Short wave component f_k : (184,5 ")

Backlash j : tangential normal

+ "

Run-out deviation F_r : (31,0 μm) (31,0 μm)

Total cumulative pitch dev F_p : (41,0 μm) (41,0 μm)

Maximum single pitch dev f_{pt} : (12,0 μm) (12,0 μm)

Adjacent pitch deviation f_u : (15,0 μm) (15,0 μm)

Pairing: Left flank Right flank

Tolerances

Evaluation of measured data is available according to DIN, ISO, AGMA standards or free values.

Gears with CP or DP profiles can also be measured and evaluated.

Graphical evaluation of „good“ or „bad“ may be printed on measuring reports.

MANUAL MODE

- Actual position and angle depicted
- Contact pattern measuring
- Measuring of backlash in a concrete position

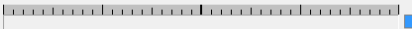
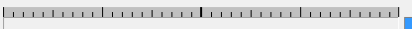
Manual mode

Safety unit is disabled !


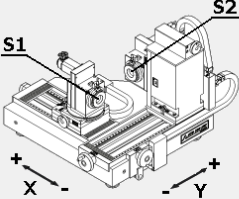
X = -195,139 mm
Y = 0,741 mm
Z = ----- mm

S1 = 0.0000° ●
S2 = 0.0000° ●

W = 90.0065°

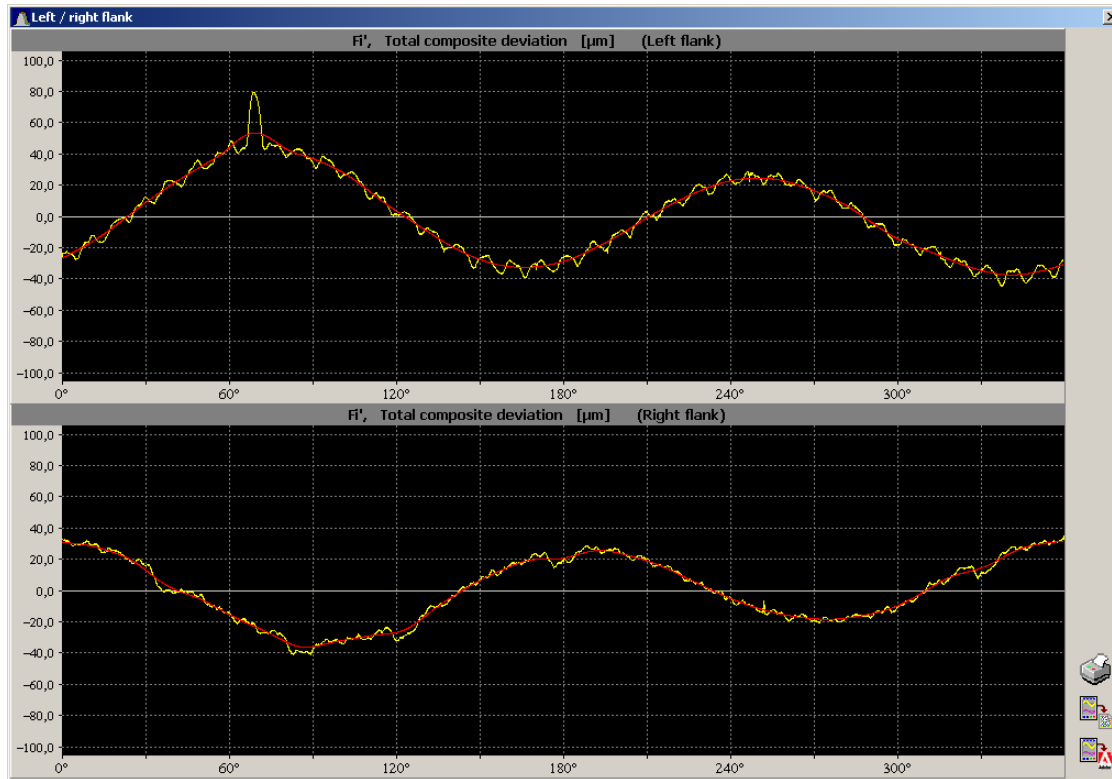
Ra = ----- mm 
Rb = ----- mm 

n1 = 0,0rpm
n2 = 0,0rpm



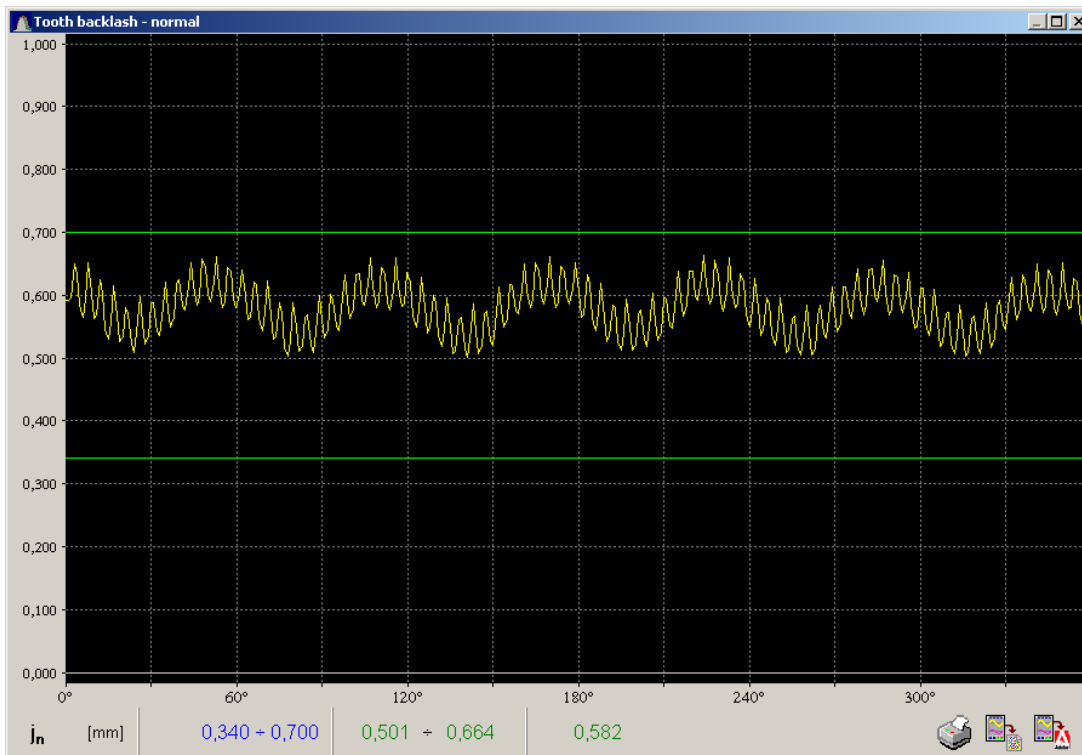
EXAMPLE 1: RUN-OUT AND BUMP

- Diagram of single flank, gear ratio 19/38
- Big run-out of pinion
- Tooth No. 8 has bump on the left flank



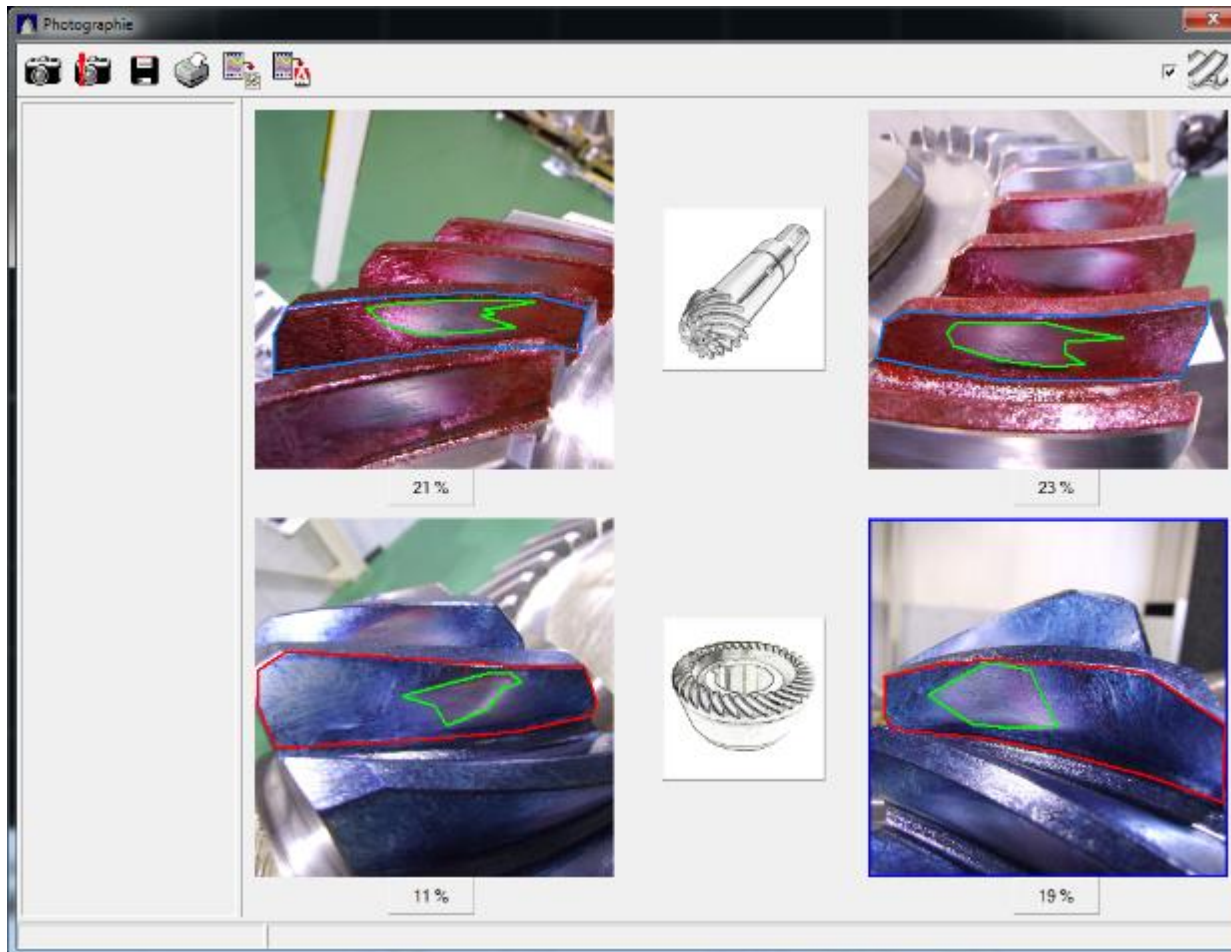
EXAMPLE 2: BACKLASH

- Chart of backlash for one revolution of gear
- Backlash is changed by pinion run-out
- It is available to measure backlash in a concrete position in manual mode



EXAMPLE 3: CONTACT PATTERN

- Stored in database with measuring results
- Ration of contact pattern surface to total tooth surface in %



EXAMPLE 4: V-H CYCLE

- Digital image of contact pattern, shown in more positions on pinion and gear
- Automatic cycle

Single flank composite measurement, bevel gears				geartec.cz	
GTB 1250					
Pinion	246-6762	Wheel	246-6763	Measured revs	4
Number of teeth	z_1 29	Number of teeth	z_2 37	Serial No.	
Transverse module	m_t 22,038	Spiral angle	β_m 23.0000° /L	Contract No.	
Pressure angle	α_n 22.5000°	Hypoid offset	a 0,000 mm	Machine No.	
Spiral angle	β_m 23.0000° /R	Drawing distance	e_1 380,914 mm	Date	12.11.2009 09:47
Load torque	50,00 Nm	Drawing distance	e_2 331,400 mm	Checked by	
Measuring speed	20rpm	Shaft angle	Σ 89.9999°	Note	

V/H cycle

Convex side of pinion



Level 1

V = -0,32000 inch H = -0,14200 inch PH = 0,08500 inch

Concave side of pinion

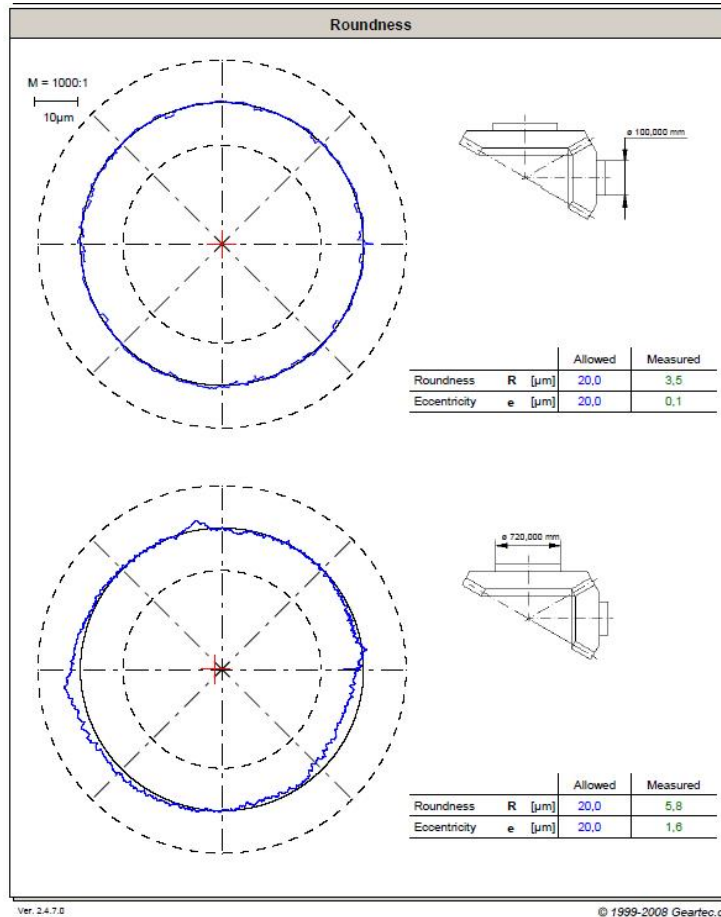


Level 2

V = 0,25200 inch H = 0,11000 inch PH = 0,08500 inch

EXAMPLE 5: SINGLE FLANK ERRORS

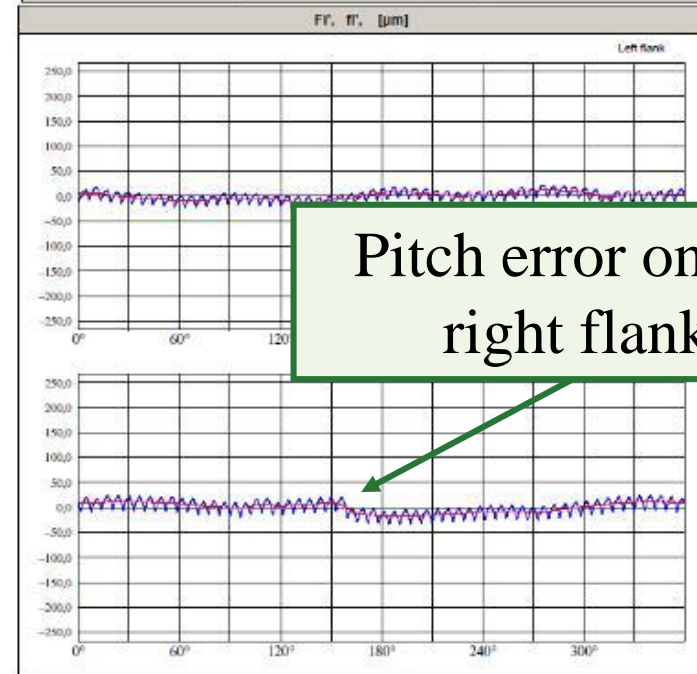
- Right flank with a little pitch error
- Both gears without radial run-out



Single flank composite measurement, bevel gears

gtb 1250 geartec.cz

Pinion	u1	Wheel	u2	Measured points	8000
Number of teeth z_1	14	Number of teeth z_2	57	Nr. of measurement	
Normal module m_n	9.887	Spiral angle β_m	30.0000°/L	Contract No.	
Pressure angle α_{fn}	20.0000°	Hypoid offset a	0,001 mm	Machine No.	
Spiral angle β_{fn}	30.0000°/R	Mounting distance d_1	378,436 mm	Date	9.7.2008 15:53
Load torque	10,00 Nm	Mounting distance d_2	140,614 mm	Checked by	
Measuring speed	5rpm	Shaft angle Σ	60.0000°	Note	



Pitch error on the right flank

Standard: DIN 3965	F-factor 25%	Allowed	Measured	
Total composite deviation F_1	[μm]	94,0 8	48,5 4	58,7 5
Single flank composite dev. f_{1s}	[μm]	38,0 8	27,0 5	41,2 7
Mean value f_{1m}	[μm]		22,3 5	28,7 6
Max value f_{1max}	[μm]		27,0 5	42,7 7
Long wave component f_{1l}	[μm]	94,0 5	23,0 2	30,8 3
Short wave component f_{1s}	[μm]	47,0 8	25,2 5	33,5 5
Teeth backlash - normal $-b$	[mm]	0,200 - 0,300	0,221	0,278

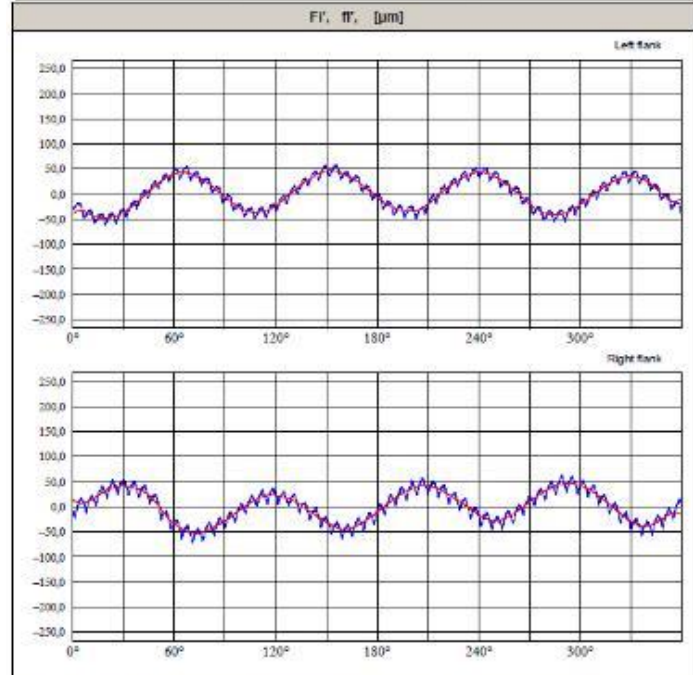
Ver. 2.4.7.0

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EXAMPLE 6: ROUNDNESS

Single flank composite measurement, bevel gears				geartec.cz	
gtb 1250					
Pinion	u1	Wheel	u2	Measured points	8000
Number of teeth	z_1 14	Number of teeth	z_2 57	Nr. of measurement	
Normal module	m_n 9.867	Spiral angle	β_{mn} 30.0000° L	Contract No.	
Pressure angle	α_n 20.0000°	Hypoid offset	a 0.003 mm	Machine No.	
Spiral angle	β_{m1} 30.0000° R	Mounting distance	a_1 370.450 mm	Date	10.7.2008 10:48
Load torque	10,00 Nm	Mounting distance	a_2 148,727 mm	Checked by	
Measuring speed	5rpm	Shaft angle	Σ 90.0000°	Note	

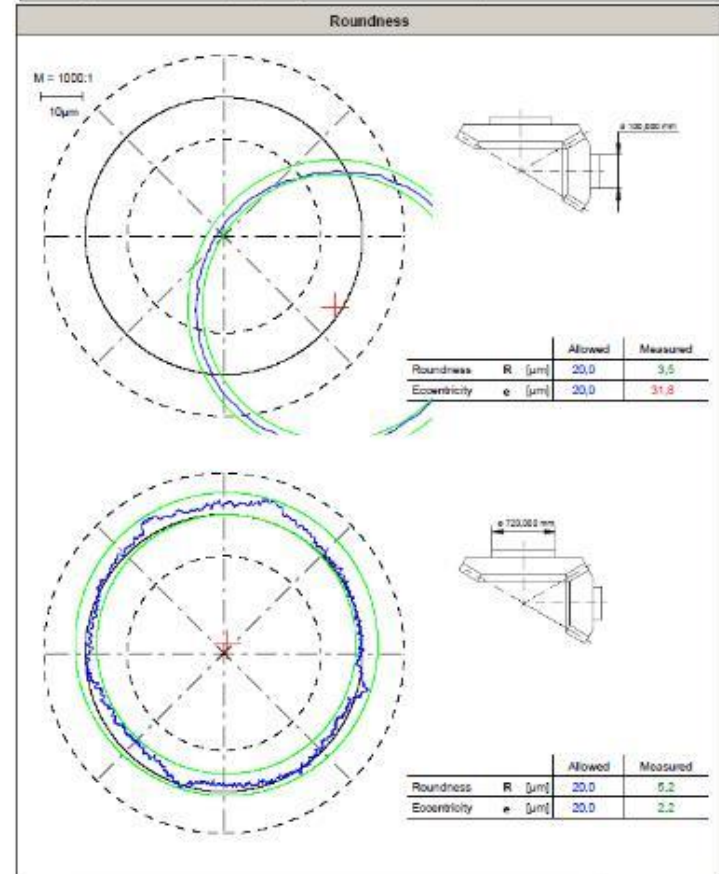


Standard: DIN 3965	F-factor: 25%	Allowed	Measured
Total composite deviation	F'_1 [μm]	94,0 8	120,4 7, 135,1 8
Single flank composite dev.	f'_1 [μm]	38,0 8	56,3 7, 50,4 7
Mean value	f'_{1m} [μm]	25,8 8	33,5 8
Max value	f'_{1max} [μm]	39,3 7	52,0 7
Long wave component	f'_l [μm]	94,0 8	95,8 7, 96,9 7
Short wave component	f'_k [μm]	47,0 8	30,4 8, 37,0 8
Tooth backlash - normal	j_n [mm]	0,200 - 0,300	0,281 - 0,374

sw_34.7.0

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Single flank composite measurement, bevel gears				geartec.cz	
gtb 1250					
Pinion	u1	Wheel	u2	Measured points	8000
Number of teeth	z_1 14	Number of teeth	z_2 57	Nr. of measurement	
Normal module	m_n 9.867	Spiral angle	β_{mn} 30.0000° L	Contract No.	
Pressure angle	α_n 20.0000°	Hypoid offset	a 0.003 mm	Machine No.	
Spiral angle	β_{m1} 30.0000° R	Mounting distance	a_1 370.450 mm	Date	10.7.2008 10:48
Load torque	10,00 Nm	Mounting distance	a_2 148,727 mm	Checked by	
Measuring speed	6rpm	Shaft angle	Σ 90.0000°	Note	

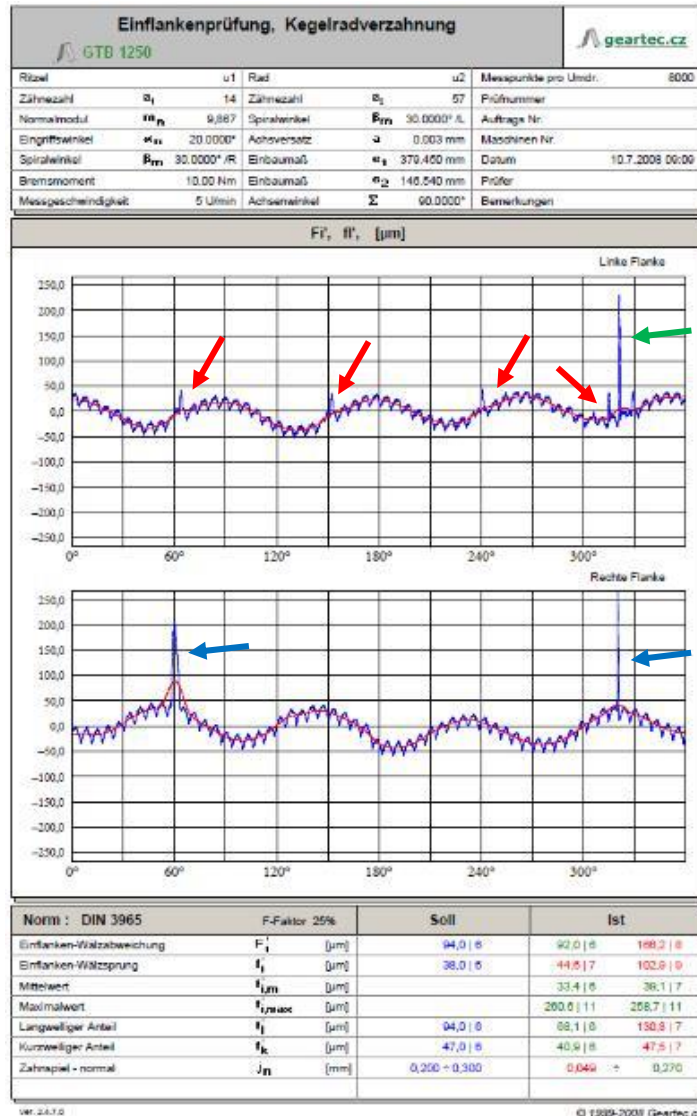


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EXAMPLE 7: BUMP DETECTION



Single flank deviations – pinion with approximately 20 µm eccentricity

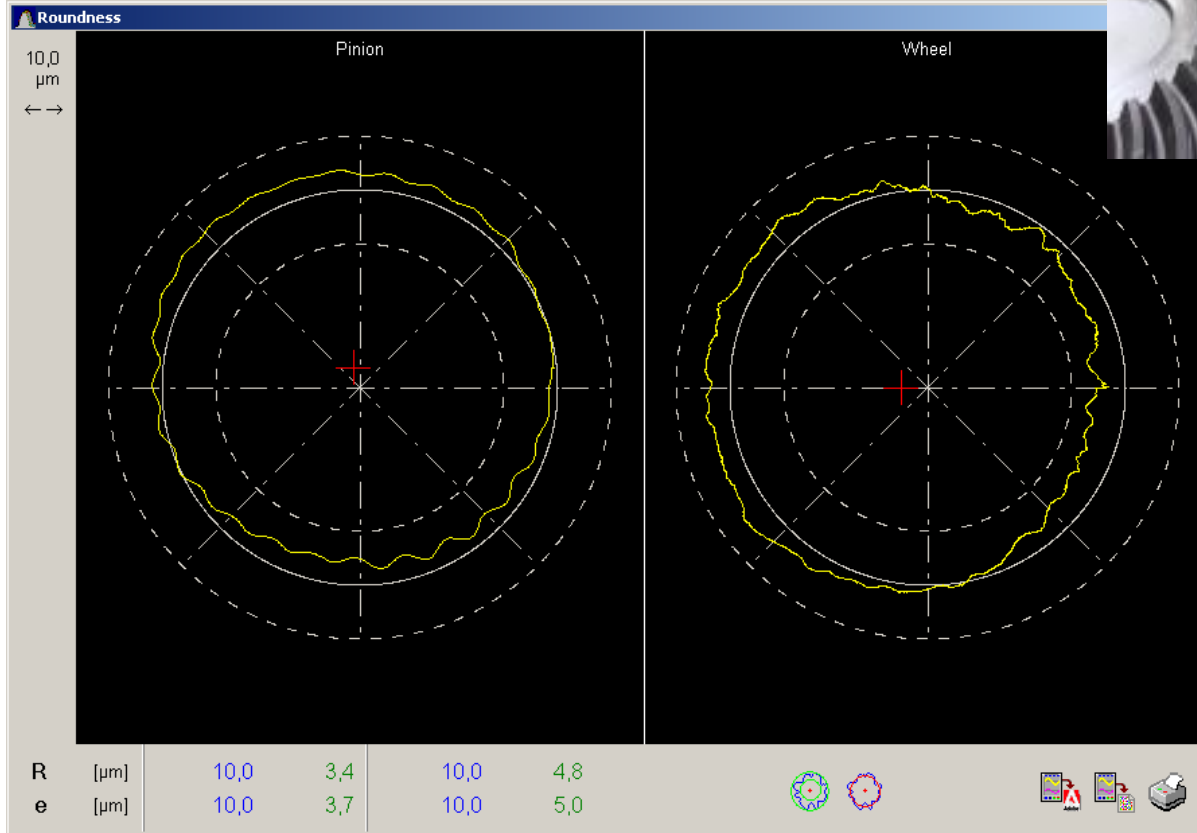
Left flank of pinion with bumps (marked in red color)

Left flank of wheel with a bump (marked in green color)

Right flank of wheel with a bump (marked in blue color)

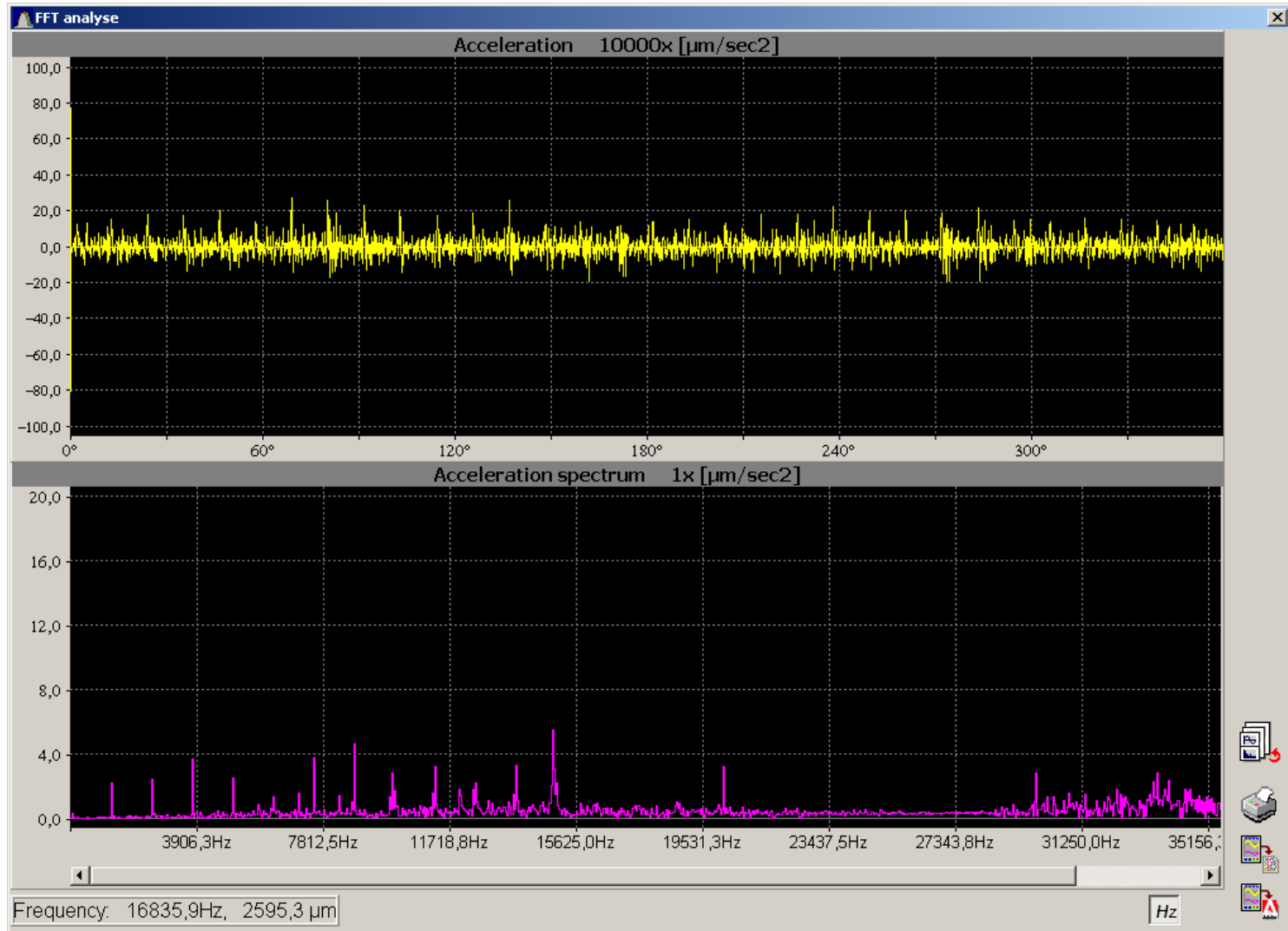
RUN-OUT AND ROUNDNESS

- Run-out of pinion and gear
- Elimination of error from single flank test



Measuring of control rings

FTT ANALYSIS AND NOISE

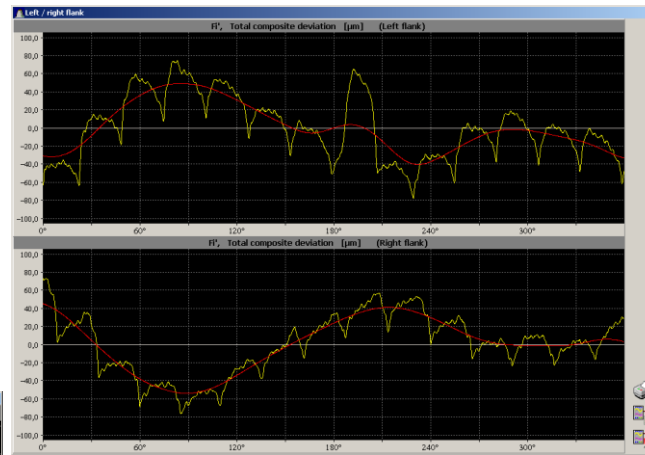


Calculated acceleration spectrum of signal

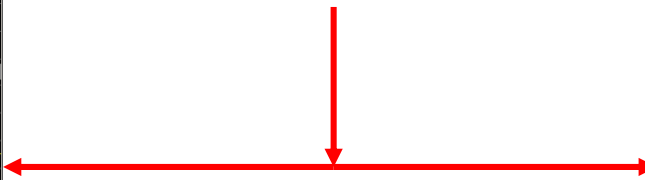
PITCH DEVIATION OF PINION / GEAR

QUESTION: Which gear causes big deviation on single flank result?

ANSWER: Use decomposition of single flank test.

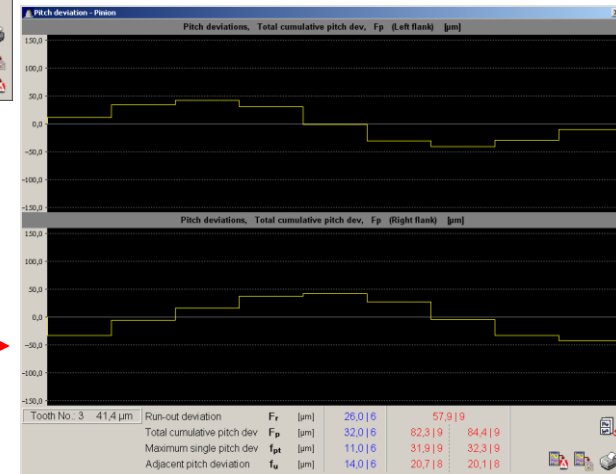
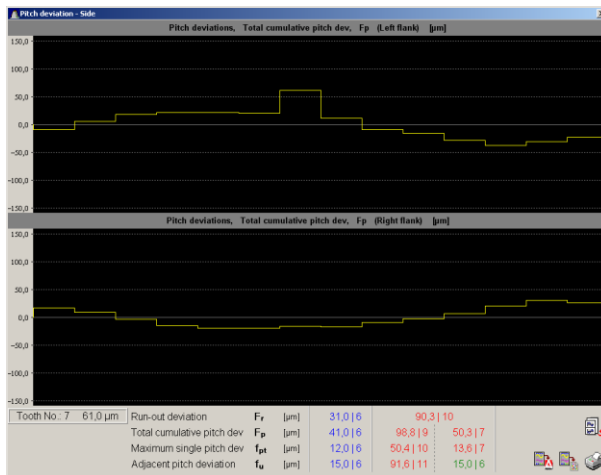


Decomposition of single flank test

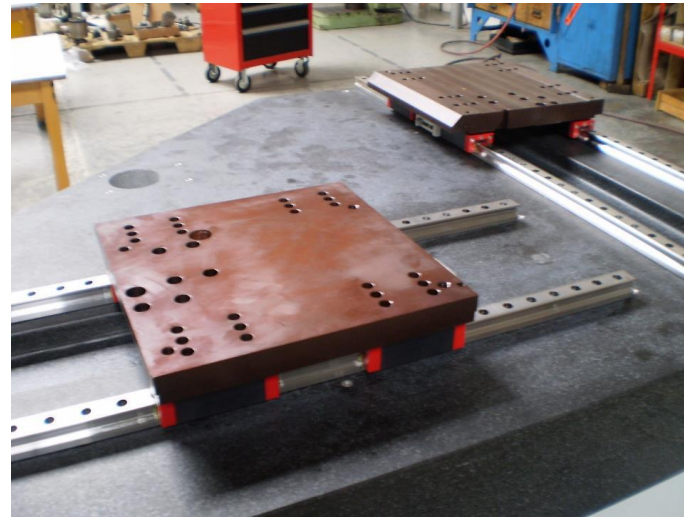


Gear

Pinion



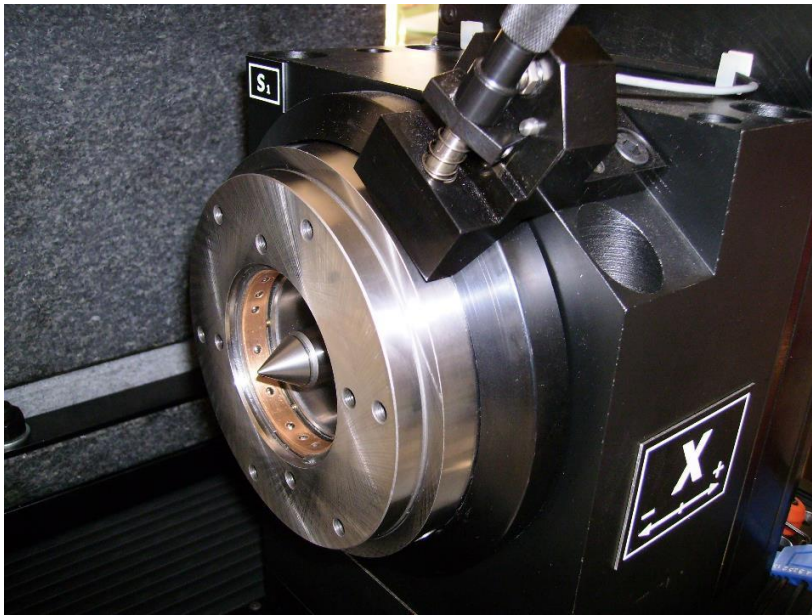
ASSEMBLY OF BASIC MACHINE



ASSEMBLY OF SPINDLES



ASSEMBLY OF PINION AND GEAR SPINDLES

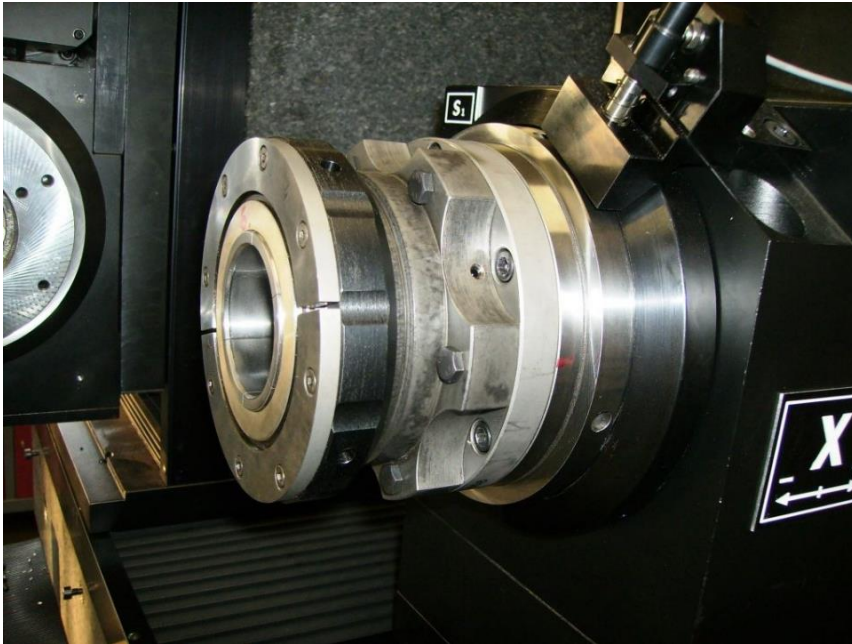


PINION – CLAMPING FIXTURES

based on customer's specification



PINION – DETAIL OF CLAMPING FIXTURE AND ITS TEST

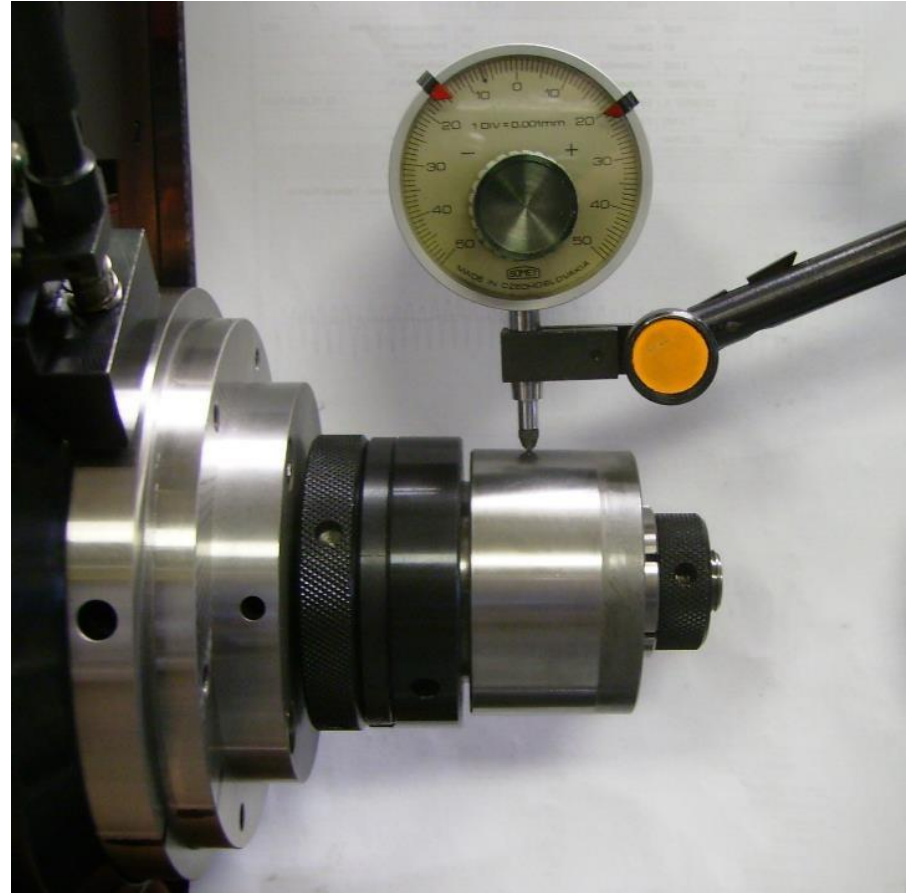
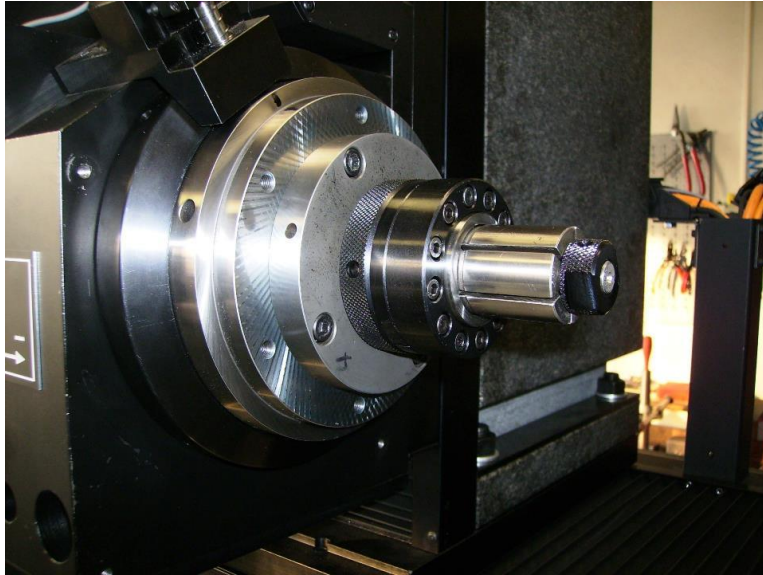


GEAR – CLAMPING FIXTURES

based on customer's specification



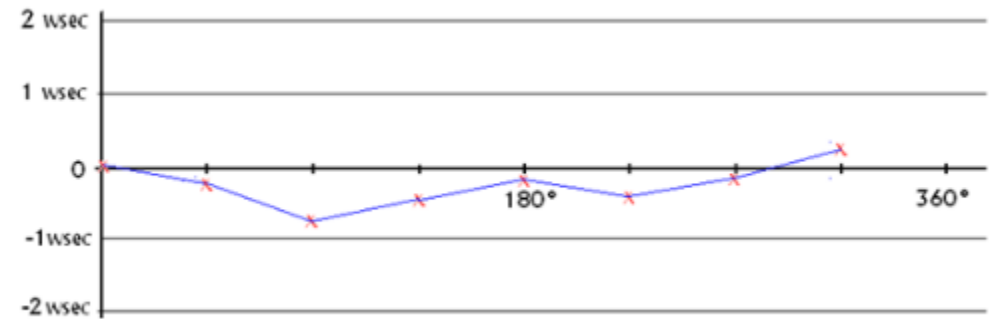
GEAR – DETAIL OF CLAMPING FIXTURE AND ITS TEST



TESTING OF MACHINE GEOMETRY



CHECKING OF ACCURACY OF ROTATION TABLE



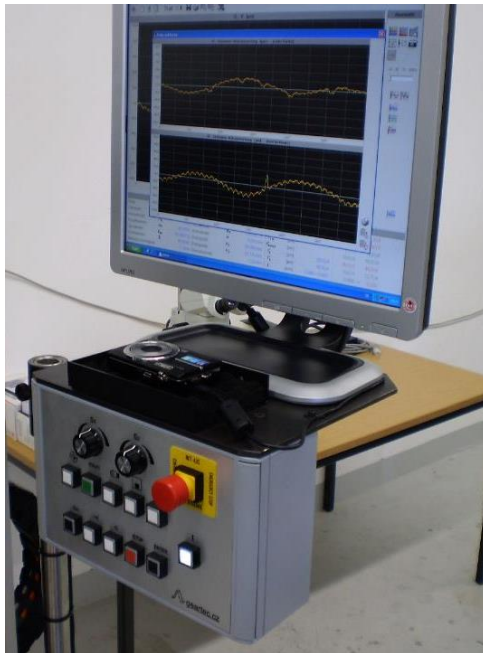
CALIBRATION ARBOR



WIRING BOX



CONTROL PANEL



Potentiometer for smooth rotation

Manual motion to designed position

TOTAL STOP

Buttons for main functions of measuring application



CONTROLLING COMPUTER

- It is based on high performance industrial computer by Advantech
- Measuring cards by Heidenhain
- Controlling I/O cards by Advantech for communication with proper hardware



ADVANTAGE OF SINGLE FLANK INSPECTION

- Standards DIN, AGMA, ISO, BS ...
- Helps improve gear quality
- Optimization of gear parameters
- Quick measuring and results



THANK YOU

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