

GTB 1600

Inspection of bevel gears by single flank tester

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 / ring gear)



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

GTB 1600 – SINGLE FLANK TESTER



Manufactured by GEARTEC.CZ in 2015 for ATA in Finland.
Other machines work at XUBI in Spain and SIEMENS in Germany.

MACHINE CAN MEASURE

Standards: DIN 3965, ISO 1328, AGMA 2008

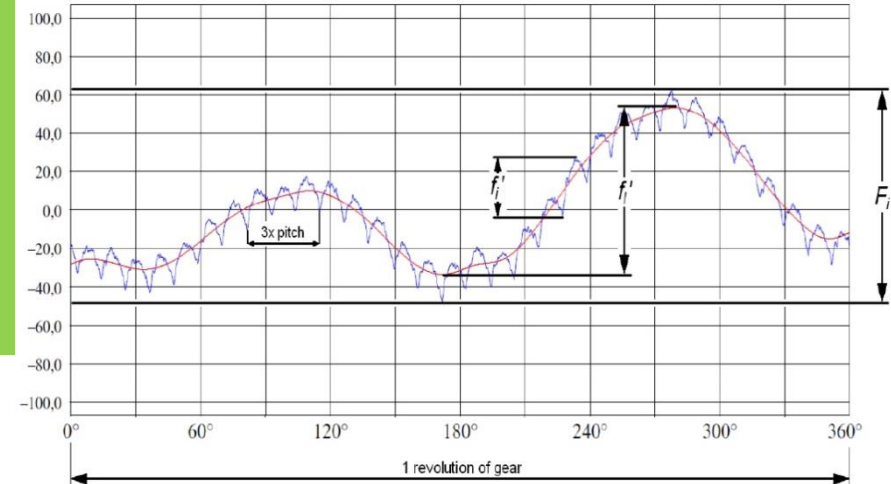
Single flank deviations

- 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 of pinion and gear

Pitch deviations of pinion and gear

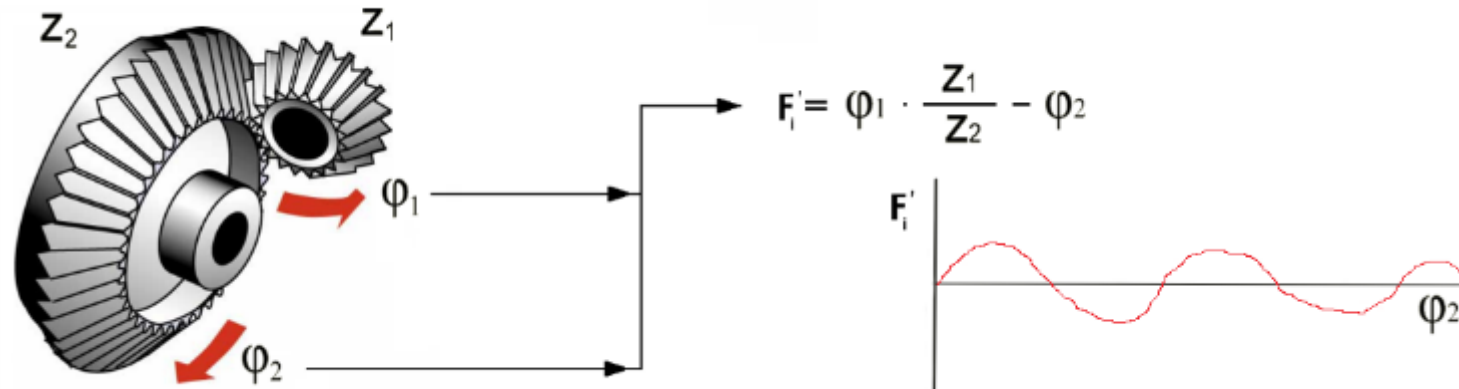
- F_p - Total pitch deviation
- f_{pt} - Adjacent pitch deviation
- f_u - Difference between adjacent pitches
- F_r - Radial run-out



MACHINE PARAMETERS

Dimensions	
Work diameter of gear, max.	1 600 mm
Mounting distance of pinion, max.	1 375 mm
Mounting distance of pinion, min.	375 mm
Mounting distance of gear, max.	730 mm
Mounting distance of pinion, min.	130 mm
Hypoid offset, max. (without hypoid offset – optional)	± 50 mm
Angle between axes, fixed	90 deg.
Weight of pinion, max.	1 500 kg
Weight of gear, max.	3 000 kg
Dimensions (L/W/H)	4000/3300/3200 mm
Weight, approximately	14 000 kg
Spindles	
Diameter / length of bore pinion spindle	Ø 310 / 1 000 mm
Diameter / length of bore gear spindle	Ø 310 / 1 000 mm
Maximum number of pinion spindle revolutions for single flank measuring	30 rpm
Maximum number of pinion spindle revolutions for noise (contact pattern) measuring	100 rpm
Main pinion spindle motor	12 kW
Main gear side motor	12 kW
Maximal brake torque (continuously variable) for basic version of machine	500 Nm

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 3960

INSPECTION REPORTS (HEADER)

Workpiece
data

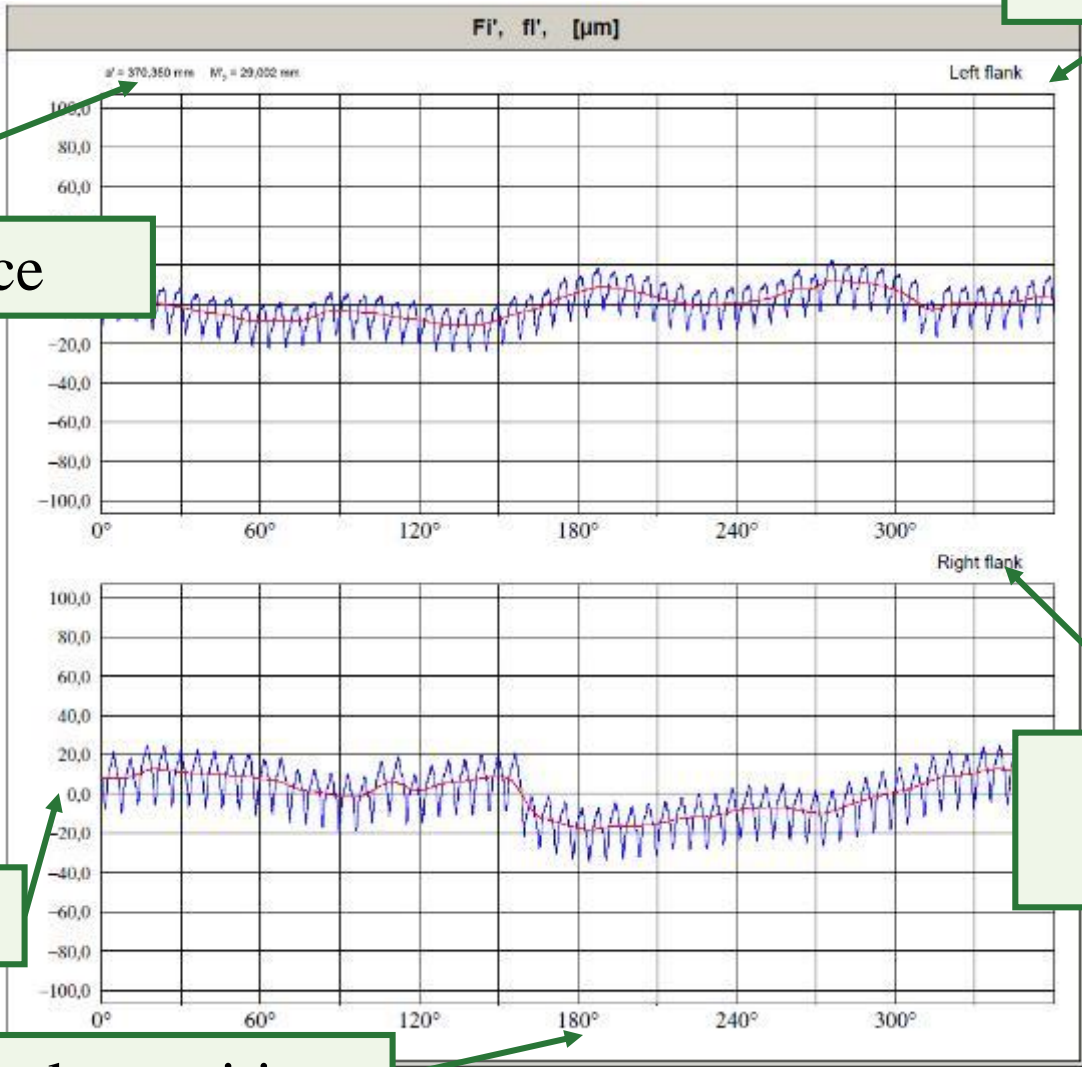
Customer's
logo

Single flank composite measurement, bevel gears						
						
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_m	30.0000°/L	Contract No.
Pressure angle	α_n	20.0000°	Hypoid offset	a	0,001 mm	Machine No.
Spiral angle	β_m	30.0000°/R	Mounting distance	e_1	379,436 mm	Date 9.7.2008 15:53
Load torque		10,00 Nm	Mounting distance	e_2	146,614 mm	Checked by
Measuring speed		5rpm	Shaft angle	Σ	90.0000°	Note

LEFT AND RIGHT FLANK

Left flank

Mounting distance



Right flank

Rolling deviation

Angular position





EVALUATION

Allowed values
according to DIN 3965

Left flank

Right flank

Standard: DIN 3965	F-factor 25%	Allowed	 Measured	
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_j' [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 border. It contains several tabs: "Basic parameters", "Complementary", "Tolerances", "V/H cycle", "Contact pattern", "Roundness", and "Setup". The "Basic parameters" tab is active. The window is divided into sections for "Pinion" and "Ring gear".

Name: Schulung 1

Pinion: Drawing No. 717268, Number of teeth z_1 9

Ring gear: Drawing No. 717265, Number of teeth z_2 13

Module: Normal module m_n 5,847; Transverse module m_t

Pressure angle: α_n 22.5000°

Face width: b 20,000 mm

Hypoid offset: a [] ± [] mm

Spiral angle: β_m 0.0000°

Pinion spiral hand: L R

Drawing distance: e_1 46,228 mm; e_2 32,055 mm

Mounting distance: e_1 46,228 ± 0,010 mm; e_2 32,055 ± 0,010 mm

Fixture height: A_{b1} 43,906 mm; A_{b2} 50,072 mm

Shaft angle: Σ 90.0000° ± 0.0500°

Backlash: j tangential normal [] "

Buttons: Cancel, Save, OK

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

Basic parameters of tothing, description of clamping fixtures



TOLERANCES

Measuring parameters

Basic parameters | Complementary parameters | Deviations | Roundness | Setup

Standard: ~ DIN 3965 ISO 1328

Evaluation: [µm] [deg]

Total composite deviation F_i^c	6	(94,0 µm)
Single flank composite dev. f_i^c	6	(38,0 µm)
Long wave component f_l^c	6	(94,0 µm)
Short wave component f_k^c	6	(47,0 µm)

Pairing

Tooth backlash j: tangential normal
0,350 ÷ 0,450 mm

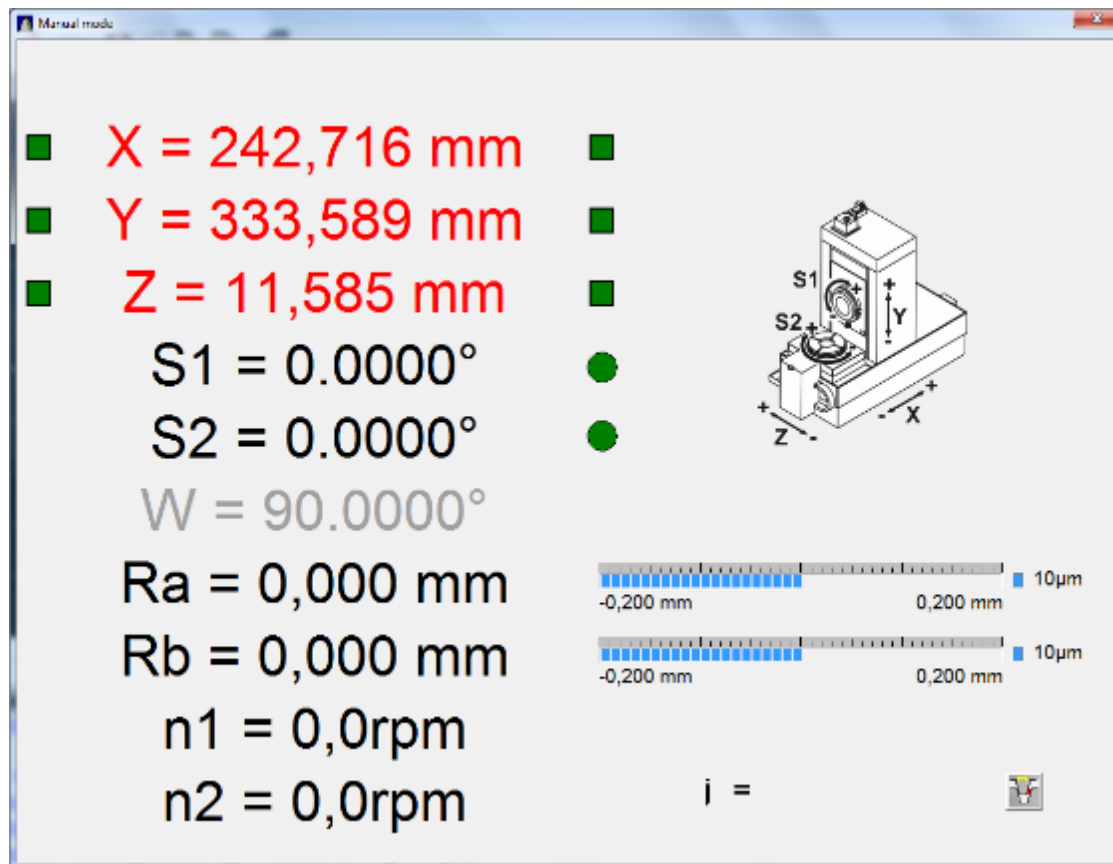
<input checked="" type="checkbox"/> Run-out deviation F_r	6	(40,0 µm)	6	(50,0 µm)
Total cumulative pitch dev F_p	6	(52,0 µm)	6	(67,0 µm)
Maximum single pitch dev f_{pt}	6	(15,0 µm)	6	(17,0 µm)
Adjacent pitch deviation f_u	6	(19,0 µm)	6	(21,0 µm)

Cancel Save OK

Option of standards and a degree for each deviation

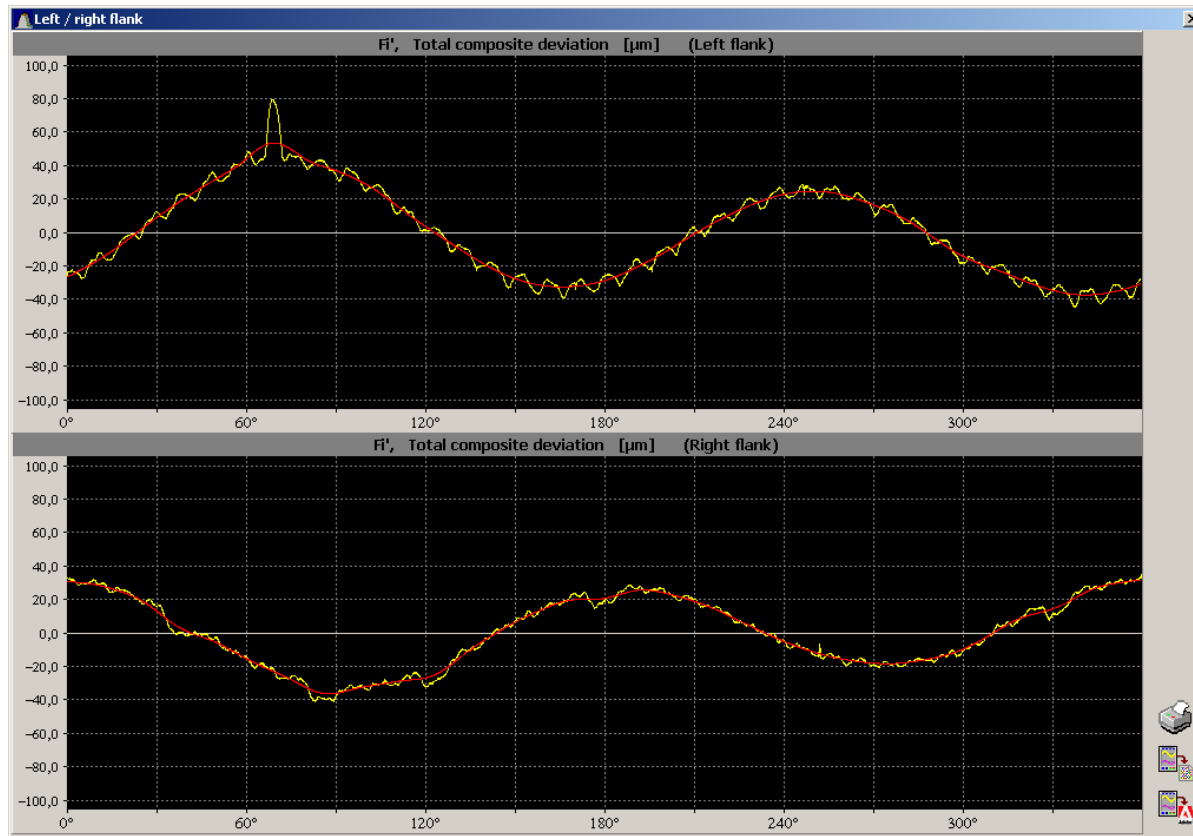
MANUAL MODE

- Depiction of actual position
- Contact pattern measuring
- Measuring of backlash in a concrete position



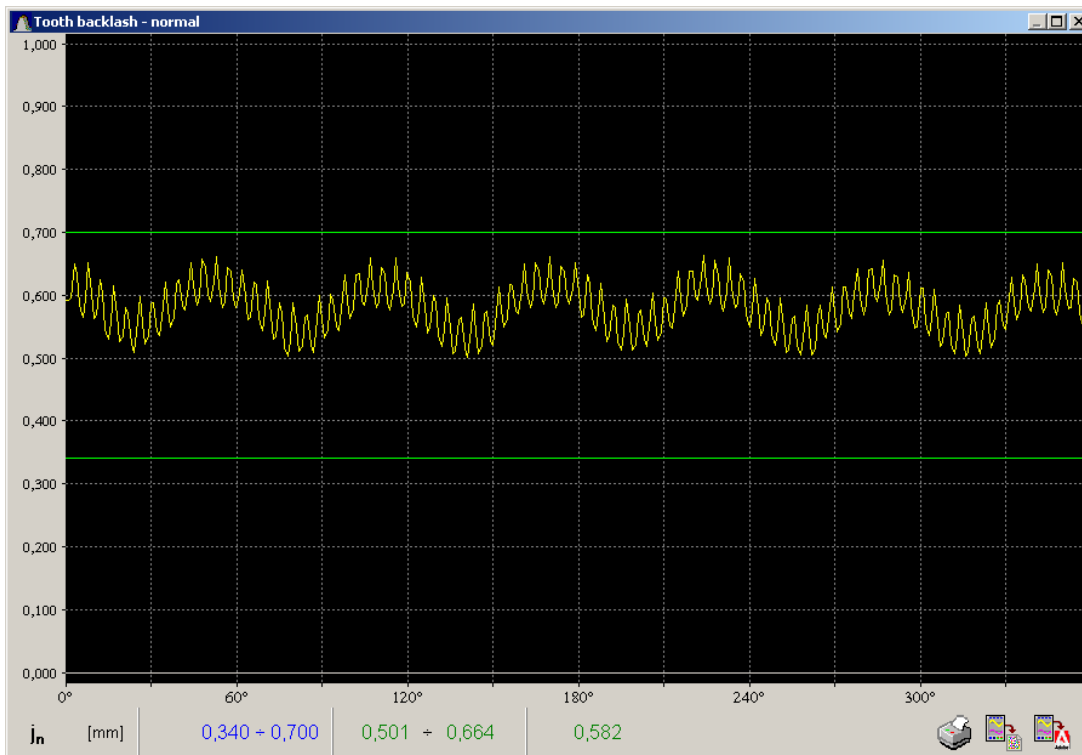
EXAMPLE 1: RUN-OUT OF PINION

- Big run-out of pinion
- Tooth No. 8 has bump on the left flank



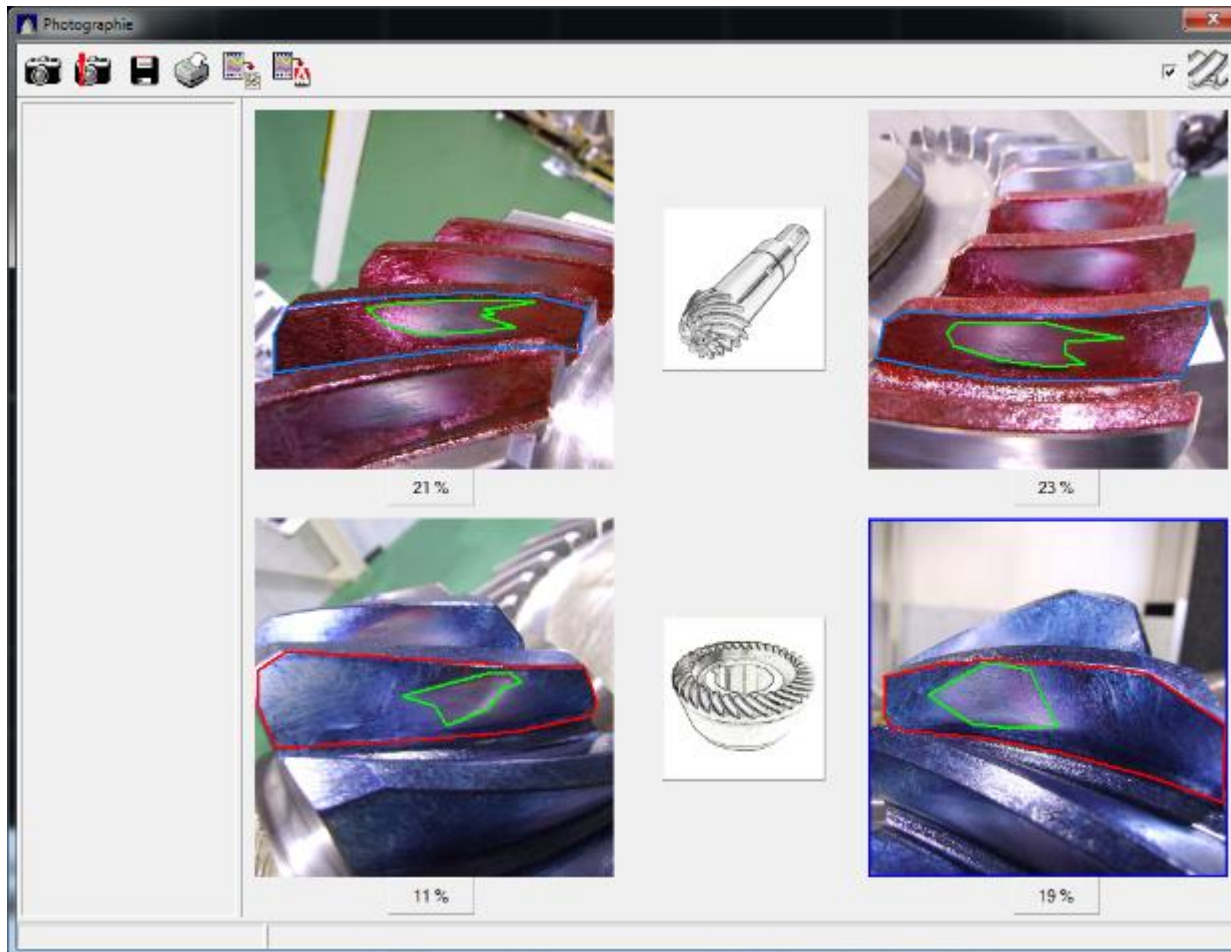
EXAMPLE 2: BACKLASH

- 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

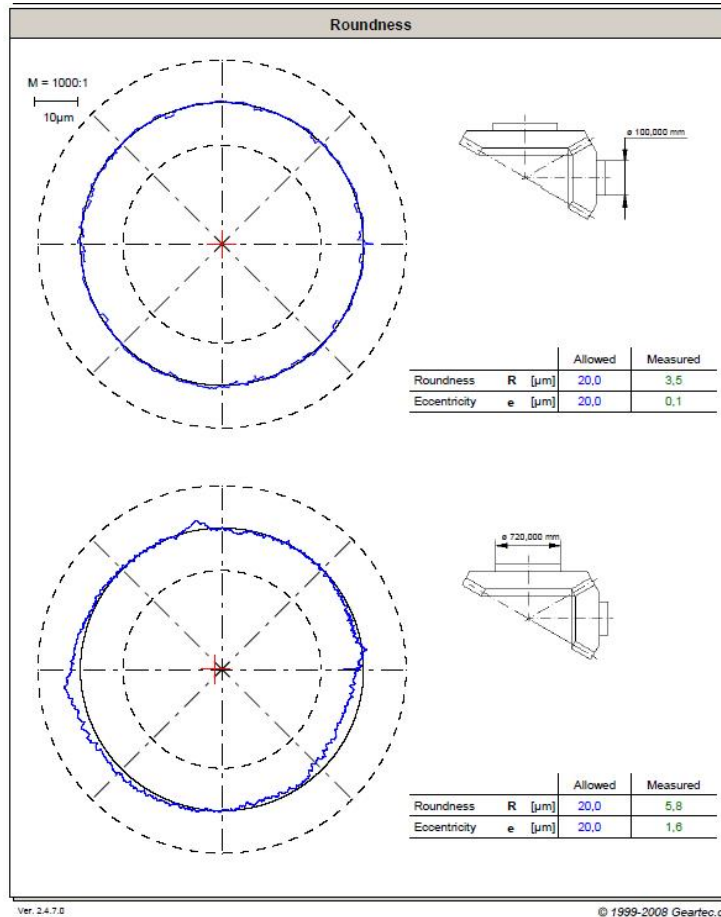


Level 2

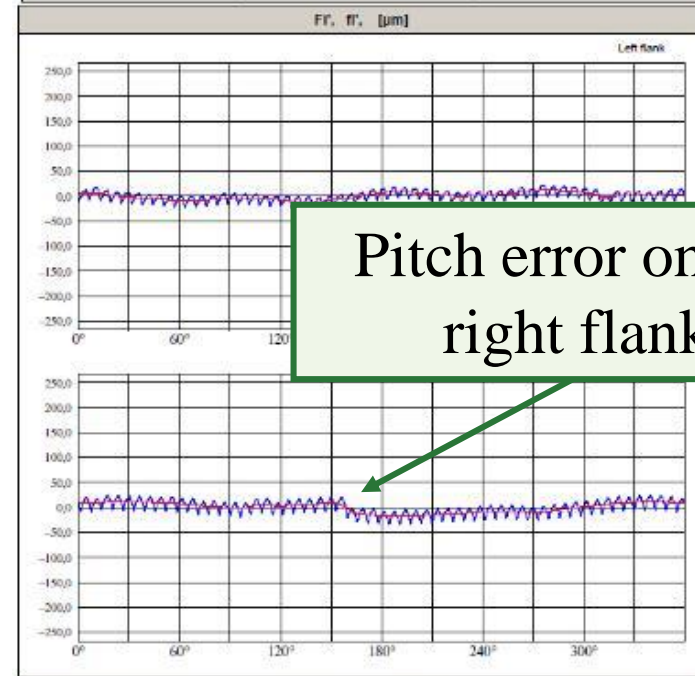
V = 0,25200 inch H = 0,11000 inch PH = 0,08500 inch

EXAMPLE 5: SINGLE FLANK ERRORS

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



Single flank composite measurement, bevel gears						geartec.cz	
gtb 1250							
Pinion	u1	Wheel	u2	Measured points		8000	
Number of teeth	z_1	Number of teeth	z_2	Nr. of measurement			
Normal module	m_n	Spiral angle	β_m	Contract No.			
Pressure angle	α_{fn}	Hypoid offset	a	Machine No.			
Spiral angle	β_{fn}	Mounting distance	a_1	Date		9.7.2008 15:53	
Load torque		Mounting distance	a_2	Checked by			
Measuring speed	5rpm	Shaft angle	Σ	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	59,7 5
Single flank composite dev.	f_1 [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_2 [μm]	94,0 5	23,0 2	30,9 3
Short wave component	f_3 [μm]	47,0 8	25,2 5	33,5 5
Teeth backlash - normal	$-b$ [mm]	0,200 - 0,300	0,221	0,278

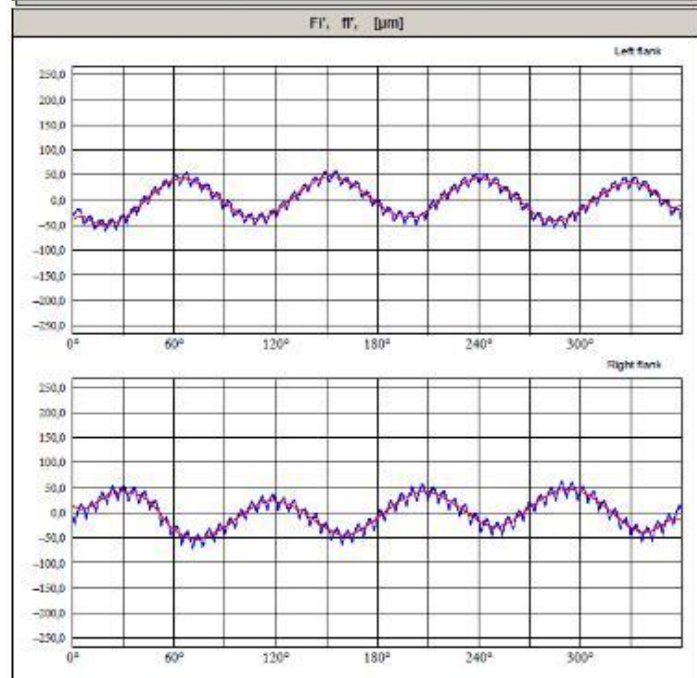
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EXAMPLE 6: ROUNDNESS

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_1 370.460 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	

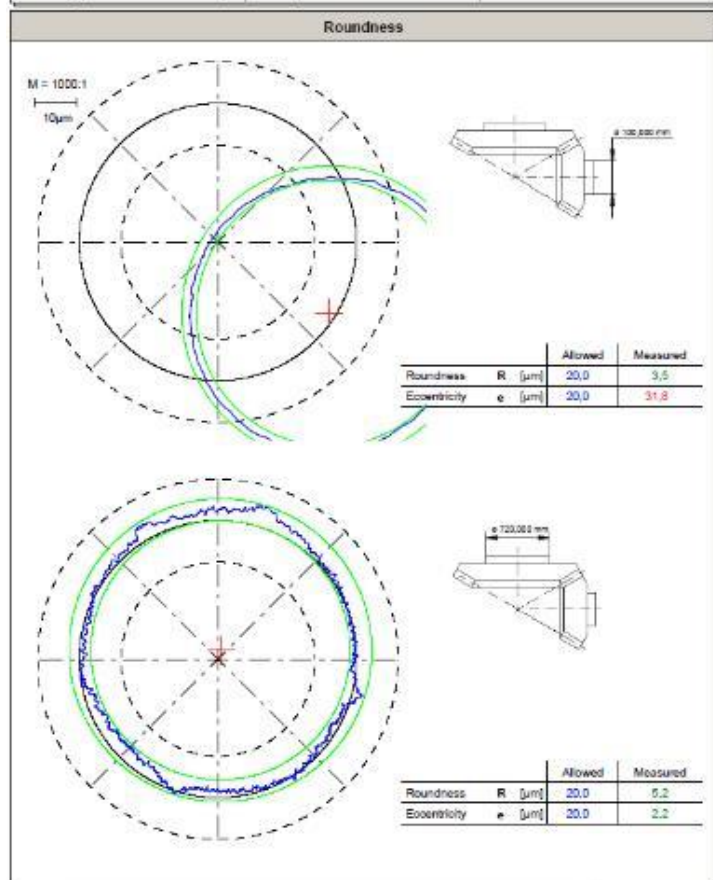


Standard: DIN 3965	F-factor: 25%	Allowed	Measured
Total composite deviation	F'_1 [μm]	94,0 8	120,4 7, 135,1 8
Single flank composite dev.	f'_1 [μm]	38,0 8	56,3 7, 50,4 7
Mean value	f'_{1m} [μm]	25,8 8	33,5 8
Max value	f'_{1max} [μm]	39,3 7	52,0 7
Long wave component	f'_l [μm]	94,0 8	95,8 7, 96,9 7
Short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

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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_1 370.460 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	

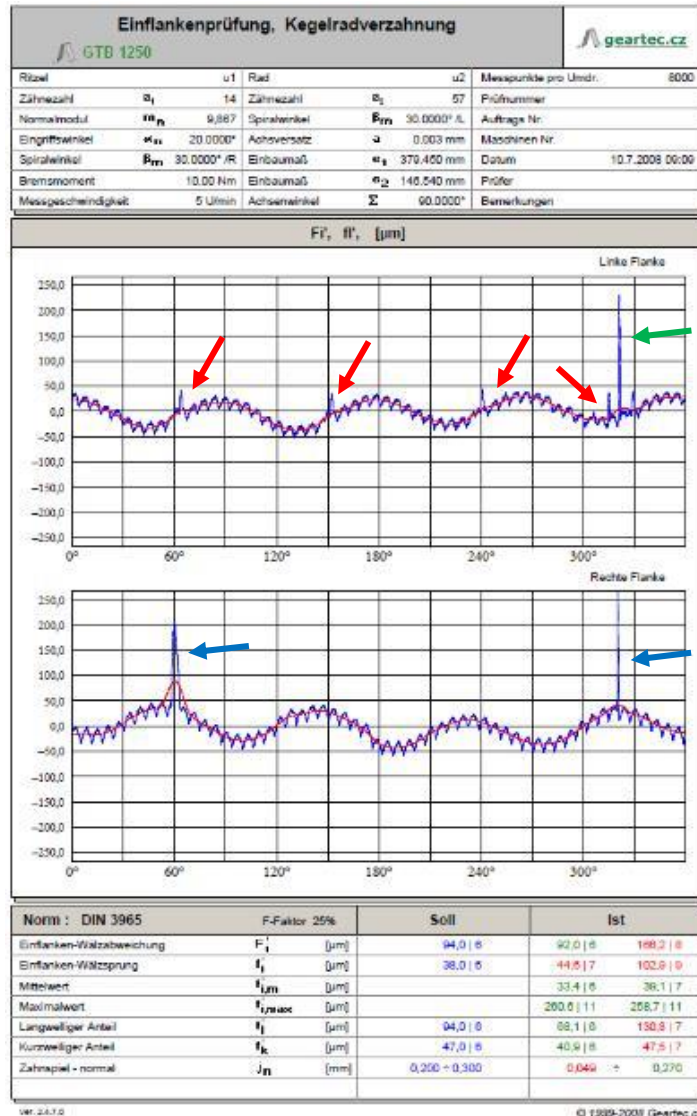


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EXAMPLE 7: BUMP DETECTION



Single flank deviations – pinion with approximately 20 µm eccentricity

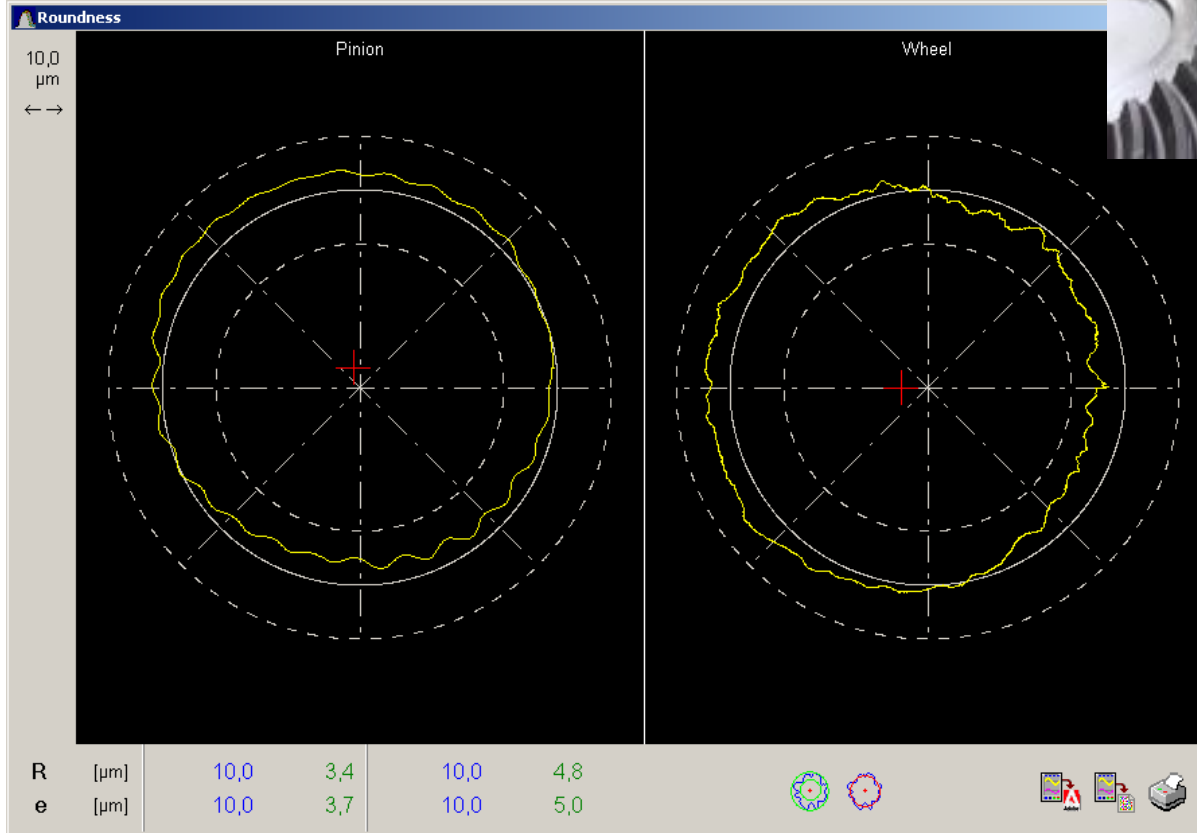
Left flank of pinion with bumps (marked in red color)

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

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

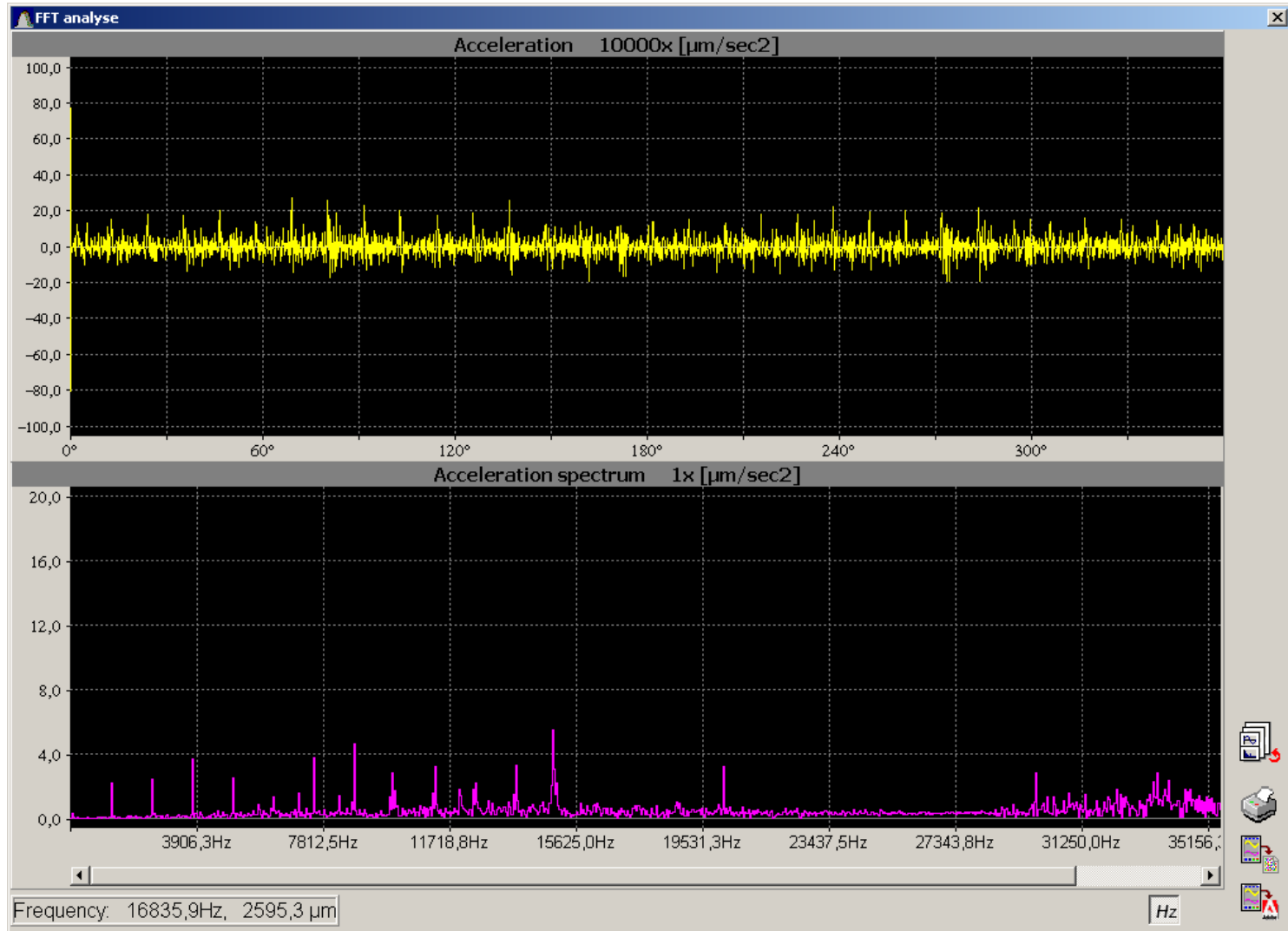
RUN-OUT AND ROUNDNESS

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



Measuring of control rings

FTT ANALYSIS AND NOISE

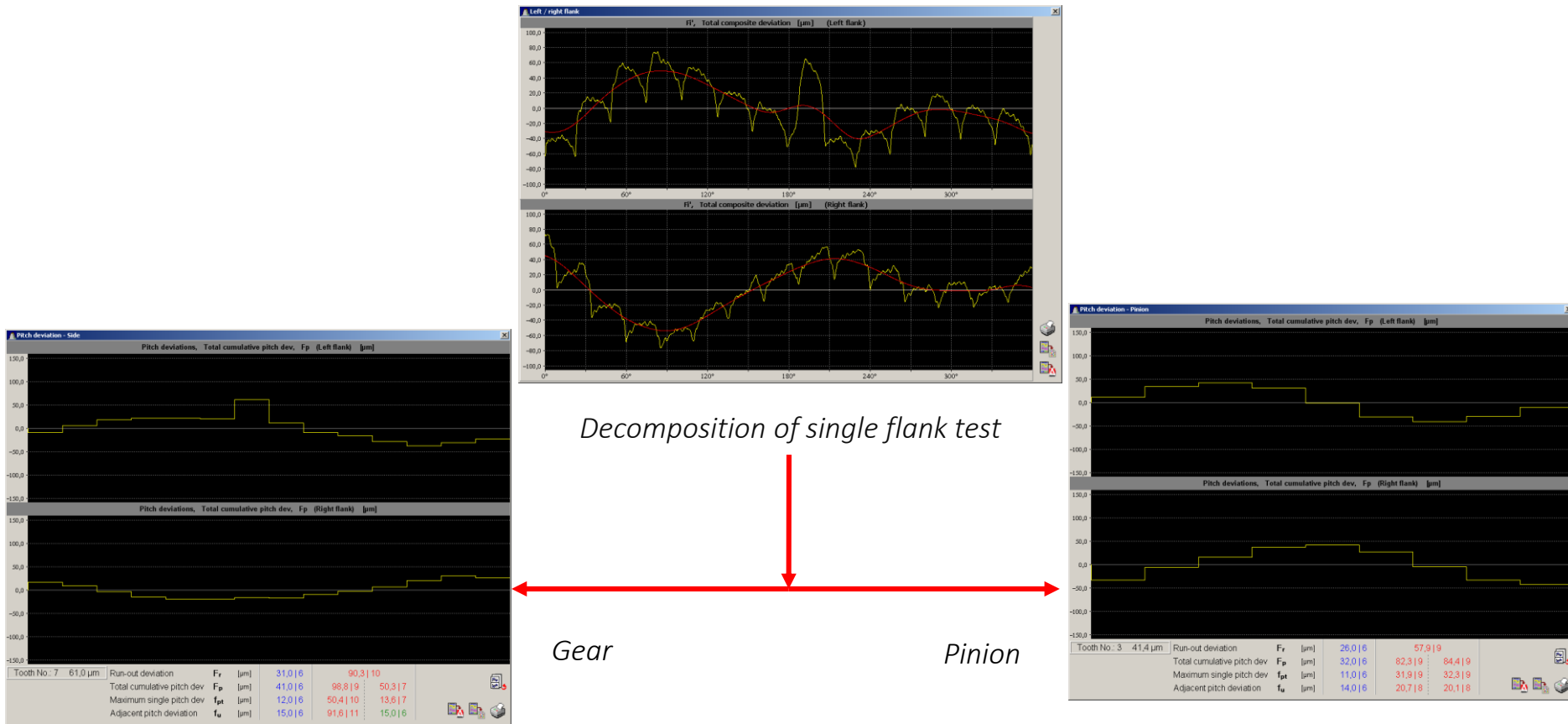


Calculated acceleration spectrum of signal

PITCH DEVIATION OF PINION / GEAR

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

ANSWER: Use decomposition of single flank test.



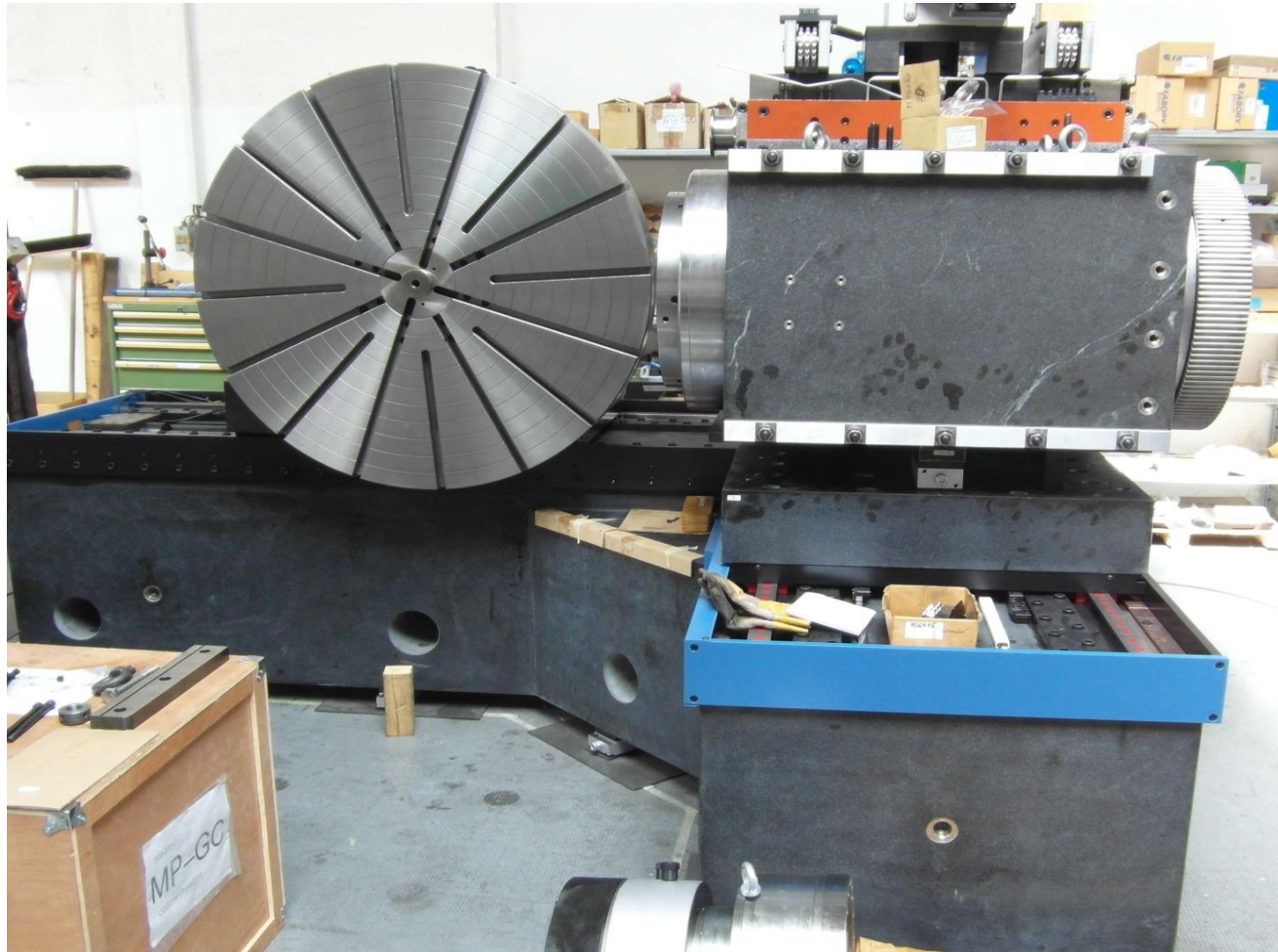
ASSEMBLY

- Granit bed and gear spindel with bore 310 mm



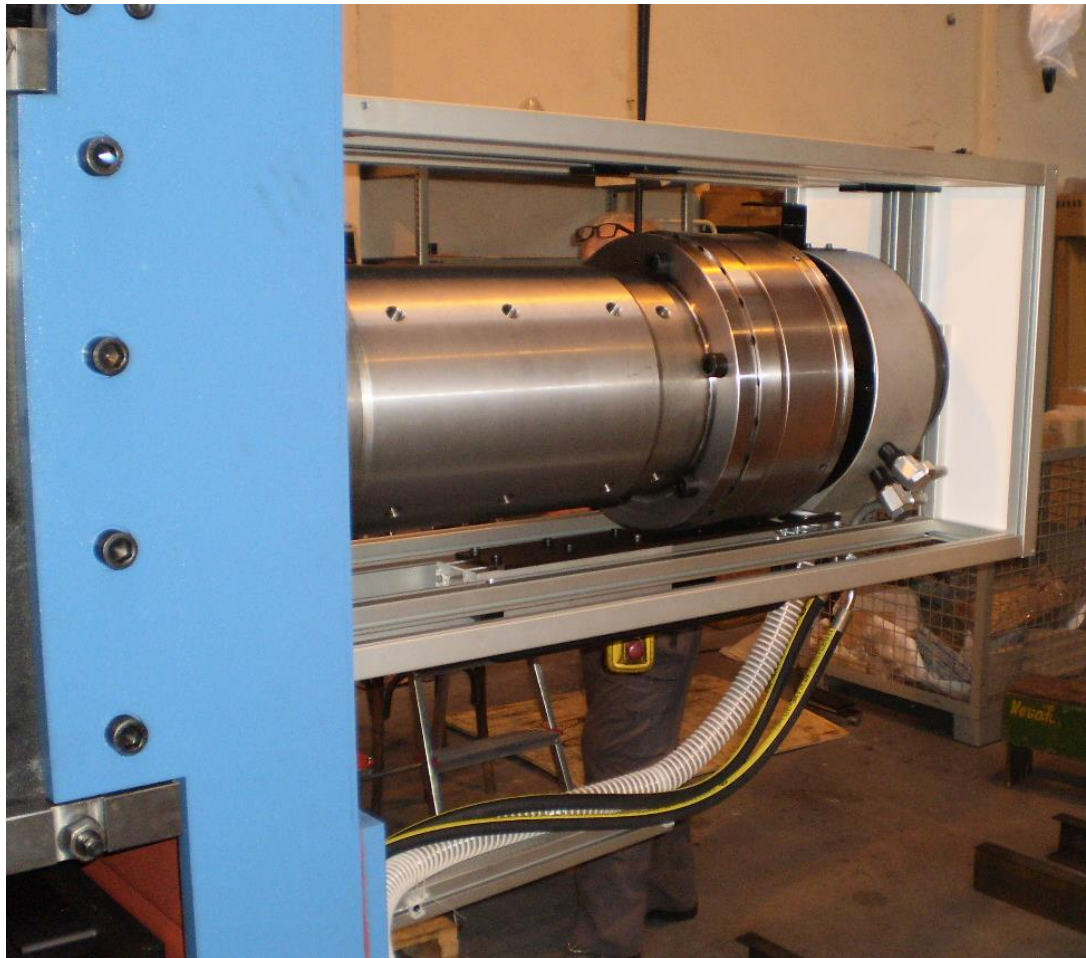
ASSEMBLY

- Gear spindle with table diameter 1200 mm

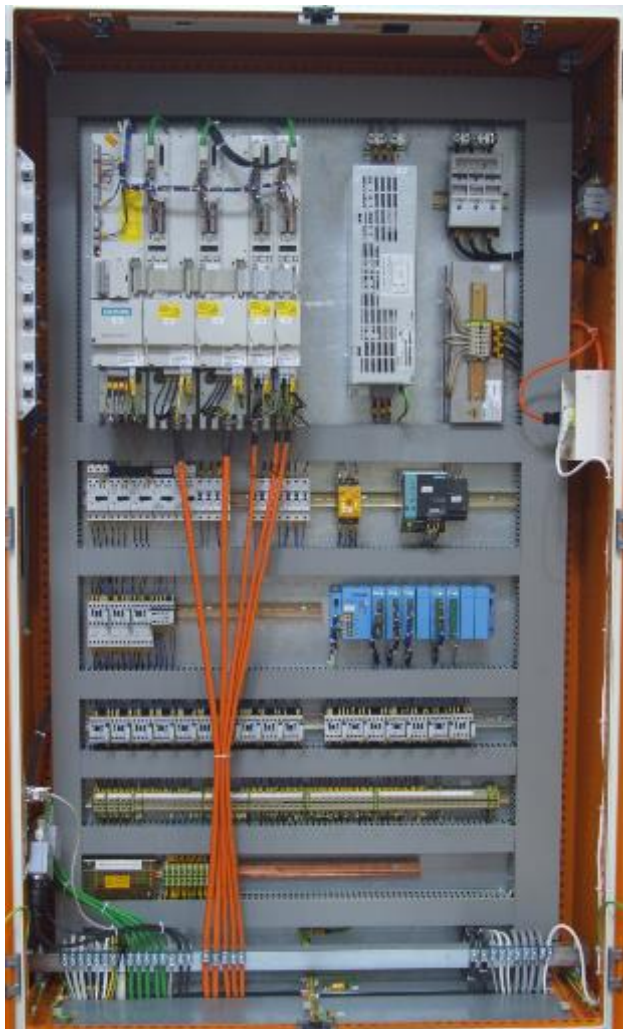


ASSEMBLY

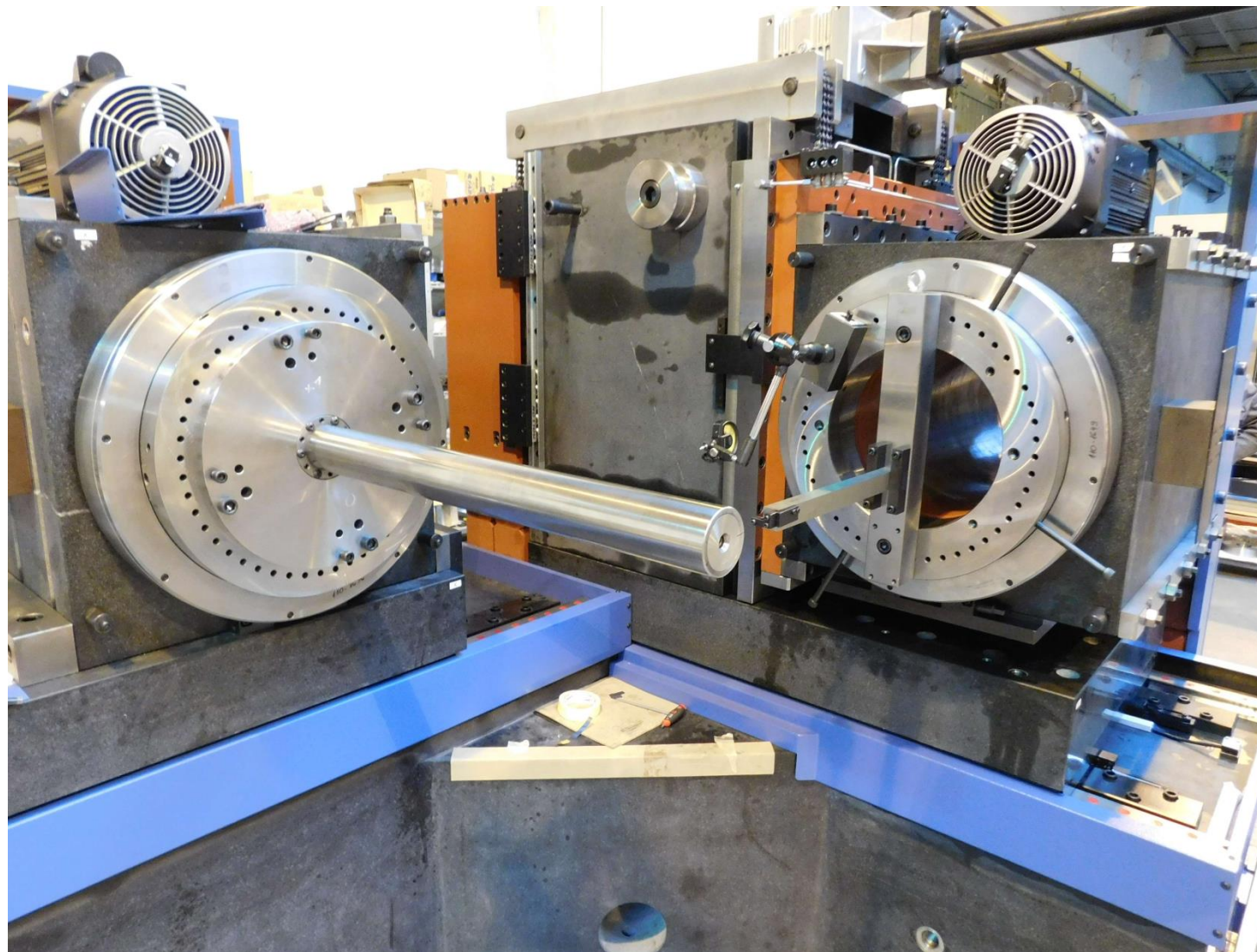
- Hydraulic clamping system for pinion



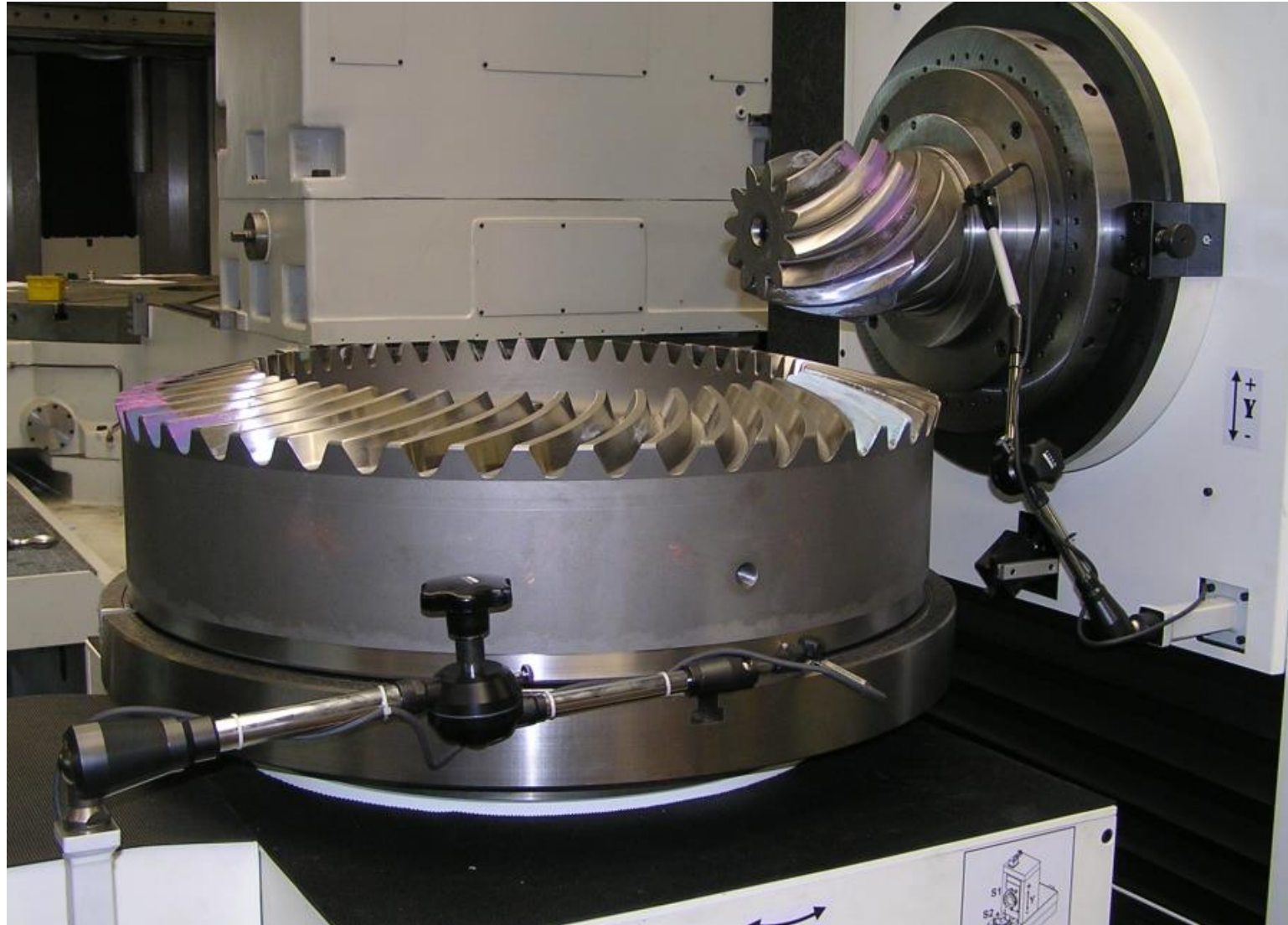
WIRING BOX AND CONTROL BOX



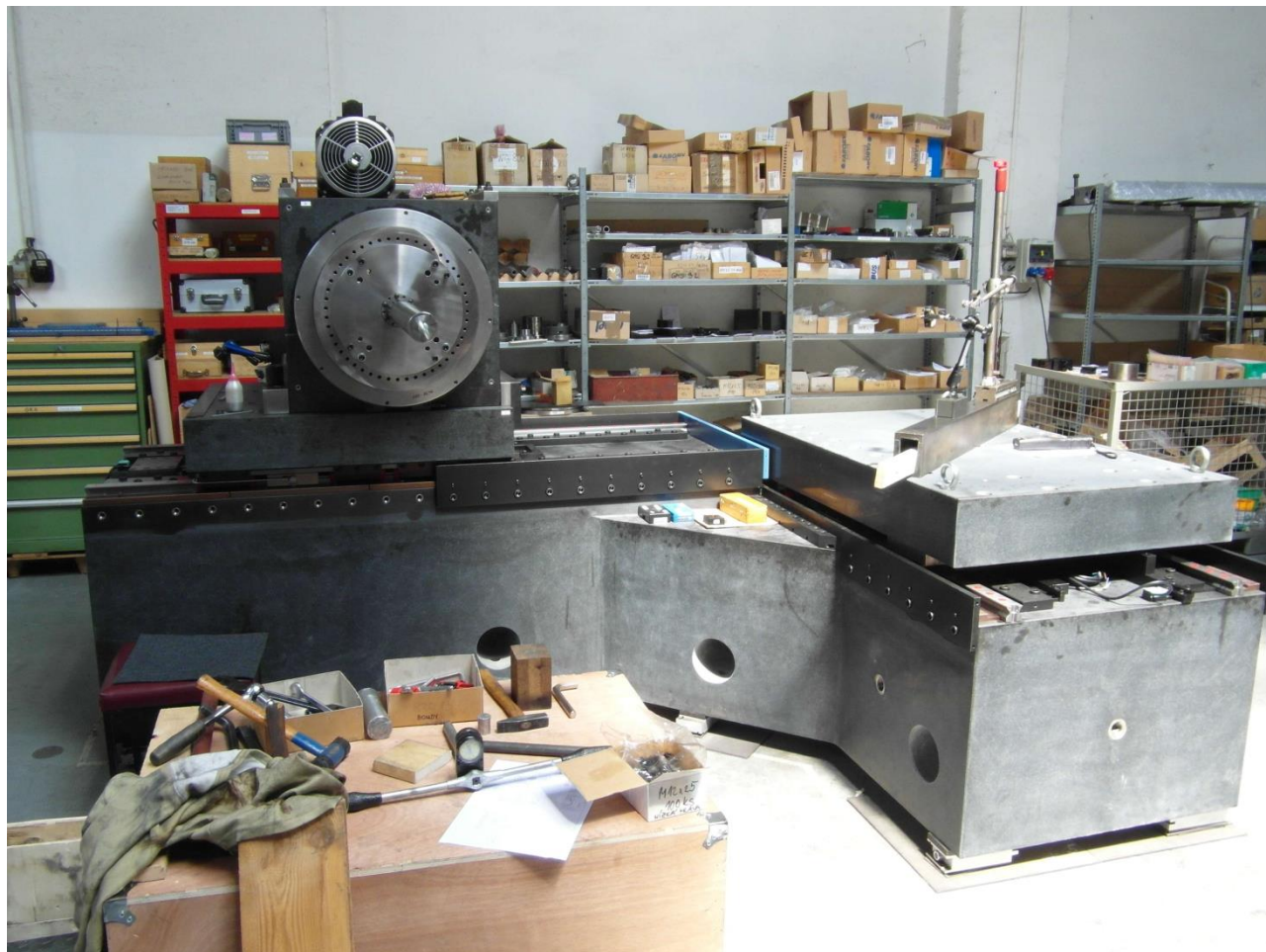
TESTING OF MACHINE GEOMETRY



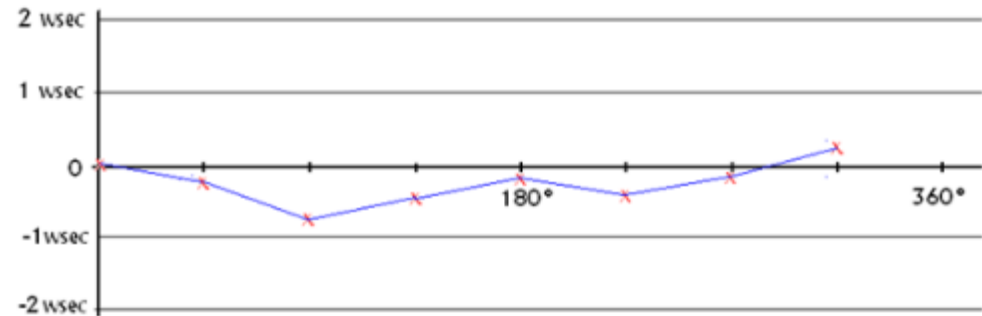
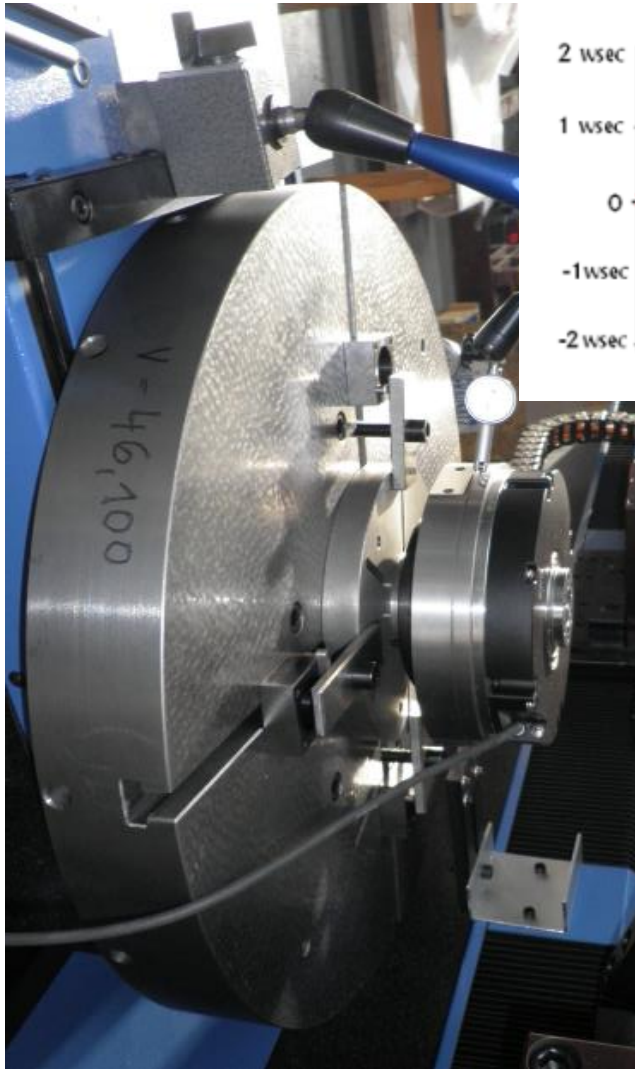
PROBES FOR ROUNDNESS MEASURING



ASSEMBLY AT PRODUCTION PLANT



CHECKING OF ACCURACY OF ROTATION OF SPINDLE



CONTROL PANEL



- Joysticks for smooth carriage
- Potentionmeters for smooth rotation
- Type buttons, steps 0,01/0,10 and 1,00 mm
- Running for all main program functions

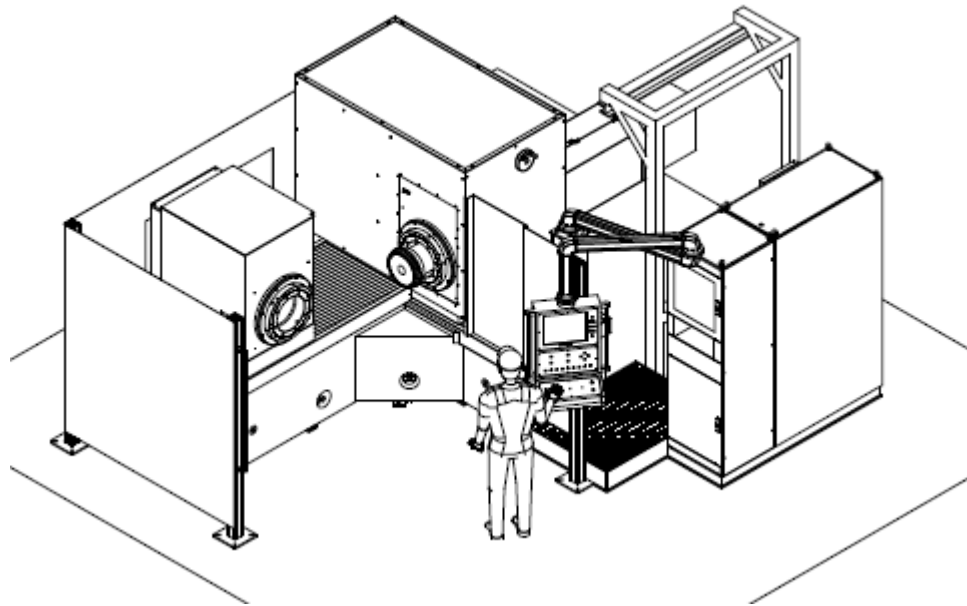
CONTROLLING SYSTEM

- 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



ADVANTAGES 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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