Jenoptik twist measuring systems - Twist measurement in practice
Dynamically stressed seals place high demands on the surface texture of a shaft at the point of contact with the sealing lip of the radial shaft seal.

The sealing function between the radial shaft seal and the shaft is highly complex. There are a number of different functional requirements, a wide range of media to be sealed and different sealing rings. Many parts are manufactured by suppliers and must be specified accordingly.

Until 1997 no uniform, objective, function-specific, reliable means of evaluation for the shaft side sealing surface was available to manufacturers. Common test methods were microscopic evaluations of the surface texture, use of the thread running method, or testing the part on a leak test bench.

Daimler developed the first uniformly applicable metrological evaluation for twist metrology in 1997. This was based on three factors: three-dimensional measurement of the surface, evaluation of the characteristics relevant to the tightness, and defining the appropriate parameters. Jenoptik has since added twist (lead angle) evaluations as an optional feature in all form and surface measuring instruments.

A revised version of twist metrology has now been available since 2009. This second generation twist metrology offers optimized evaluation algorithms, additional twist parameters and a uniform representation of both the graphical and numerical measurement results.

The technical details are defined in the Mercedes-Benz 2009 standard MBN 31 007-7, which replaces the first generation evaluation method, the last version of which dates back to 2002. This brochure has been written to give the reader a practical overview of twist metrology and provide you with an aid for daily measuring routines.

By kind permission of
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Twist structure and twist types

Twist is a surface characteristic occurring over the entire area of rotation-symmetrical surfaces with a sealing function.

A twist structure exhibits continuous or interrupted threads in an area along the peripheral direction which includes the angle zero, a few arc minutes, a few degrees and also large angles in high-thread structures.

A distinction is made between macro and micro twist due to the differing occurrence and formation.

Different methods are used for the evaluation of macro and micro twist.

Dressing twist

Cause: The structure applied to the grinding disc with constant feed during the dressing process is transferred to the workpiece.
Zero twist periodic

Cause: The structure applied to the grinding disc with constant feed during the dressing process is transferred to the workpiece by the imbalance of the grinding disc.

![Diagram of Zero twist periodic](image)

Special form of the dressing twist with twist angle $\gamma = 0$.
The threads are exactly in peripheral direction and they close.

Zero twist non-periodic

Cause: The structure applied to the grinding disc with inconstant or no feed during the dressing process is transferred to the workpiece.

![Diagram of Zero twist non-periodic](image)

Non-periodic, surrounding structure with twist angle $\gamma = 0$. 
Feed twist

Cause: The defined or undefined cutting edge will form an image on the surface depending on the feed (e.g. turning, rotary grinding).

Offset twist

Cause: Parallelism deviation of grinding disc axis and workpiece axis.

This relates to the micro twist. The micro twist structure is uniform across the workpiece circumference. It is therefore sufficient to record an adequately large measuring area in relation to the microstructure.

The measurement of micro twist structures requires high resolution, area measuring optical methods.
Measuring method

An adequate number of measured data across a defined circumference and axis area of the sealing surface under inspection is required to evaluate macro twist structures.

In order to reliably determine the processing structure, the lateral resolution in the axial direction must be higher than in peripheral direction.

Axial measurement conditions

The profile method of the roughness metrology is used as a basis for measuring the surface texture. A probe system with independent datum must be used in order to be able to measure wavinesses correctly also.

- Evaluation length: 2 mm
- Perm. radial run-out deviation: 20 µm
- Measuring point distance: 0.5 µm
- Filter λs: λs = aus
- Measurement speed: ≤ 0.5 mm/sec
- Stylus tip radius: 2 µm or 5 µm

1) In periodic length range 0.02 mm to 0.4 mm (5x upper period length)

The permissible parallelism deviation of workpiece axis and traverse axis is 10 µm.

Radial measurement conditions

**Measurement grid 1:**
For evaluating threads ≤ 15:
- Angular range: 360°
- Angle step: 5°
- Number of measurements: 72

**Measurement grid 2:**
For evaluating threads > 15:
- Angular range: 36°
- Angle step: 0.5°
- Number of measurements: 72
Measuring instruments

Both roughness or form measuring systems can be adapted to twist measurement. They measure roughness according to standards and have a precision rotation axis for area measurement of the surface texture.

The accuracy of the measuring systems is inspected with specific twist standards for the parameters \( D_t, D_G, D_P \).

- Twist measurement with the CNC controlled roughness measuring station HOMMEL-ETAMIC wavemove

- Twist measurement with the combined form and roughness measuring system HOMMEL-ETAMIC roundscan

- Set of twist standards for verification of the twist measuring system. Calibrated parameters: \( D_t, D_P, D_G, D_y \).
Our service range

Metrology
Tactile metrology
Pneumatic metrology
Optical metrology

Product range
Roughness measurement
Contour measurement
Form measurement
Optical shaft measurement
Dimensional measurement
Optical surface inspection

Inspection process
In-process
Post-process
PLC
Final inspection
Measuring room

Service
System solutions
DAkkS-DKD calibration service
Consulting, training and service

www.jenoptik.com/metrology
Evaluation method

After recording the measured data, the profile data are prepared in the pre-processing for determination of the periodic structures.

The periodic structures are evaluated as standard in the period length range 0.02 mm to 0.4 mm.

The twist profile is then calculated from the 5 strongest frequencies of the power density spectrum and from this the parameters.

Twist profile calculated from raw data record.
Twist parameters

Twist angle $\gamma$ [º]
Angle between the peripheral direction and a twist structure.
The angle is oriented to the right (+ sign) when the direction of the structure is from bottom right to top left. The angle is oriented to the left (- sign) when the direction of the structure is from bottom left to top right.

Twist depth $D_t$ [µm]
Maximum vertical dimension between the wave peak and the wave alley of the calculated twist surface.

Number of threads $D_G$
Number of periods in peripheral direction referenced to 360º.

Theoretical supply cross section $D_F$ [µm²]
Cross-sectional area of a period length in an axial section of the twist surface.

Theoretical supply cross section $D_F$ per turn $D_{Fu}$ [µm²/U]
Cross-sectional area of a period length in an axial section of the twist surface, multiplied by the number of threads.

Period length $D_P$ [mm]
Distance between two successive wave peaks or wave valleys in axial direction.

Contact length in percent $D_{Lu}$ [%]
A measure for the theoretical enclosure of the shaft surface in peripheral direction by the sealing lip contact surface as a ratio of the total circumference. The calculation is made in a cutting depth corresponding to a material ratio of the twist surface of 80 %.
Drawing entries

The drawing note uses the basic symbol for specification of surface parameters. The measuring conditions and limit values depend on the component, the functional application and the type of radial shaft sealing ring. The focus of twist drawing entries is on the macro twist parameters.

Validity range

The validity range is the period length range specified by the drawing entry in which the twist parameters are evaluated. Twist types outside the validity range are not evaluated.

The validity range is indicated in front of the tolerated twist parameter, separated by an oblique stroke. The smallest period length that can be evaluated is 0.02 mm.

If the validity range is intended to begin at this lower default limit value, this value must be omitted in the drawing note and only the upper limit value is specified. If no validity range is specified in the drawing, 0.02 mm to 0.4 mm applies as a default for the validity range.

Drawing entries according to ISO 1302:2002

The specifications in the product documentation (e.g. drawing) follow the rules according to ISO 1302:2002 using graphic symbols and additional texts.

The basic definitions are as follows:

- a: surface parameter with numeric value in µm
- b: second requirement (surface parameter in µm)
- c: production method
- d: specification of valley direction
- e: machining allowance in mm

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Entry for ground surfaces

The tolerance values for the twist parameters are determined dependent on the twist angle. Larger limit values are generally permissible for zero twist types. The measurement and evaluation conditions, especially the evaluation length and the validity range, have a great effect on the parameter type. These specifications should therefore be part of the drawing specifications.

Rz must be between 1 µm and 4 µm. Evaluation length 4 mm with 5 sampling lengths and cut off 0.8 mm.

For the twist angle $D\gamma = 0^\circ$ the twist depth $D_t$ may not exceed 0.8 µm (validity range 0.02 mm to 0.4 mm).

For the twist angle $D\gamma \neq 0^\circ$ the twist depth $D_t$ may not exceed 0.5 µm (validity range 0.02 mm to 0.4 mm).
Entry for turned, rolled and roller burnished surfaces

For these production methods, a tolerance specification for the twist angle, i.e. the orientation of the processing structure, is often sufficient.

**turned with right orientation**

1. $R_z$ must be between 1 µm and 4 µm. Evaluation length 4 mm with 5 sampling lengths and cut off 0.8 mm.
2. The twist angle $D_y$ must be greater than 0º, right orientation specified.
   No validity range specified so that the standard case of 0.02 mm to 0.4 mm applies, axial evaluation length 2 mm (5 x upper limit of the validity range).

**turned with left orientation**

1. $R_z$ must be between 1 µm and 4 µm. Evaluation length 4 mm with 5 sampling lengths and cut off 0.8 mm.
2. The twist angle $D_y$ must be smaller than 0º, left orientation specified.
   Validity range from 0.02 mm to 0.3 mm.
3. The twist depth $D_t$ may not exceed 1.5 µm.
   Validity range from 0.02 mm to 0.3 mm.
4. The period length $D_P$ must not exceed 0.1 mm.
   Validity range from 0.02 mm to 0.3 mm.
   Twist measurement (2nd to 4th line): axial evaluation length = 1.5 mm (5 x upper limit of the validity range).
TwistLive® quick twist measurement method

The measured value recording for the twist measurement requires 72 profiles. This means a measuring time of approx. 15 minutes depending on the measuring instrument.

The TwistLive® quick twist test is based on the measuring method described above and contains a specially developed evaluation method for reducing the measuring time. The resulting twist structure is updated and the twist parameters calculated after every recorded measurement here. The result of the observed parameter stabilizes as the measurement progresses.

When the specified stability criterion is reached, the measurement is ended. This is typically the case after approx. 25-30 % of the nominally necessary measurements. The required measuring time is therefore typically reduced to about 5 minutes.

Example measurement twist depth Dt.
After 12 measurements, the final value is stable within 1.5 %.

Advantages:

- 100 % compatible with the standard MBN 31 007-7 in the 2009 version
- Measuring time reduction typically 70-75 %
- Live display of the results during the measurement