

# GTWG 200

Inspection of worm gears by single and double flank testing machine

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GEARTEC.CZ, 2017

# Why single flank testing?

## Main requirements in worm gear production

- quality (DIN standard)
- defined backlash
- low noise / high lifetime
- influence of assembly precision
- contact pattern
- pitch deviation of worm gear

All these parameters are measured by  
single flank testing machine GTWG600

# GTWG 200



Manufactured by GEARTEC.CZ in 2017



# Machine parameters

Diameter of worm gear, max.	200 mm
Length of worm gear, max.	250 mm
Diameter of worm, max.	50 mm
Center distance	0-200 mm
Vertical position	0-150 mm
Measuring speed	5-60 rpm
Brake, max.	0,5 Nm
Weight of worm gear, max.	3 kg
Weight of worm, max.	0,5 kg

# Machine can measure

Standards: DIN 3974, ISO 1328

## Single flank deviations of worm gears

- $F_i'$  - Tangential composite deviation
- $f_i'$  - Tooth to tooth composite deviation
- $f_l'$  - Long wave component of tangential composite deviation
- $f_k'$  - Short wave component of tangential composite deviation
- $j$  - backlash

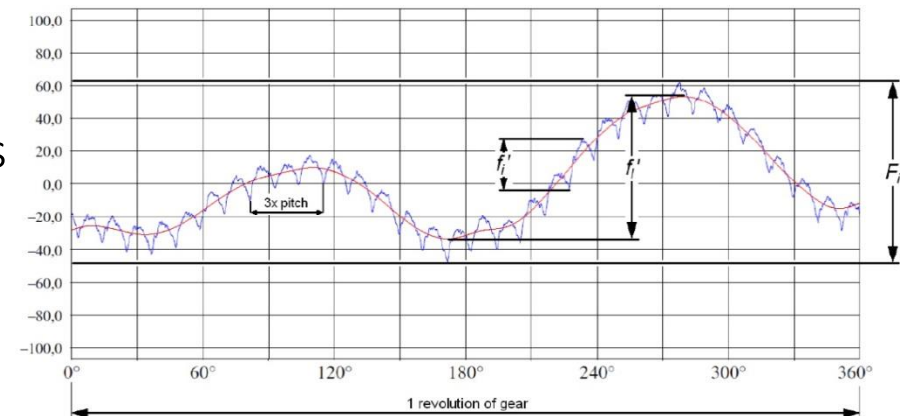
## Pitch deviations of gear and worm

- $F_p$  - Total pitch error
- $f_{pt}$  - Adjacent pitch error
- $f_u$  - Diff. between adjacent pitches
- $F_r$  - Radial runout

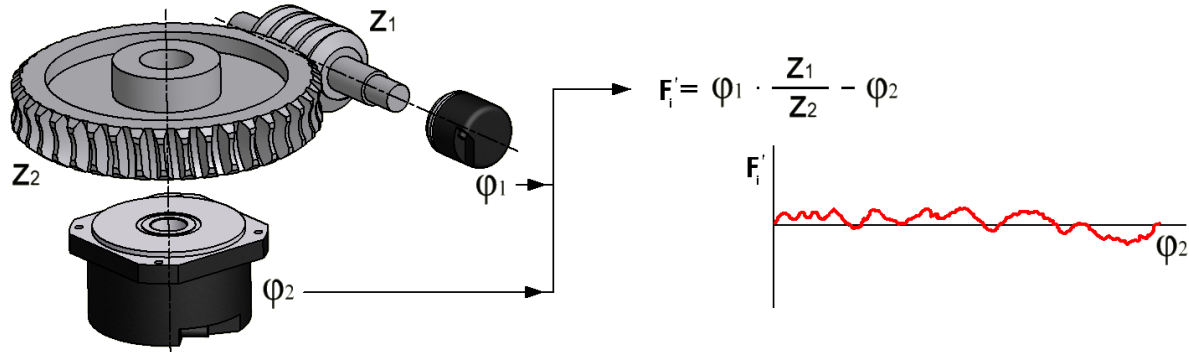
Contact pattern

FFT analysis

Roundness, eccentricity of gear and worm



# Principle of single flank testing





- mounting distance during testing is static
- left and right flanks are tested separately
- two accurate angle encoders
- accuracy up to 1 arc second (5 micro rad)  
~ 1  $\mu\text{m}$  on radius 200 mm
- results is transmission error
- deviation and tolerances according to DIN 3974 standard

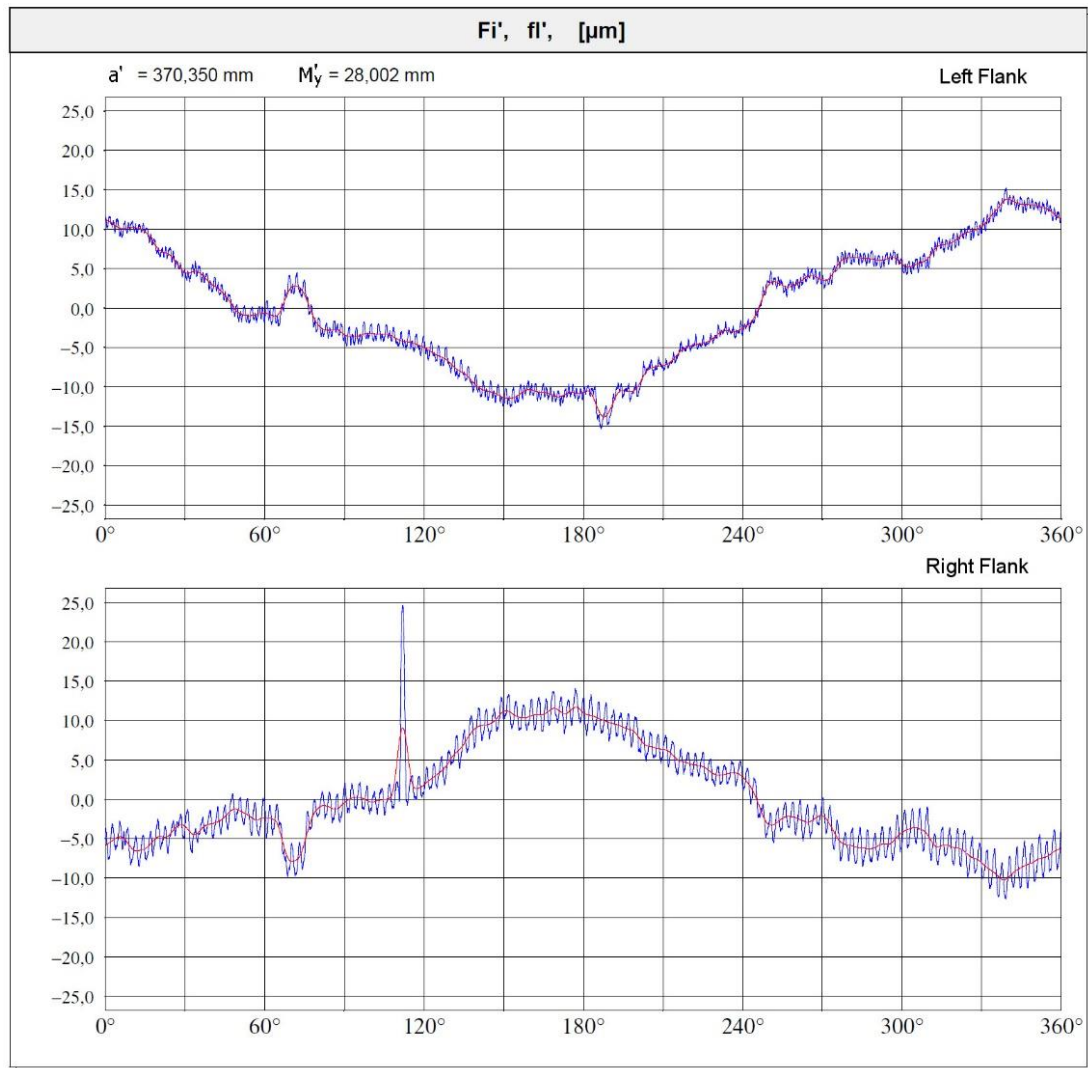
# Inspection certificates (header)

Worpiece data

Customer's logo

Single flank composite measurement, Worm gears						
			6991 HR GEARTEC			
Worm	S0131011a		Wormgear	S0131011a		Measured points 8000
Number of teeth	$z$	1 / R	Number of teeth	$z$	90	Part No.
Axial module	$m_x$	3.200	Pitch diameter	$d_m$	290.000 mm	Contract No.
Pressure angle	$\alpha_n$	15.0000°	Shaft angle	$W$	0.0000°	Machine No.
Pitch diameter	$d_m$	70.000 mm	Worm position	$M'_y$	0.000 mm	Date 5/17/2013 12:29
Centre distance	$a'$	180.200 mm	Worm position	$M'_z$	130.000 mm	Checked by Richter
Measuring speed	20rpm		Load torque	0.00 Nm		Note

# Inspection certificates - chart





# Measurement evaluation

Allowed values according to DIN 3974

Left and right flank

Standard: DIN 3974	F-factor 25%	Allowed	Measured
Total composite deviation	$F'_i$ [ $\mu\text{m}$ ]	17.8   3	11.3   2    10.9   2
Single flank composite dev.	$f'_i$ [ $\mu\text{m}$ ]	6.7   3	4.4   2    5.6   3
Mean value	$f'_{i,m}$ [ $\mu\text{m}$ ]		3.5   1    4.4   2
Max value	$f'_{i,max}$ [ $\mu\text{m}$ ]		4.6   2    6.8   4
Long wave component	$f'_l$ [ $\mu\text{m}$ ]	10.0	7.1    6.3
Short wave component	$f'_k$ [ $\mu\text{m}$ ]	5.0	4.2    5.1
Backlash - tangential	$j$ [mm]		

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Measured values



# Software interface

The screenshot shows the 'Measuring parameters' window with the 'Basic parameters' tab selected. The window title is 'Measuring parameters'. The name field contains '5391 HR GEARTEC'. Below this, there are two columns: 'Worm' and 'Wormgear'. The 'Worm' column has the following parameters: Drawing No. (S0131011a), Number of teeth (z) (1), Axial module (m<sub>x</sub>) (3.200), Pressure angle (α<sub>n</sub>) (15.0000°), Lead (Left/Right), Pitch diameter (d<sub>m</sub>) (70.000 mm), Centre distance (a') (180.200 ± 0.050 mm), Shaft angle (W) (0.0000° ± 1.0000°), Worm position (M<sub>Y</sub>) (23.500 ± 0.020 mm ΔY 14.936 mm), and Worm position (M<sub>Z</sub>) (137.000 ± 0.500 mm). The 'Wormgear' column has the following parameters: Drawing No. (S0131011a) and Number of teeth (90). At the bottom, there are 'Cancel', 'Save', and 'OK' buttons.

*Basic object parameters*

The screenshot shows the 'Measuring parameters' window with the 'Complementary' tab selected. The window title is 'Measuring parameters'. The 'Initial position' is set to 'Manually'. There are radio buttons for 'Automatically, MANUAL stock dividing' and a 'Return to initial position' checkbox. The 'Measured flank' is set to 'Both'. The 'Continuous measuring' checkbox is unchecked. The 'Time averaging' checkbox is unchecked. The 'Measured revs.' is set to 'Revolution'. The 'Quantity' is 1. The 'FFT production speed' is 0 rpm. The 'Measuring speed' is 50 rpm. The 'Acceleration angle' is 3°. The 'Measured points' are set to 8000. The 'Load torque' is 0.00 Nm. The 'Part No.' field is empty. The 'Checked by' field is 'Richter'. The 'Note' field is empty. The 'Contract No.' and 'Machine No.' fields are empty. At the bottom, there are 'Cancel', 'Save', and 'OK' buttons.

*Complementary object parameters*

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

# Tolerances

**Measuring parameters**

Basic parameters | Complementary | **Tolerances** | Roundness | Roller size | Setup

Standard  
 ~  DIN 3974

Evaluation  
 [μm]  [deg]

Total composite deviation  $F_i$   /  μm  
Single flank composite dev.  $f_i$   /  μm  
Long wave component  $f_l$   μm  
Short wave component  $f_k$   μm

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Backlash  tangential  axial  
Evaluation  [μm]  [deg]  
 $j$   +  mm

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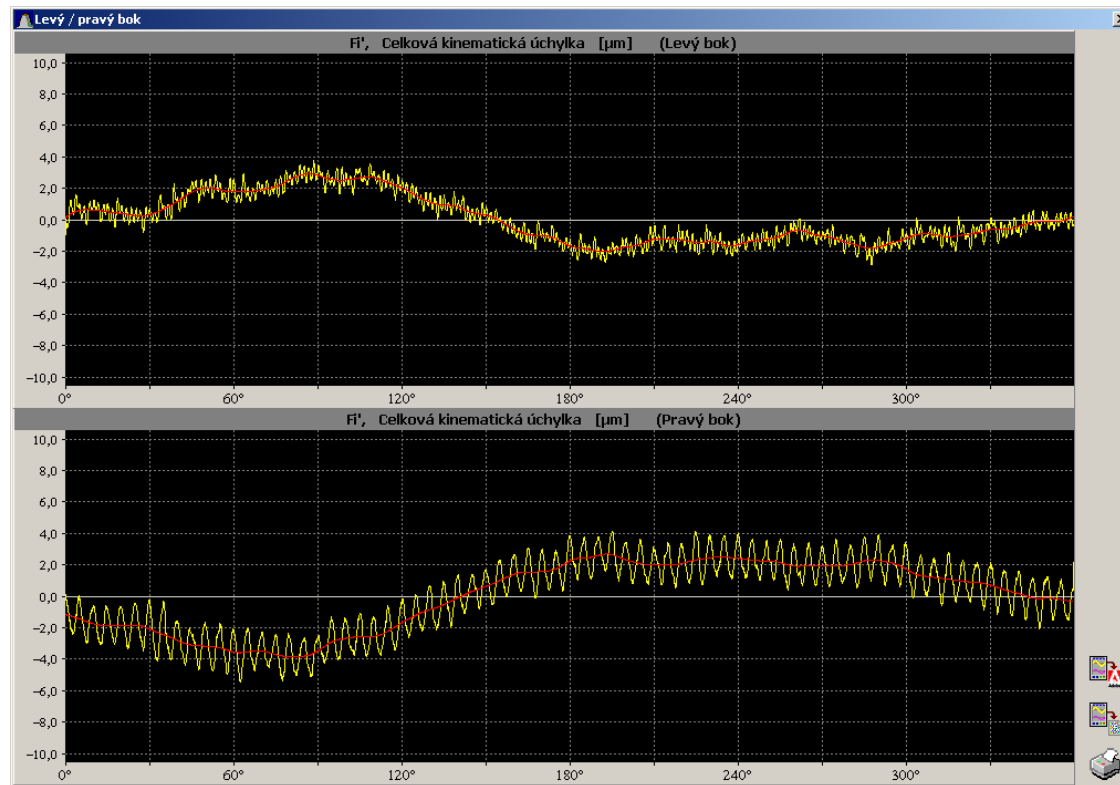
Run-out deviation  $F_r$   (7.0 μm)  (9.0 μm)  
Total cumulative pitch dev  $F_p$   (10.0 μm)  (14.0 μm)  
Maximum single pitch dev  $f_{pt}$   (3.0 μm)  (3.5 μm)  
Adjacent pitch deviation  $f_u$   (3.5 μm)  (4.0 μm)

*Tolerances*

# Example 1: Profile error

## Worm gear set, gear ratio 1:72

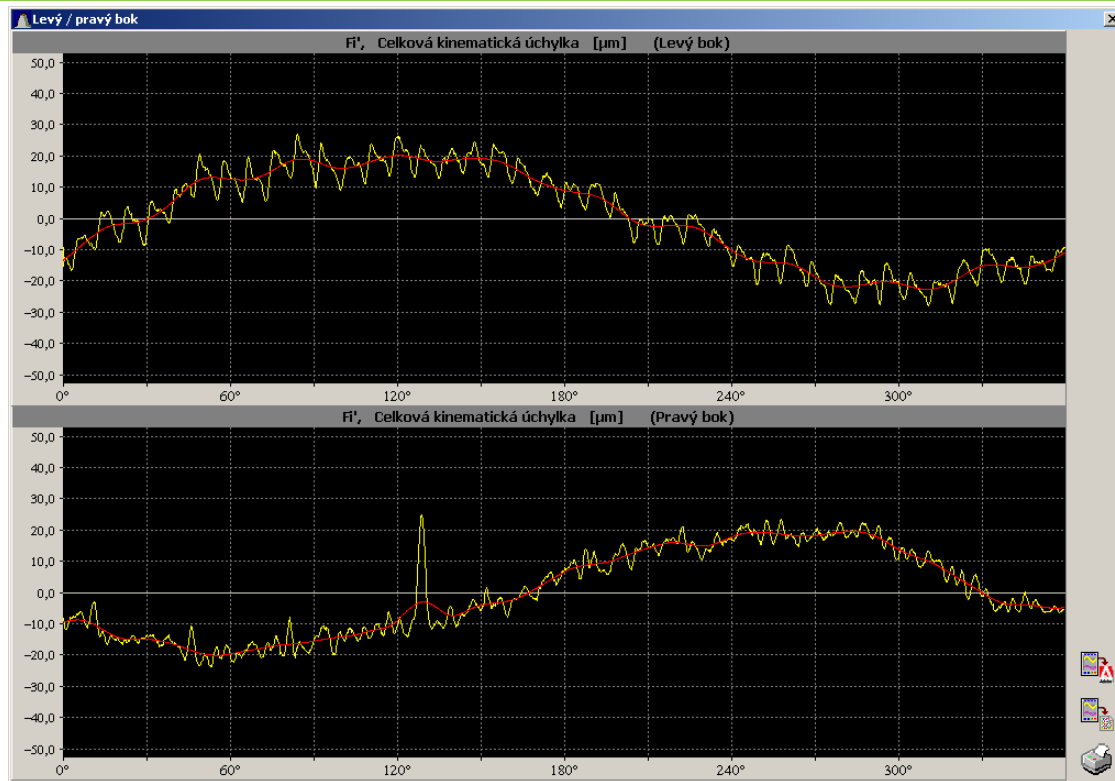
- Tooth to tooth deviation 0.003 mm on Right flank
- Left flank is DIN1, right flank is DIN2



# Example 2: Run-out & nick

## Worm gear set, gear ratio 1:41

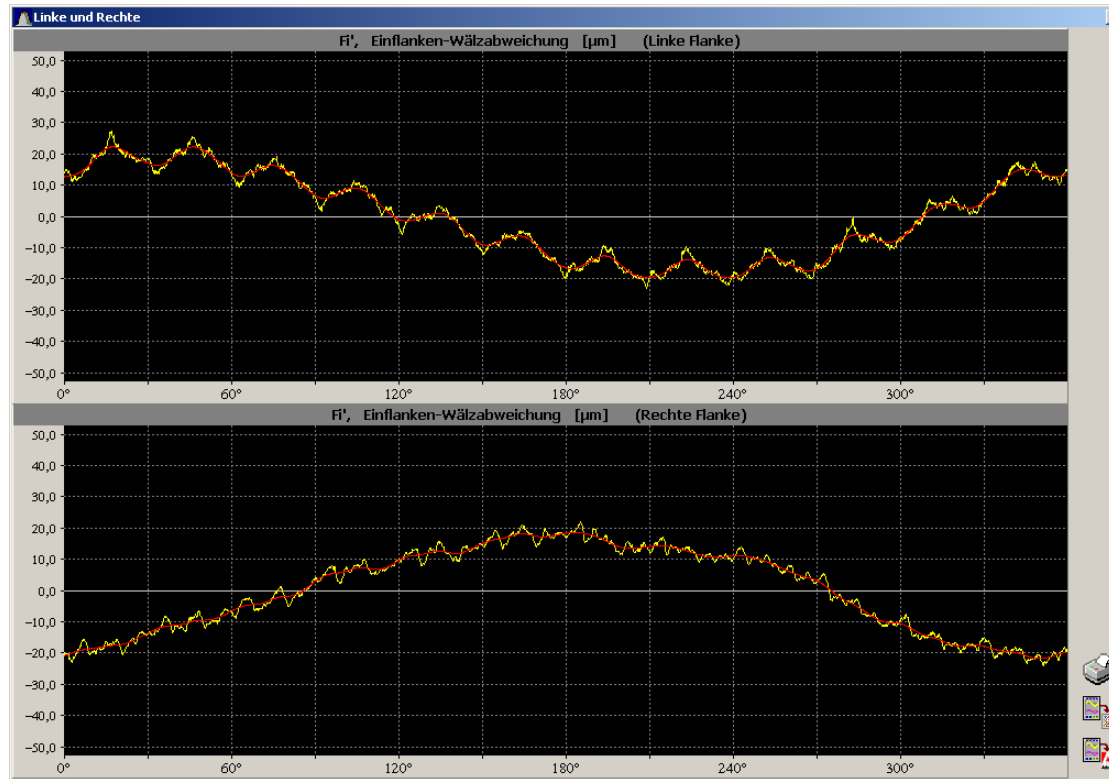
- Run-out of gear about 0.020mm
- Right flank has a nick 0.035 mm on tooth no. 15



# Example 3: Different flanks

## Worm gear set, gear ratio 5:61

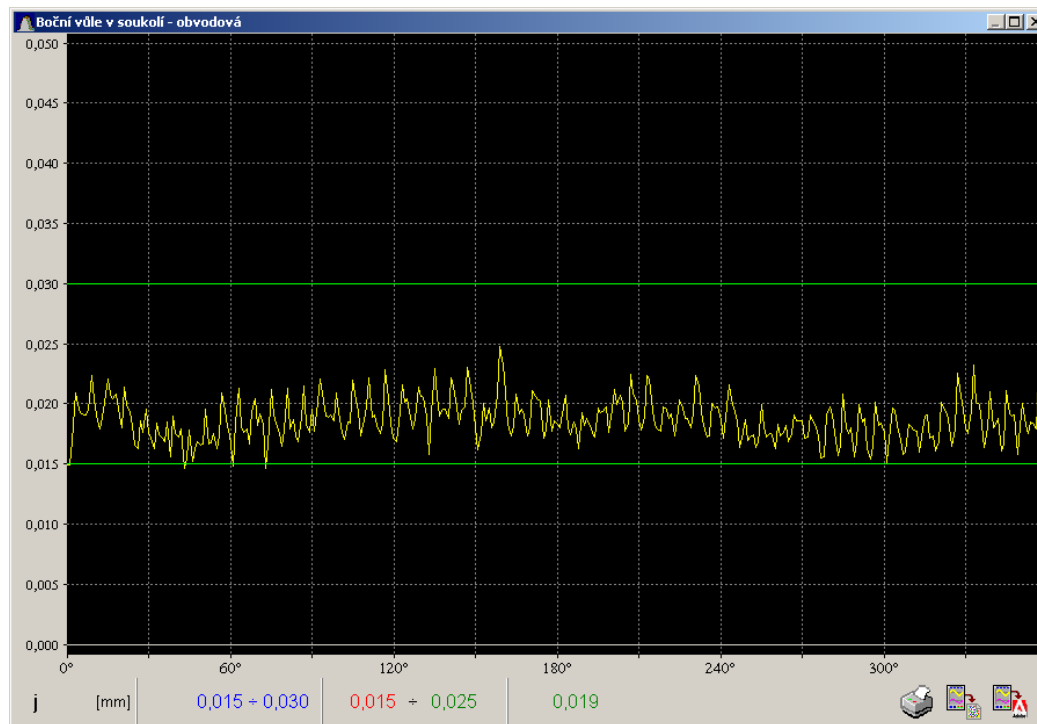
- Run-out of gear about 0.020 mm
- Worm's left flank has run-out 0.010 mm



# Example 4: Backlash

## Continuous measuring of backlash

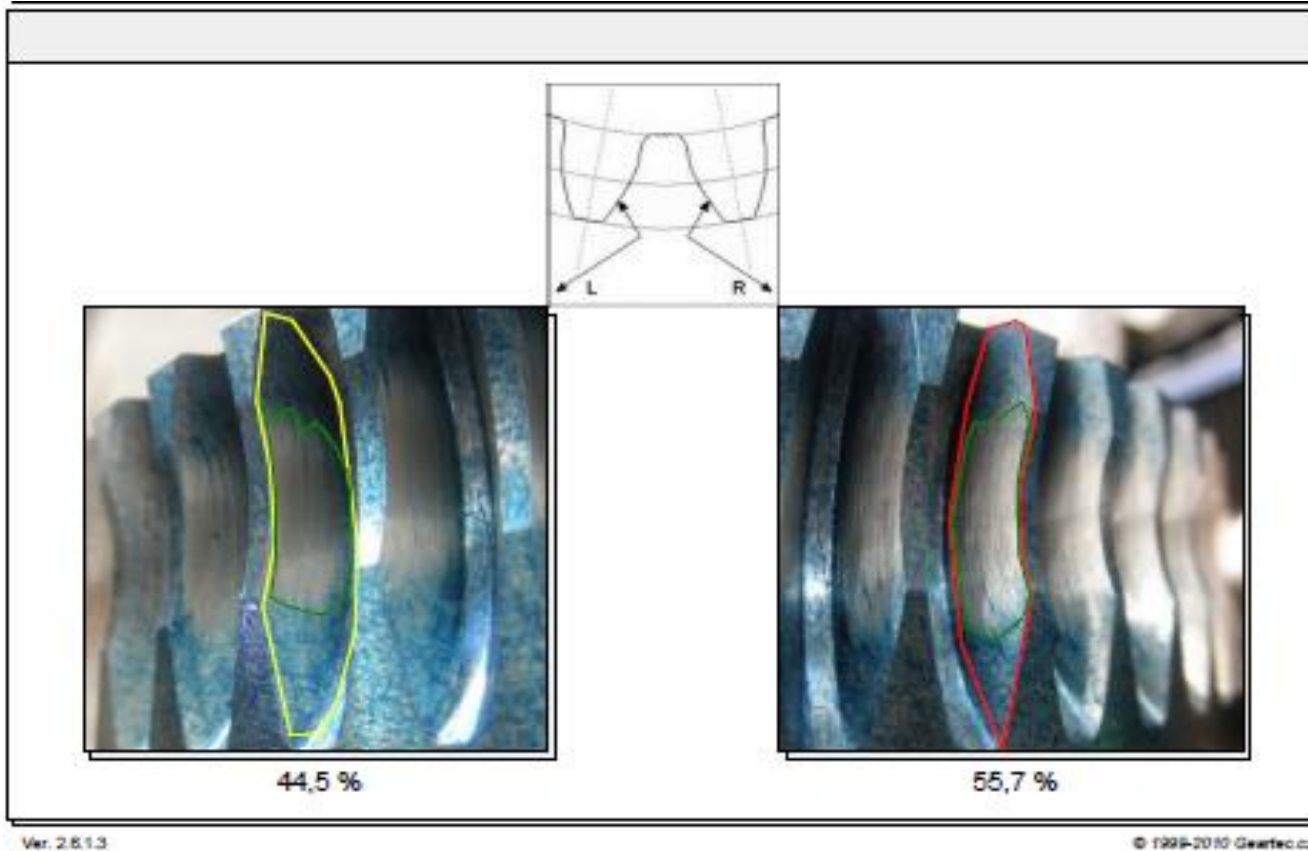
- Chart of backlash for 1 revolution of gear
- Backlash is changing over tooth contact



# Example 5: Contact pattern

## Digital image of contact pattern

- Stored in database with measuring results

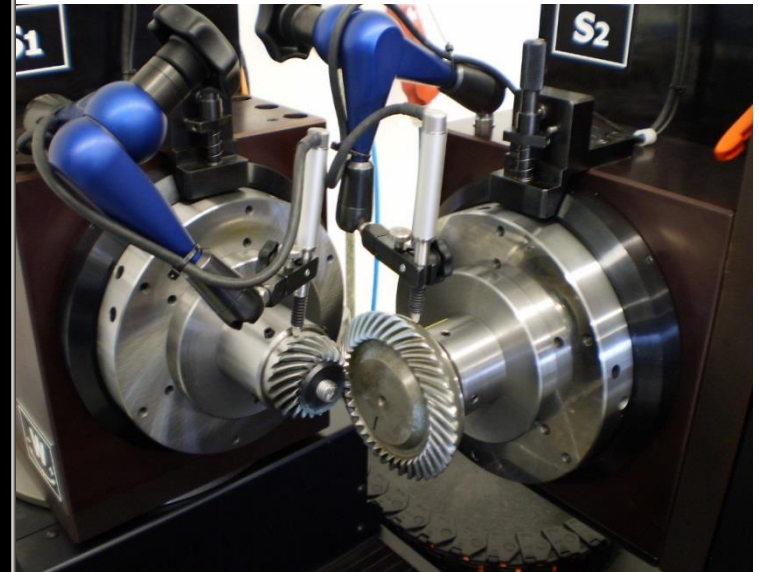
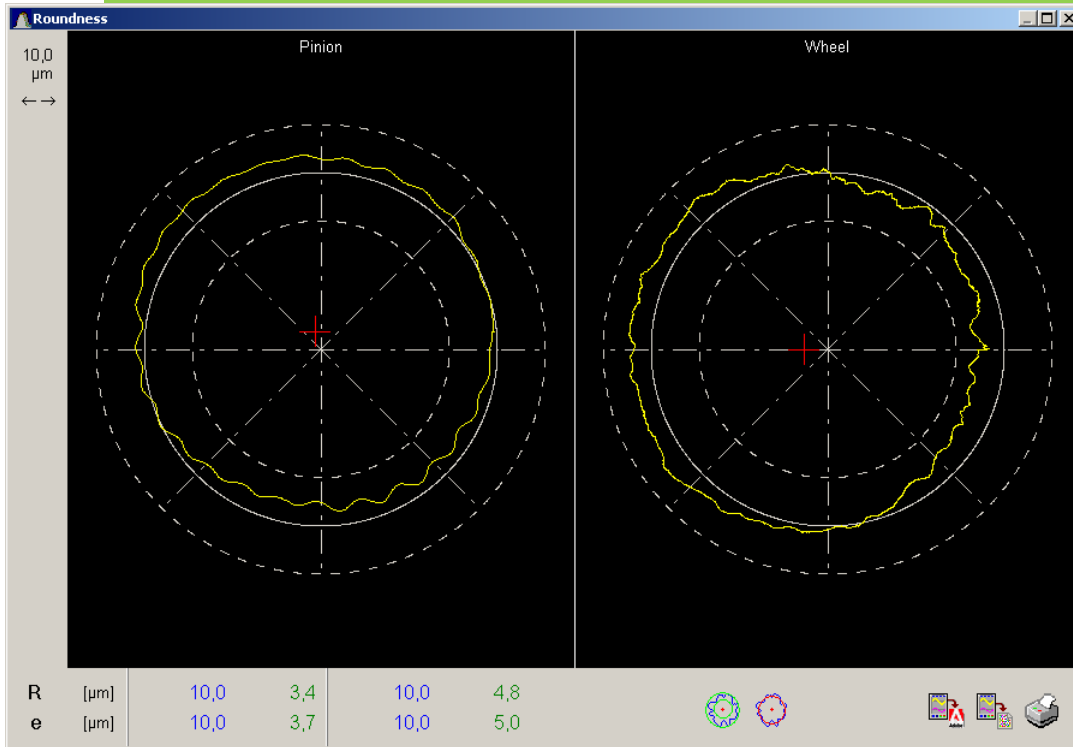




# Example 6: Run-out and roundness

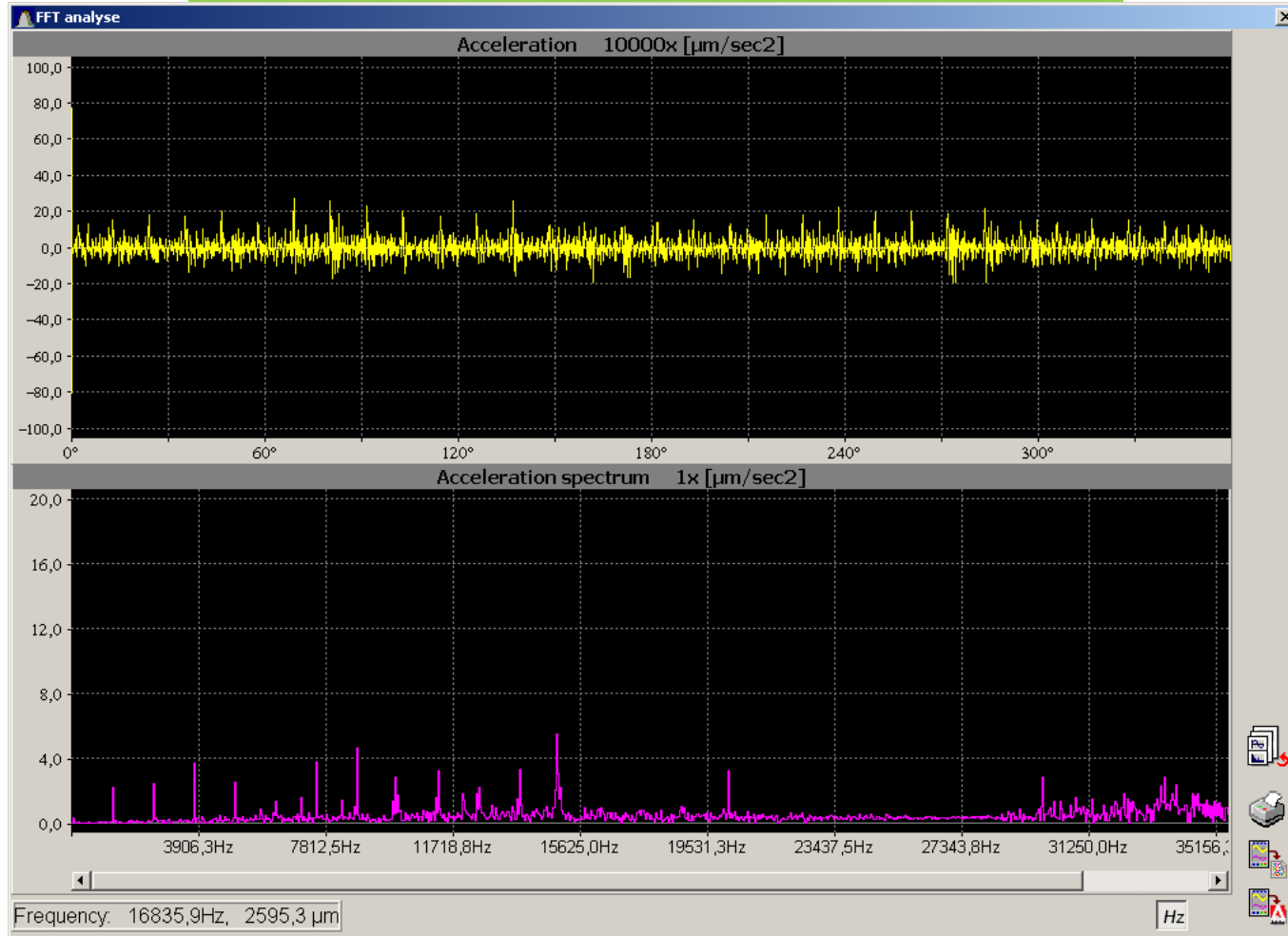
## Measuring of control rings

- Run-out of worm shaft and worm wheel
- Elimination of run-out error



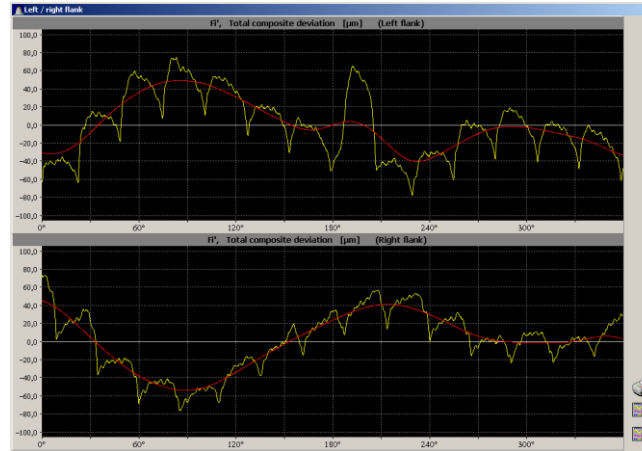
# Example 7: FFT analysis and noise

Calculated acceleration spectrum of signal



# Example 8: Pitch deviation of gear

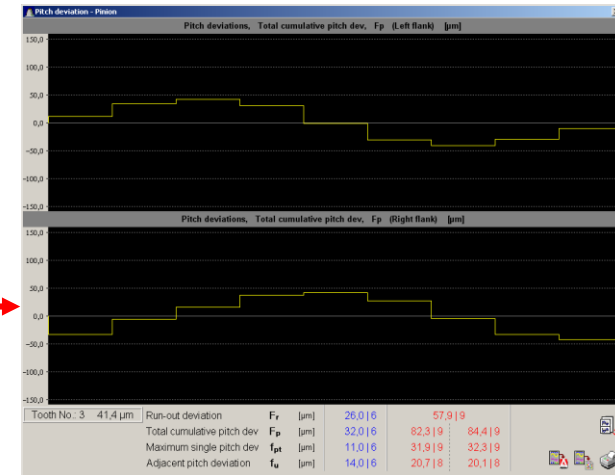
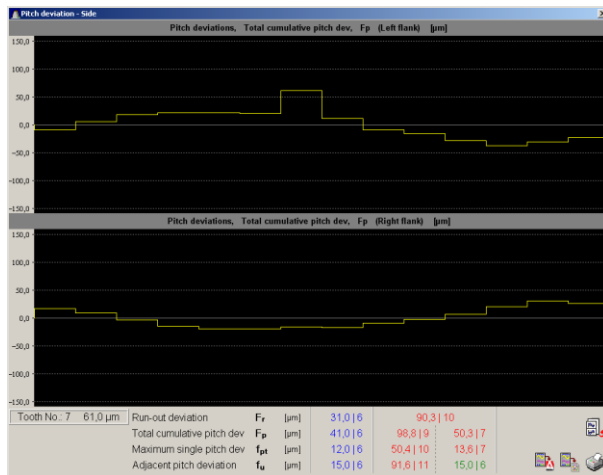
## Calculated diagram of pitch deviation



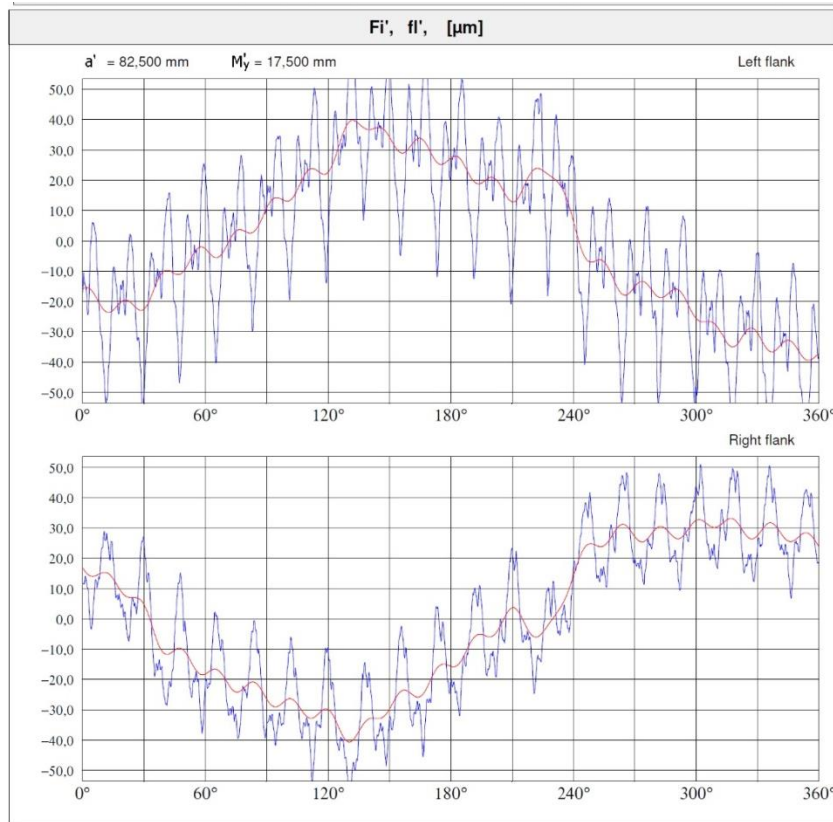
Wromgear

Worm

Decomposition of single flank test



# Example 9: Worm with a splitting error



There is not 180 deg. between tooth Nr. 1 and Nr. 2, but 180 deg and cca 99 wsec.

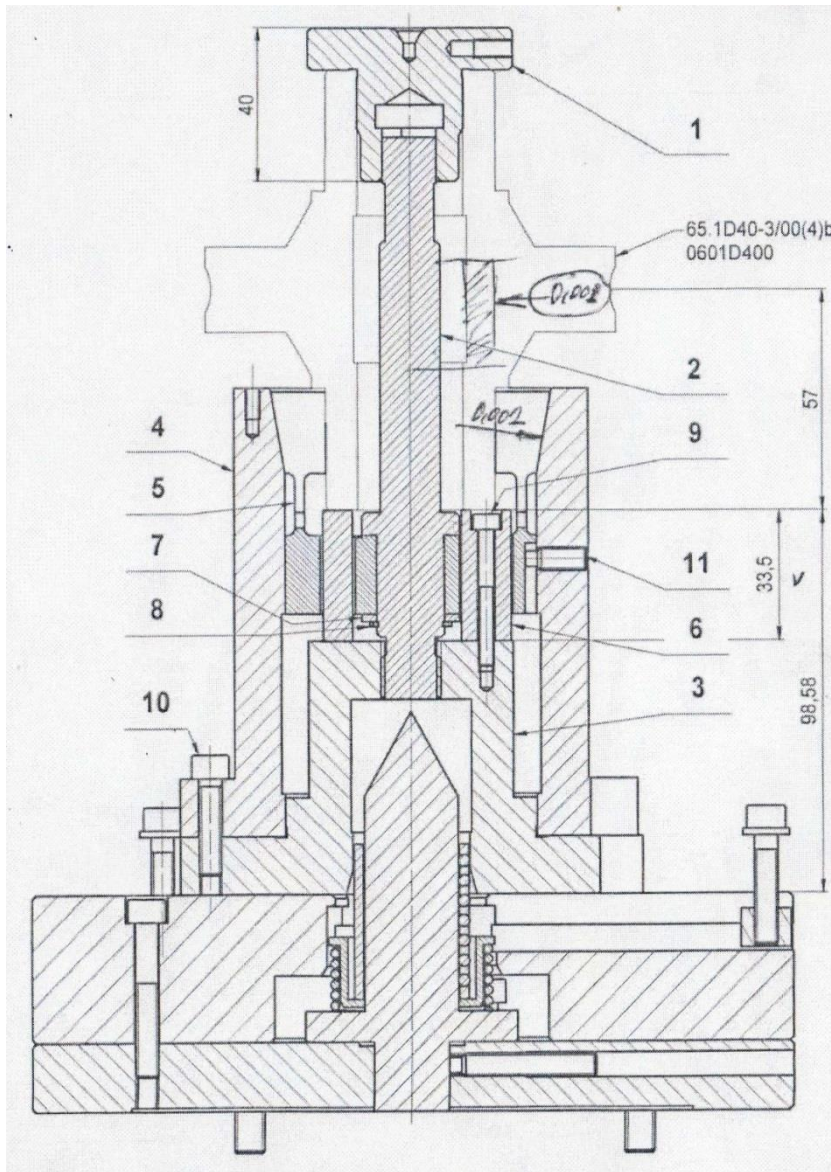
Right flank has wavy surface, cca 5  $\mu\text{m}$

Standard: DIN 3974	F-factor 25%	Allowed	Measured	
Total composite deviation	$F_i'$ [ $\mu\text{m}$ ]	84,6   8	136,9   10	110,4   9
Single flank composite dev.	$f_i'$ [ $\mu\text{m}$ ]	36,1   8	64,5   10	46,1   9
Mean value	$f_{i,m}$ [ $\mu\text{m}$ ]		48,1   9	30,3   8
Max value	$f_{i,max}$ [ $\mu\text{m}$ ]		72,4   10	49,7   9
Long wave component	$f_l'$ [ $\mu\text{m}$ ]	45,0	79,2	73,7
Short wave component	$f_k'$ [ $\mu\text{m}$ ]	30,0	58,2	37,6
Backlash - tangential	$j$ [mm]	0,100 $\div$ 0,150	0,097 $\div$	0,198

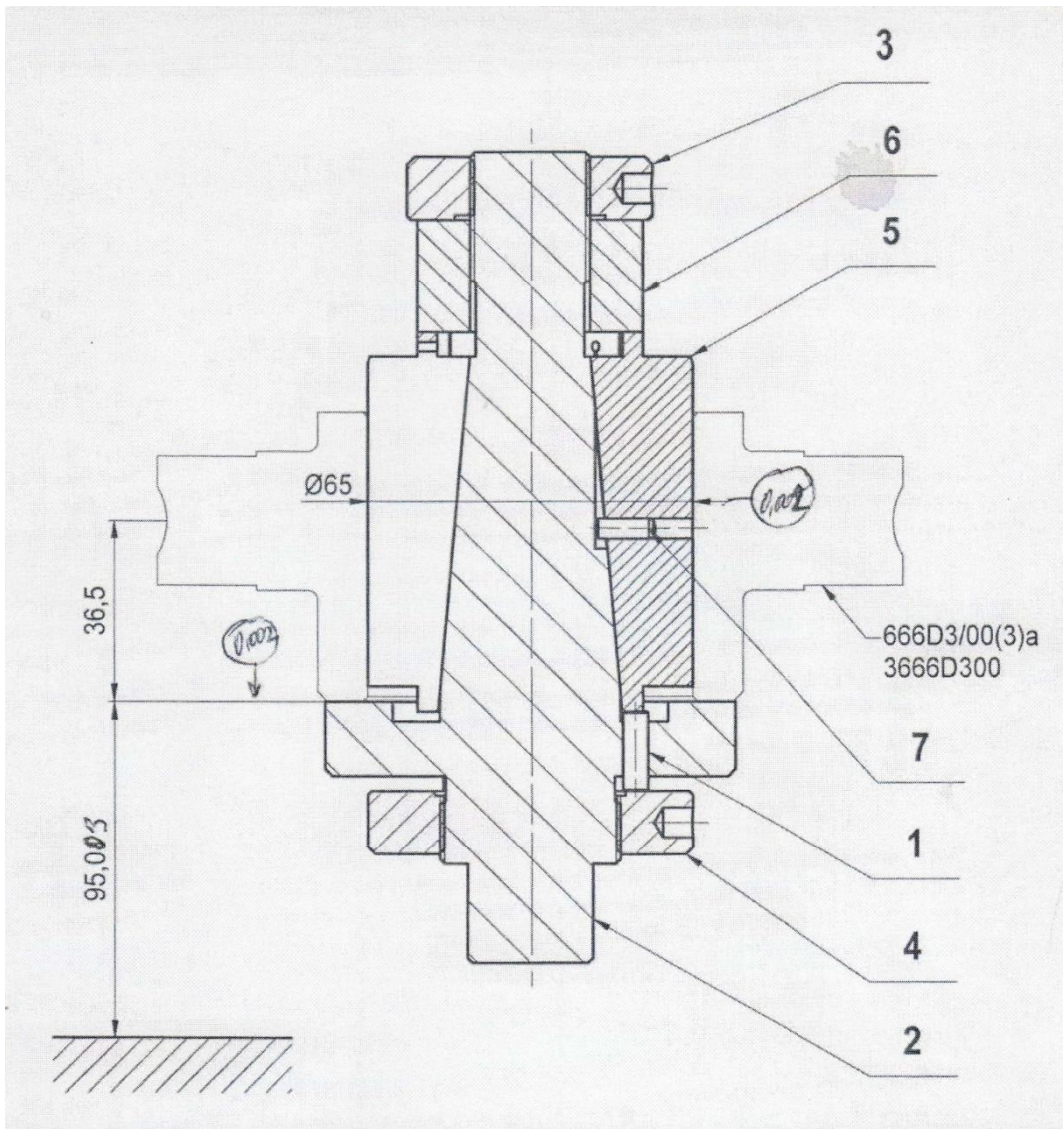
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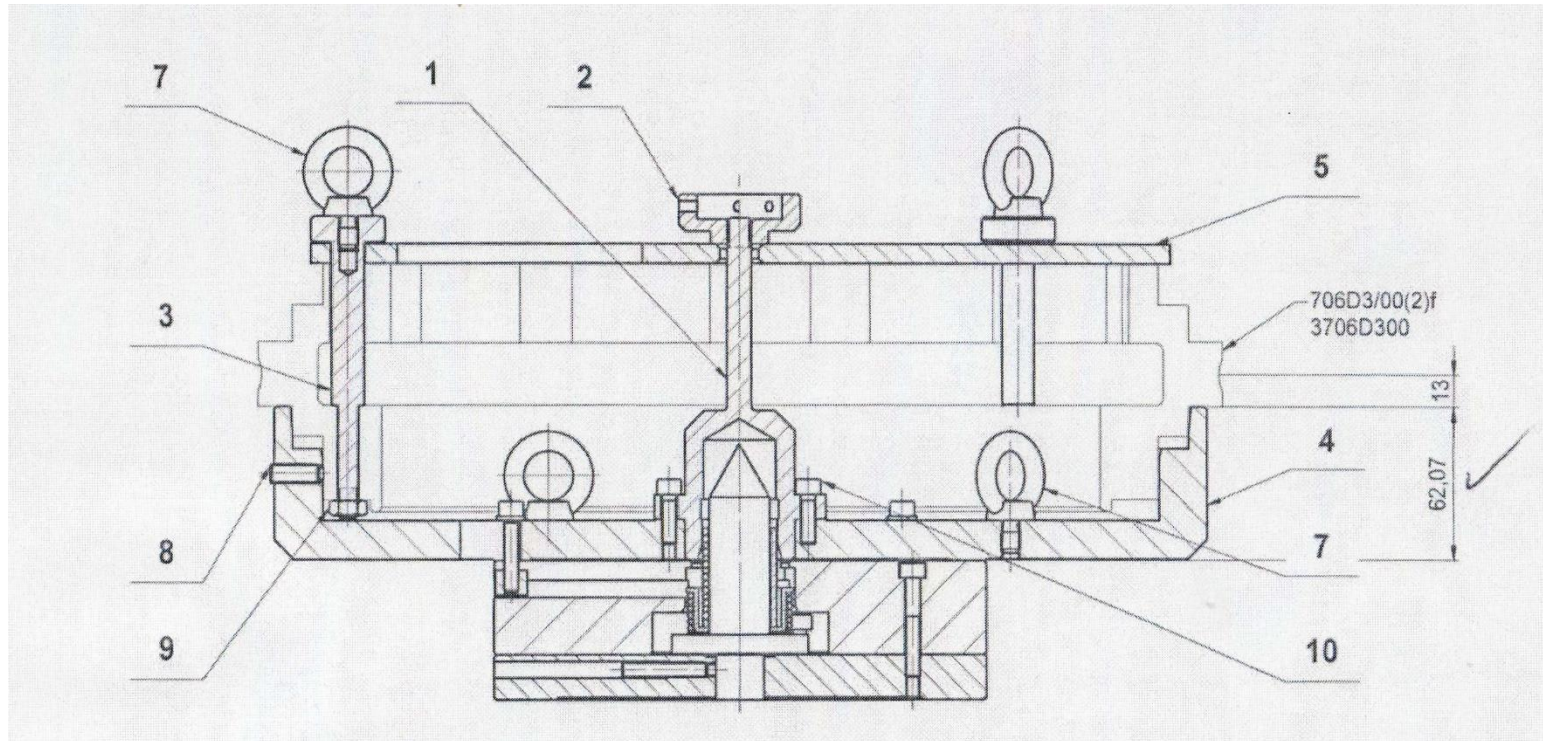


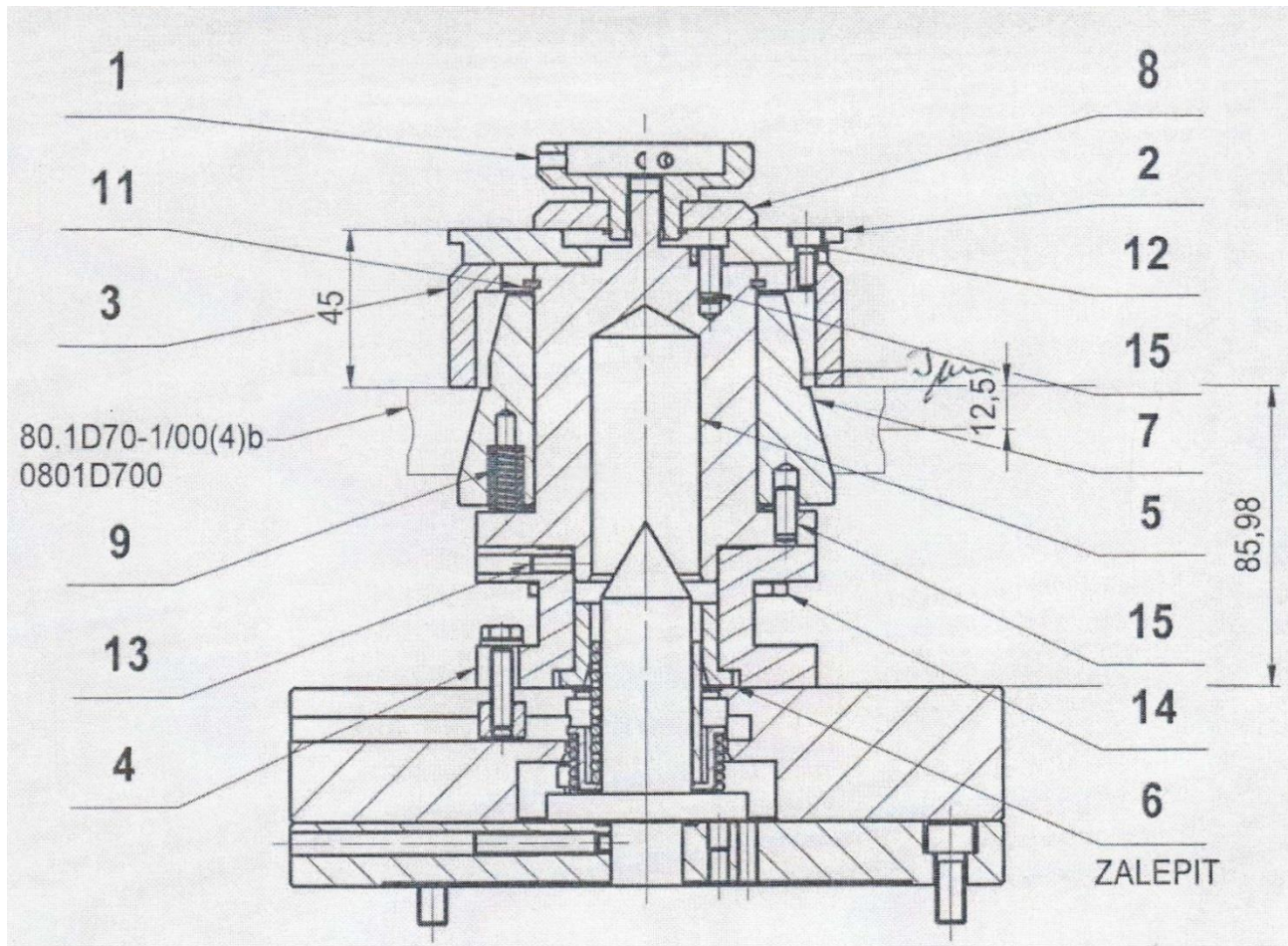
Worm gear is clamped by outside diameter



Worm gear is clamped by inner diameter

Big worm gear is clamped by outside diameter

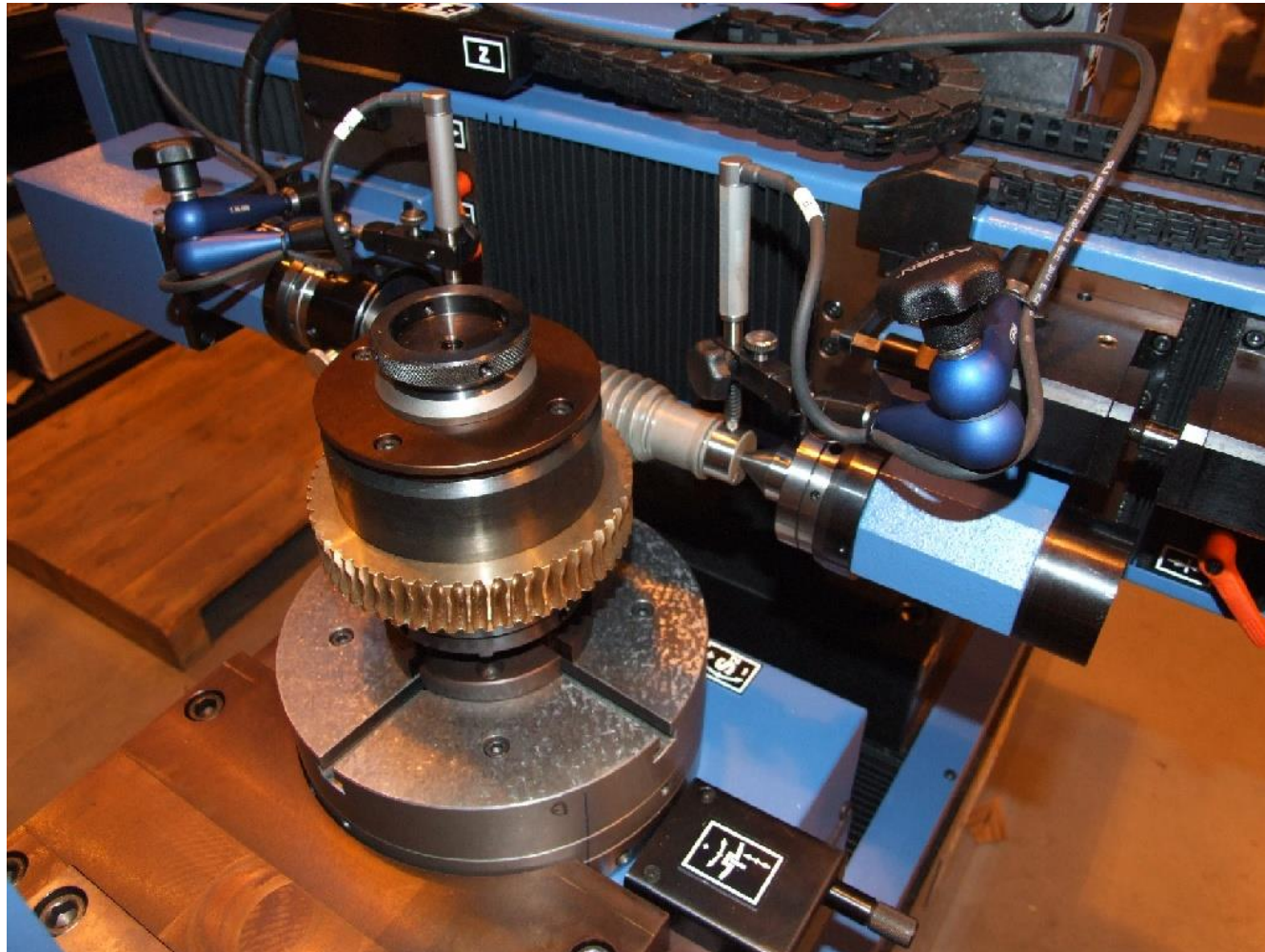


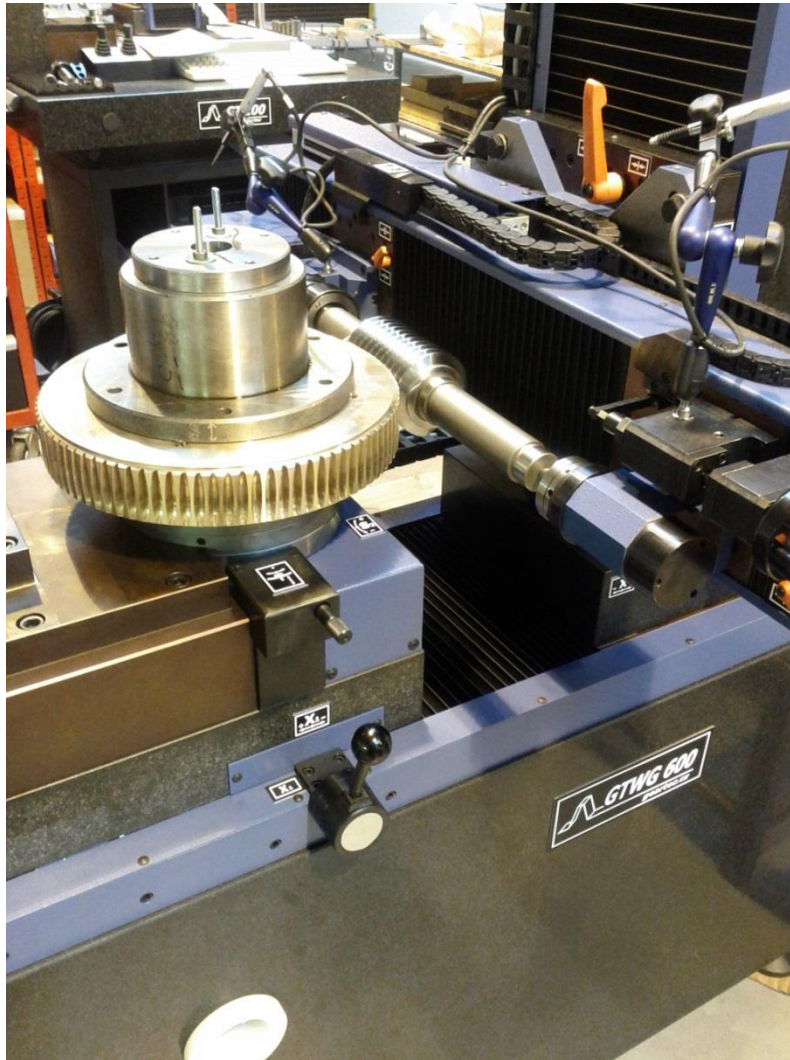


Worm gear is clamped by inner cone surface



The gear is clamped behind the bore by a precise fixture





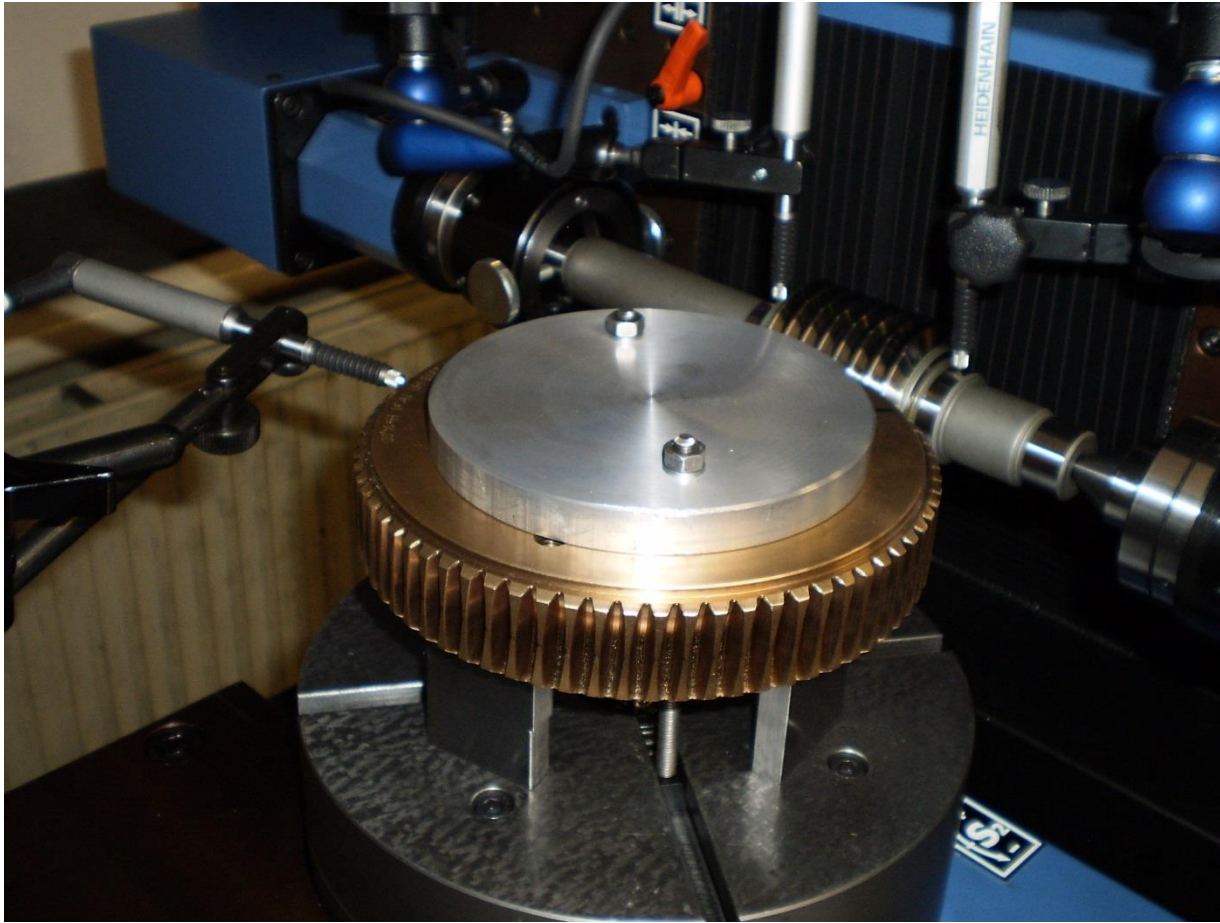
The gear with a control diameter is clamped behind the bore.

The accuracy of clamping was manually checked.

The gear is clamped between centers

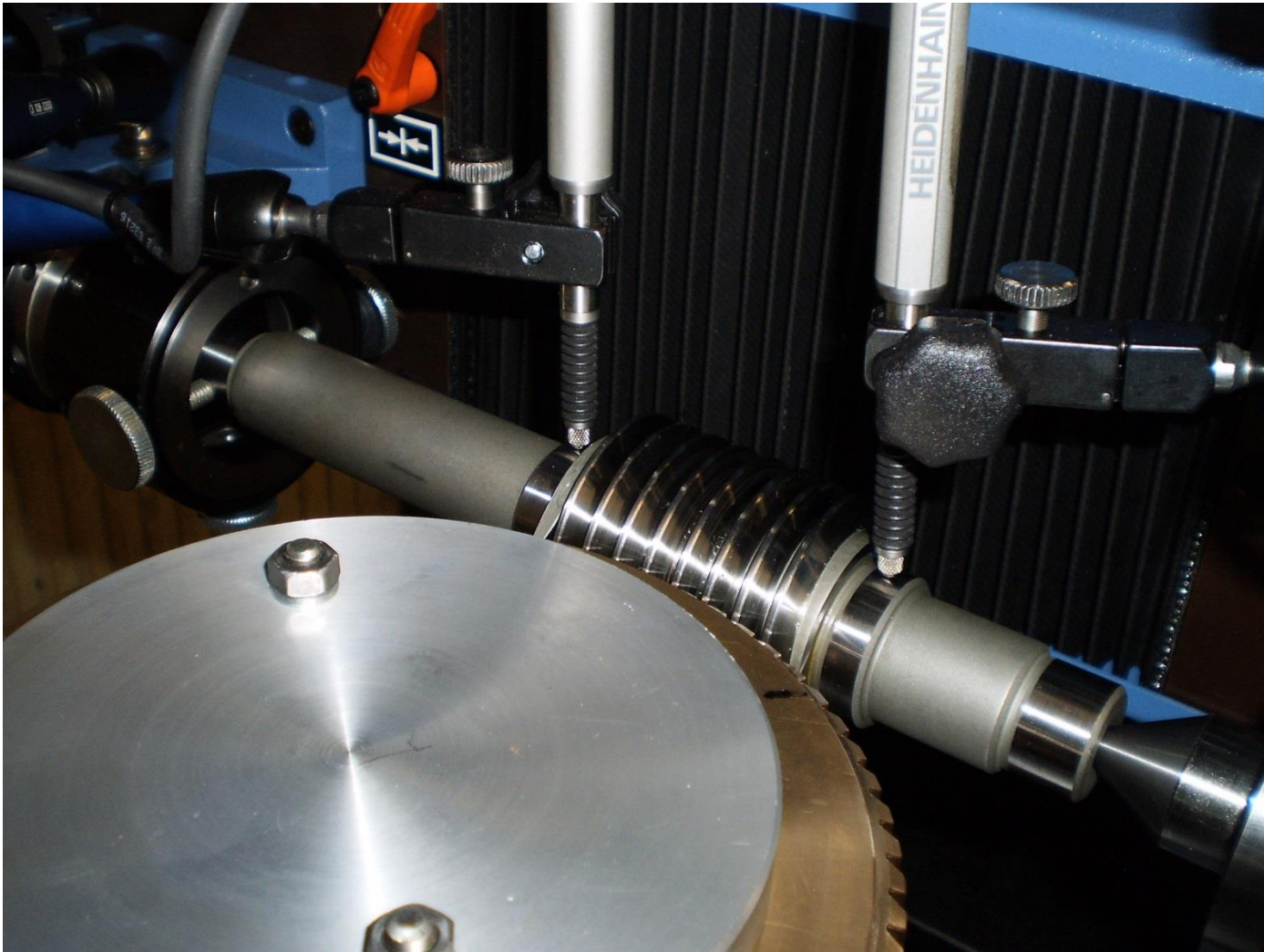


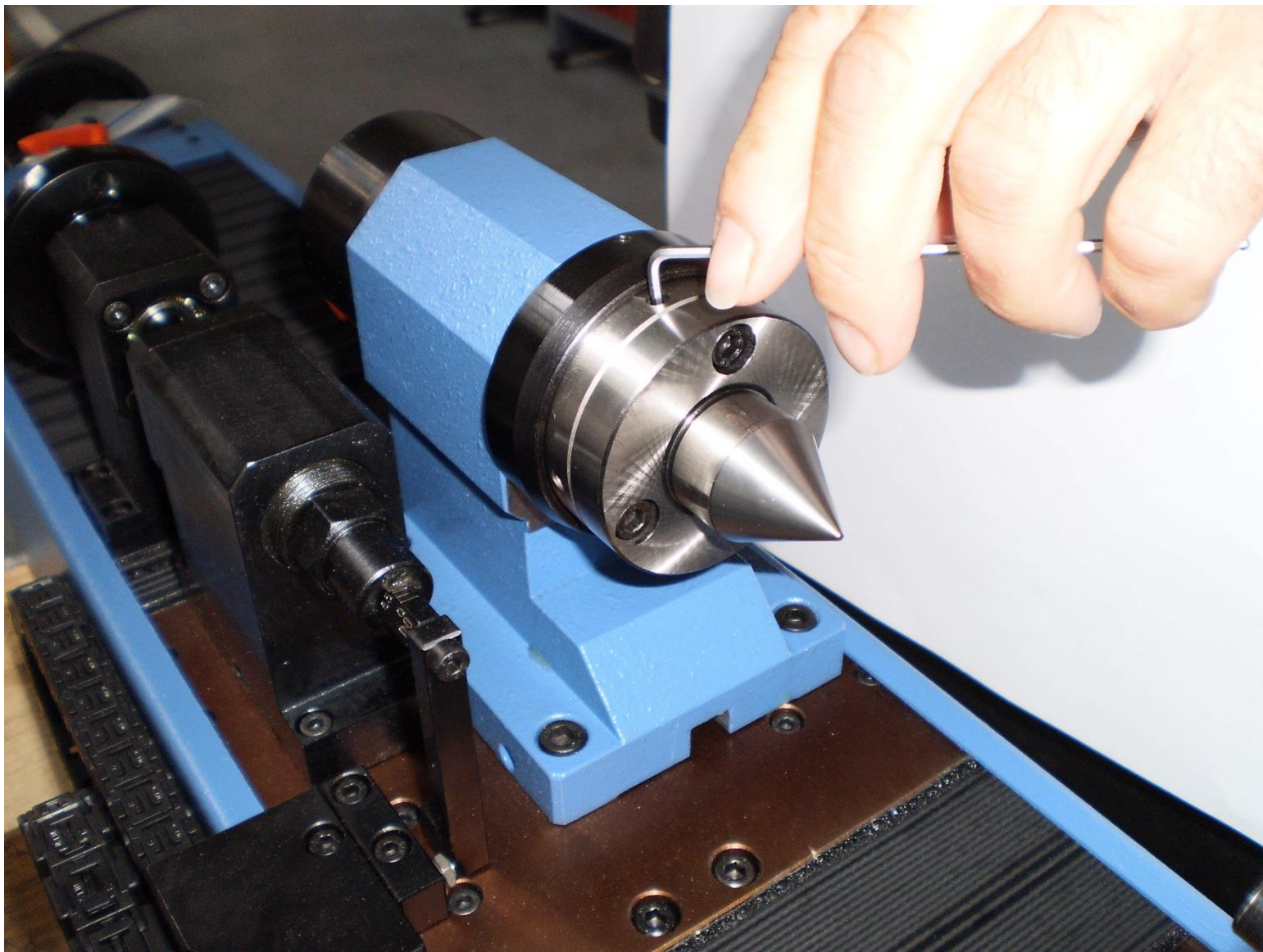
The gear with a control diameter is clamped behind the bore



Inaccuracy of clamping is measured and mathematically compensated accordingly

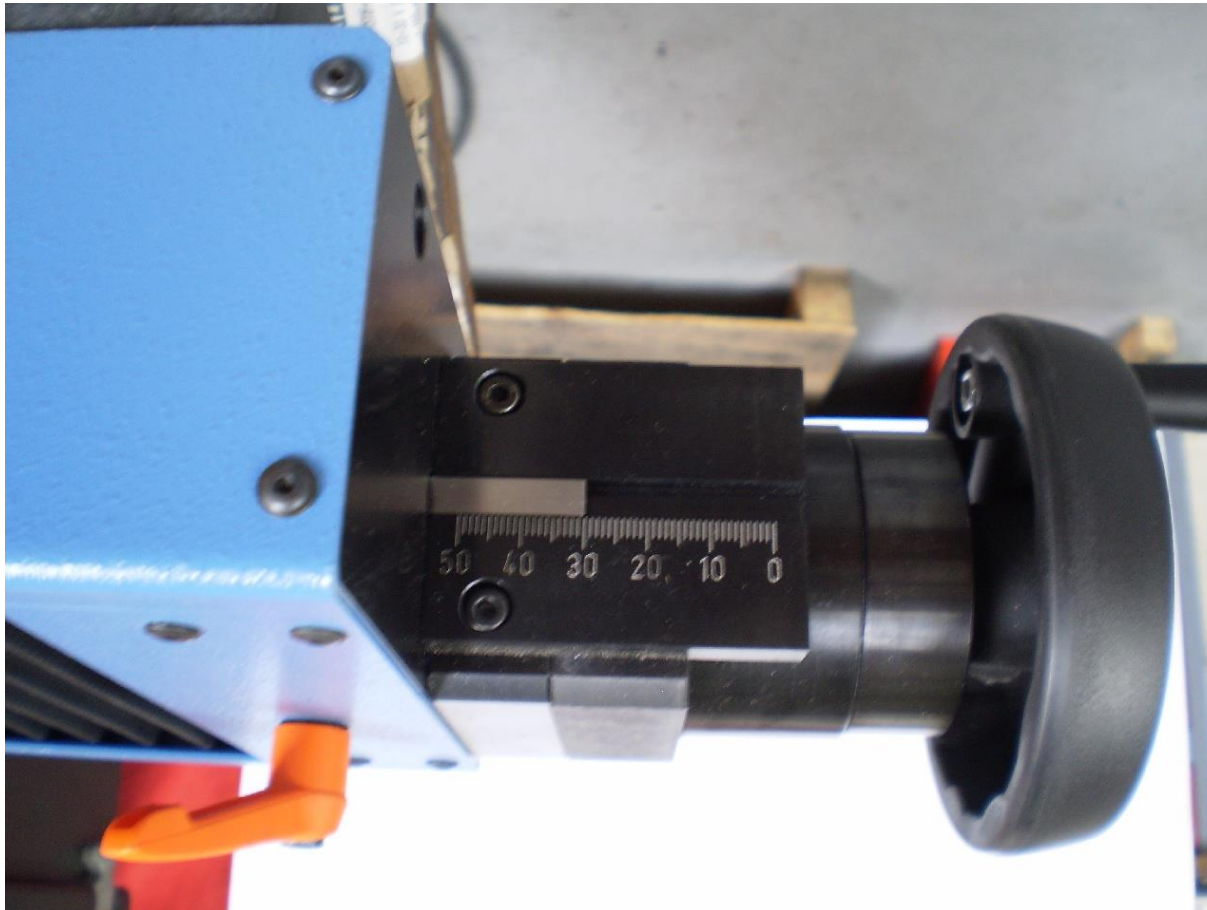
## The way of worm clamping control



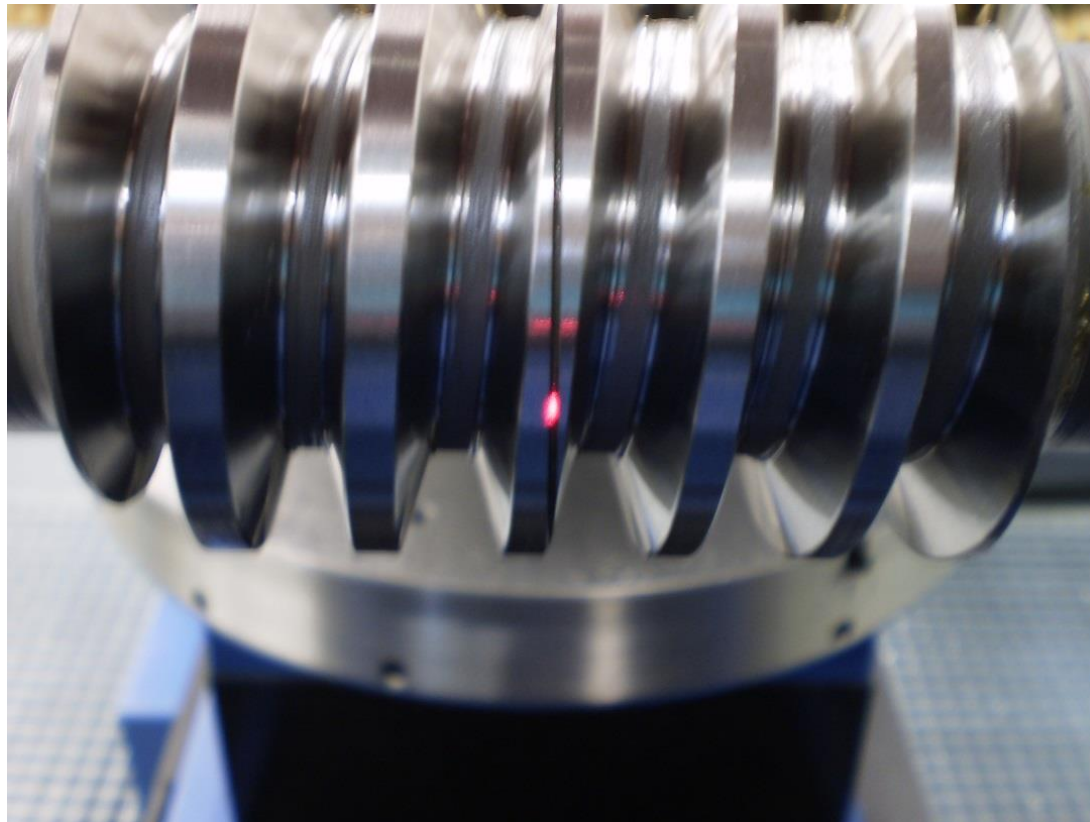


The way of centers lining up

Position of the worm is manual controlled

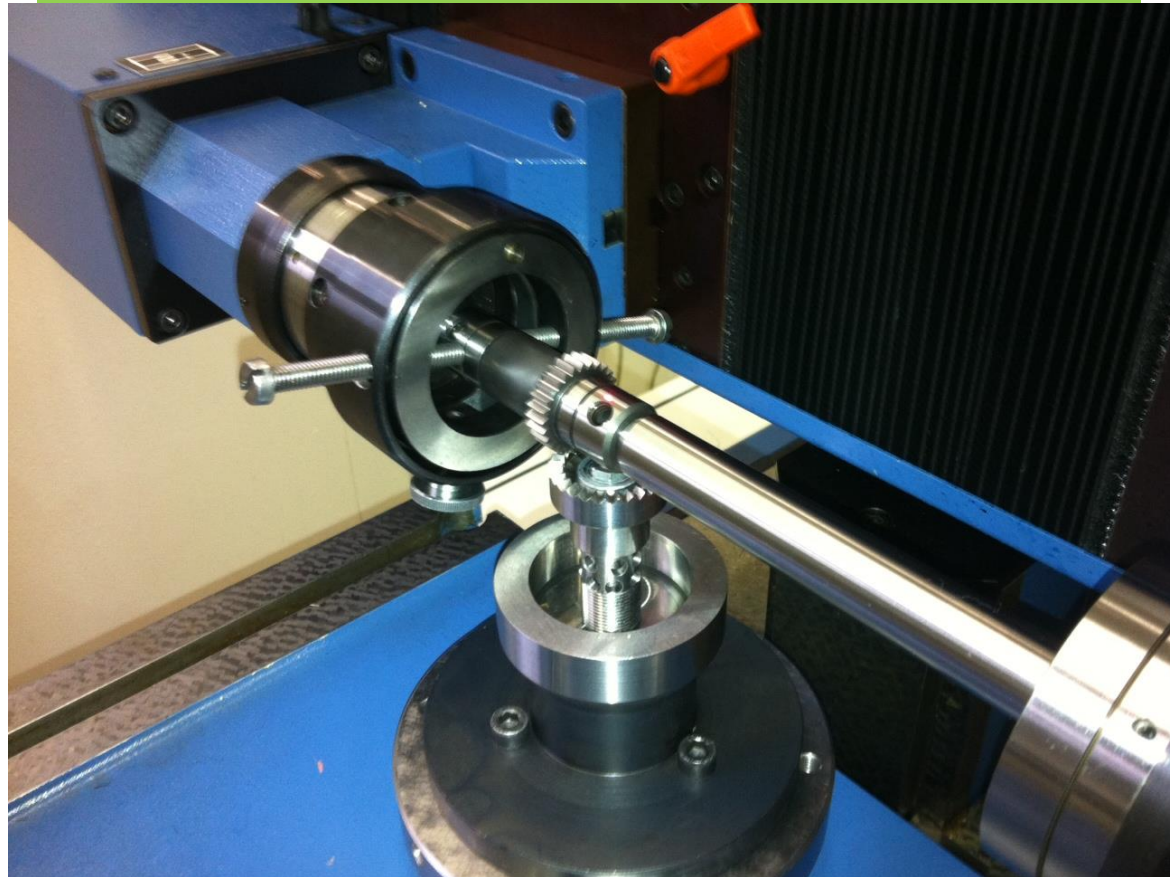


Position of the worm center is controlled by a laser sensor

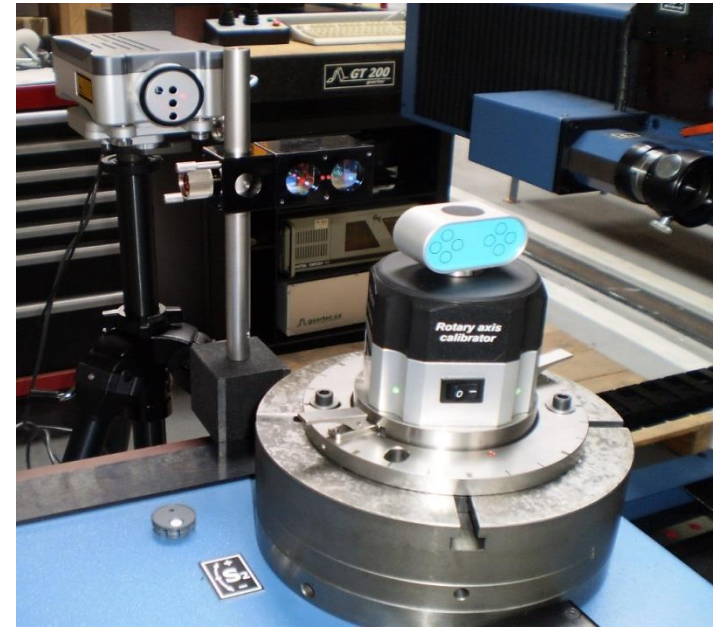
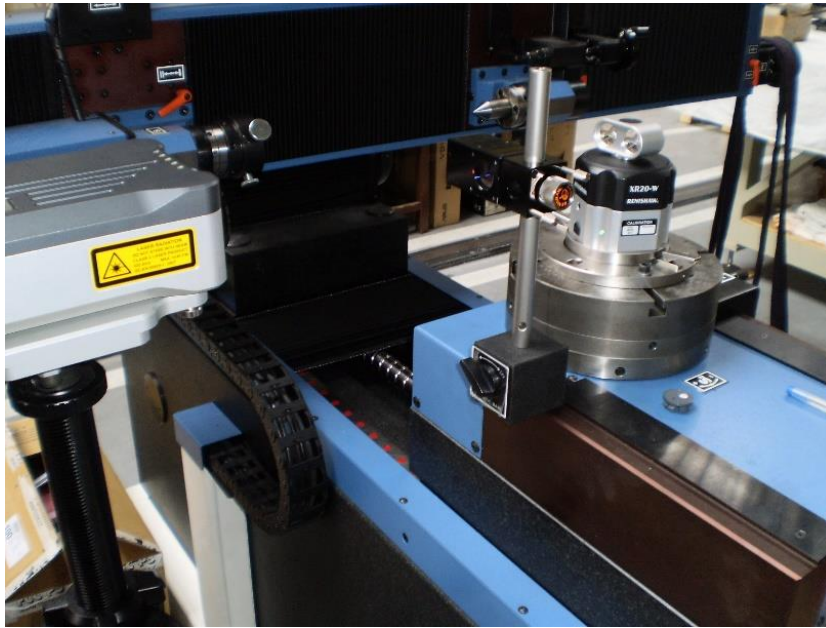




Bevel gears are also possible to measure



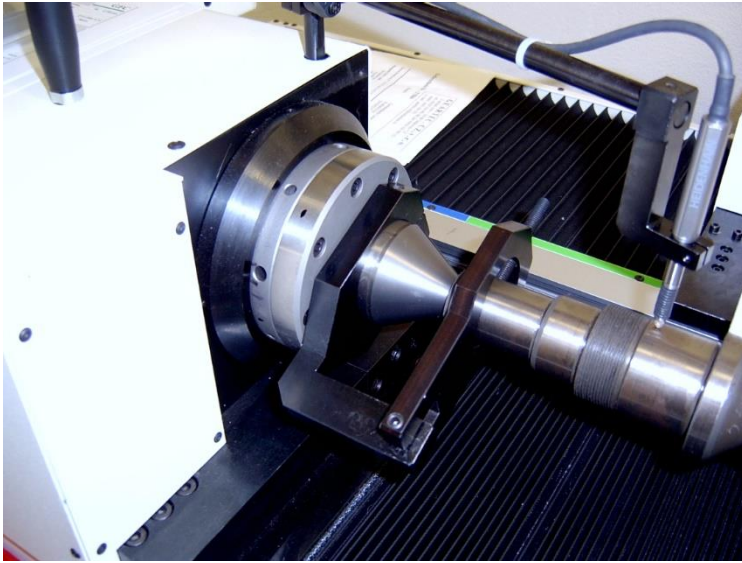
# Measuring of accuracy with laser



*GTWG600 is also capable of measuring by laser technology.*

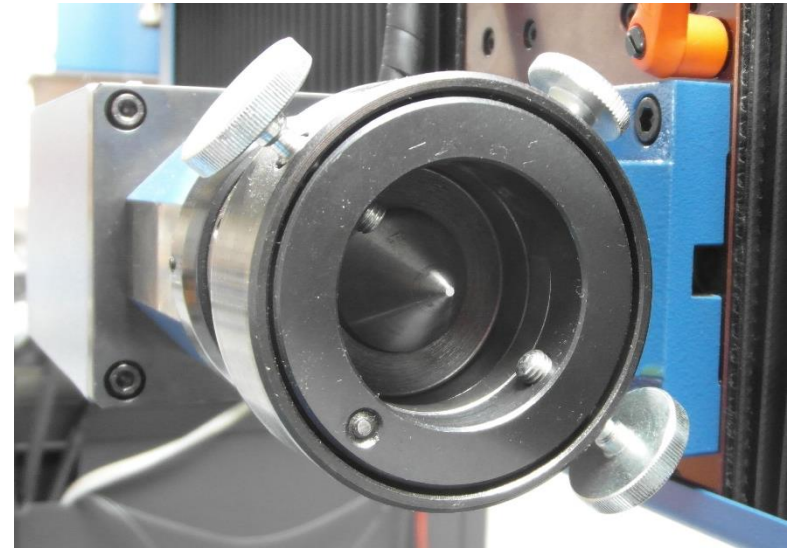
# Accessories - Clamping

## Two standard fixtures



*Clamping range 0 – 20, 0- 40 mm  
Intended for users with common  
accuracy measurement*

## Special fixtures



*Clamping range 0 – 40 mm  
Intended for users with higher  
accuracy measurements*

# Accessories – Calibration

Calibration arbor &



Master worm gears (DIN3)



# Thank you.

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