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MEASURING TWIST ON MACHINED SURFACES

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ABSTRACT

The development of production technologies has increased the productivity and improved surface quality as well. The main direction of the research has aimed at identifying the relationship between surface quality and functionality and at finding the correlation between the process parameters and surface quality. There is a need to define certain measures to describe the surface quality, including definitions related to twist, besides the other surface roughness parameters. In the following article we describe the twist related machining parameters and processes that lead to twist. We test the thread run tests, applied in industrial practice, and revealed some weaknesses in the twist measurement standard.

1. INTRODUCTION

The importance of twist-free surface manufacturing has become more important with the improvement of the machining methods. Twist is defined on the circumference of the rotationally symmetric parts. This texture is experienced on the topography of the surface and causes a transport effect. The periodic surface structure could cause the sticking of the surfaces and extreme wear, as well. In the case of dynamic shaft sealing the supply effect would mean either dry running or oil leakage. It was proven in [1] that the generally used surface roughness parameters are not suitable to describe twist, and therefore the implementation of new measures is necessary.

2. TWIST CHARACTERISTICS

The first twist measurements were defined and implemented in the automotive industry, which was taken over by ISO. The basic twist parameters were defined according to DIN EN ISO 25175-3:2012-03. The main five parameters are described below and illustrated in Fig. 1:

- DP – period length [μm],
- Dγ – twist angle [° ' "],
- Dt – twist depth [μm],
- DF – theoretical supply cross section [μm^2],
- DG – number of threads [-].

The following twist types are defined by the standard for a ground surface:

- dressing twist: caused by the feed of the single-point dressing tool,
- zero twist: no twist angle experienced, therefore it has no supply effect,
- feed twist: caused by the axial feed of the tool,

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- offset twist: caused by the non-parallel axes of the tool and the workpiece [2] [3].

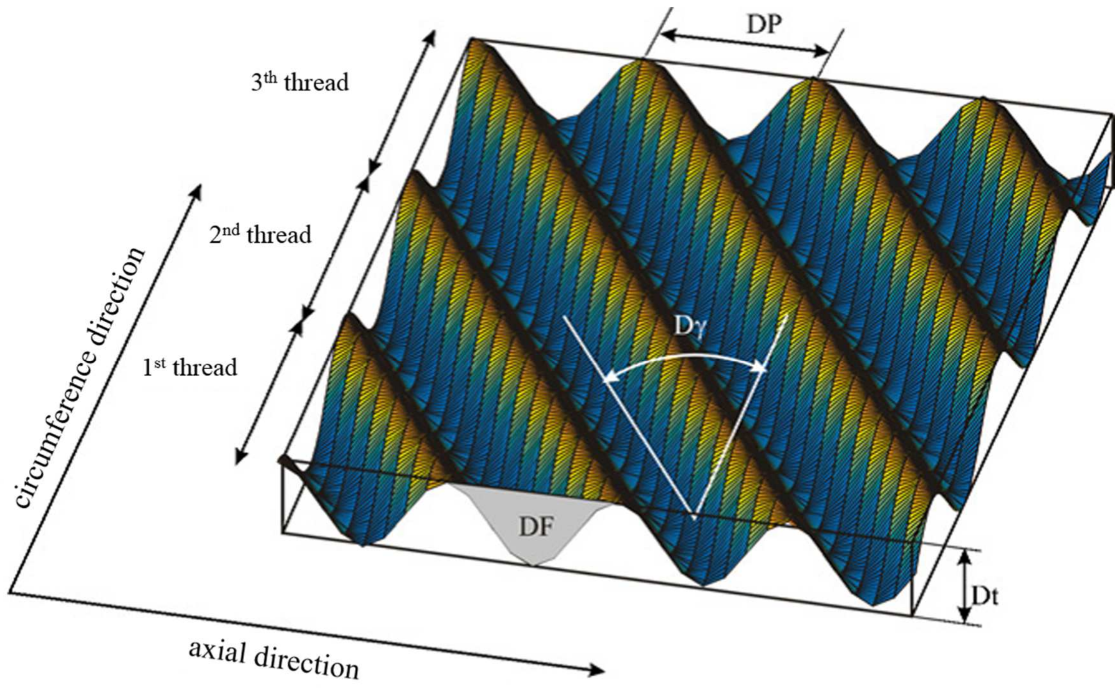

Fig. 1
Twist geometry and ISO parameters [4]

3. SURFACE TWIST IN MANUFACTURING PROCESSES

The development of new measurement techniques was triggered by the new manufacturing methods of hardened surfaces. Tools with well-defined edge geometry provide huge material removal performance in certain applications. These manufacturing processes have beneficial surface integrity and operational costs. However, the surface will be twisted due to the kinematics [5].

3.1. The twist relevant factors in grinding

In the case of tools with an undefined edge geometry, twist can occur despite the random topography. The identification of the twist is more difficult, because the surface is covered by small scratches all along the surface. We have to expect twist with certain combinations of grinding process and technology and dressing parameters.

We will get surface twist in the case of axial feed motion and when the generator line of the grinding wheel cylinder is not parallel with the workpiece axis. The dressing of the wheel also leads to twist when the dressing tool is a single-point diamond. In this case the dressing tool generates a dressing spiral which is transferred to the workpiece surface [3].

Theoretically, twist-free topography can be provided in abrasive manufacturing processes. Table 1 contains the combination of the manufacturing and dressing methods with the surface texture produced [5].

Table 1

Effect of process and dressing methods [5]

Grinding method	***Wheel material***	***Dressing tool***	***Twist-structure***
Cylindrical grinding • with axial feed		Single-point diamond	Twist
		Diamond dressing block	Twist
Cylindrical grinding • with in-feed		Single-point diamond	Zero twist
		Diamond dressing block	Zero twist
Cylindrical grinding • with in-feed • with oscillation	Aluminum oxide	Single-point diamond	Zero twist
		Diamond dressing block	Twist-free
Cylindrical grinding • with in-feed • with oscillation • with longer spark-out time		Single-point diamond	Twist-free
		Diamond dressing block	Twist-free
Centerless grinding • through-feed		Single-point diamond	Twist
		Diamond dressing block	Twist
Centerless grinding • in-feed		Single-point diamond	Zero twist
		Diamond dressing block	Zero twist
Peel grinding		Single-point diamond	Twist
Peel grinding	CBN	Diamond dressing wheel	Twist
Quick-point grinding		Diamond dressing wheel	Twist

High performance abrasive processes used for hardened surface machining are:

- quick-point grinding,
- peel grinding,
- high-speed cylindrical grinding with in-feed.

Quick-point grinding is performed by a narrow CBN or diamond wheel. The tool is conical and angles along two planes related to the workpiece. The two angles create a special contact patch similar to a point. A narrow grinding wheel is used in peel grinding also, but the difference is in the axial feed, which provides a line contact.

The material removal is done by one feed. There is no need for roughing and finishing and a spark-out section. Because of this, these two manufacturing methods are economical and widely used; however, the surface will be twisted. In these cases extra in-feed movements are applied to avoid twist.

High-speed cylindrical grinding with in-feed motion does not crate surface twist if an extra oscillating movement is employed during manufacturing [5][6].

3.2. Alternative manufacturing methods with well-defined edge geometry tools for avoiding surface twist

A surface machined with conventional hard turning is periodical, therefore it is twisted. There are new process variations being developed to lessen the surface twist when machining with a well-defined edge tool. The processes are the following:

- vibration-processing method,
- tangential turning,
- rotational turning,
- start-stop turning.

The twist geometry can be regulated with the variation of the process parameters, tool geometry and proper kinematics. The aim is to provide a twist-free surface without supply effect. Some manufacturing processes need special expensive tools and machines which can be used in small application area [7].

4. TWIST MEASUREMENT: THREAD RUN TEST

Measuring equipment manufacturers are attempting to define and develop an exact method to measure the basic twist parameters. However, they are not yet able to provide a method and equipment suitable for serial conditions. The methods applied in the practice are only suitable to measure the twist-freeness of the surfaces. The most commonly applied measurement is the thread run test.

The thread run test measures the axial way of a measurement line in one minute on the surface of a part at a specified rotational speed (see Fig. 2). The diameter of the measurement line can be varied between 0.25 and 0.08 mm. Besides this, the standard also specifies the weight to be used in measurement.

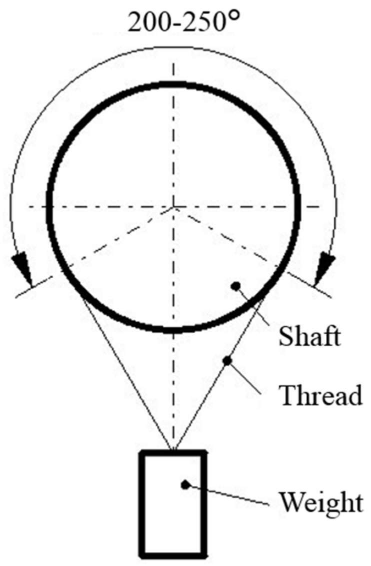

Fig. 2
Scheme of thread run test [2]

The notation a_m denotes the mean value of the axial movements of the measurement line defining the twist-free or twisted surface of the parts. This method is not suitable to measure the standard parameters of twist [2].

There is no proper method to measure and evaluate quickly the standard twist parameters on the surface in industrial practice. Companies in the automotive industry are using the thread run test despite several uncertainties during the measurement.

4.1. The aim of the experiment

The aim of the experiment is to find a correlation between the parameters (thread diameter, material properties) and the measurement results for grinded surfaces.

4.2. Experimental conditions

The experiment was performed on a CN controlled lathe (Optiturn L440 type CNC) at the University of Miskolc, Institute of Manufacturing Science. The circumferential speed can be easily regulated to get the desired value. The workpiece was clamped in the chuck in a horizontal position and carefully cleaned. We put an appropriate weight on the end of the measuring line. The weight is depending on the line diameter (see Table 2).

The applied lines were the following:

- steel line (S),
- braided line (B),
- monofilament line (M).

The diameter of the lines is: 0.08 mm (a), 0.18 mm (b), 0.25 mm (c).

Table 2
The applied measuring line and the weights [9]

Applied parameters	Applied weight [g]
S-(a)	165
B-(c)	10
M-(b)	10

The measurements were performed on a shaft with various diameter steps. The measured surfaces were grinded. Table 3 contains the machining parameters of the surfaces, where:

- D – shaft diameter [mm],
- v_c – cutting speed[m/s],
- v_w – workpiece speed [m/min],
- q – speed ratio [-],
- $v_{f,L}$ – axial feed [mm/min],
- a_e – depth of cut [mm],
- Z – allowance on diameter [mm].

Table 3
Grinding parameters of the surfaces [8]

	S1	S2	S3	S4	S5	S6	S7
D	29m5	44h5	58h5	52k5	46k5	42k5	41h8
v_c	99.75						
v_w	64.3	75.2	98.0	99.8	97.5	89.0	70.0
q	93	80	61	60	61	67	69
$v_{f,L}$	200	180	180	180	180	200	220
a_e	0.15						
Z	0.3						

4.3. The measurements

The circumferential speed has to be 20 m/min during rotation (standard description). The workpiece was rotated for one minute and the axial displacement of the line was measured (a_1). The process was repeated in the other direction and we obtained the a_2 values. The average of the two measurements was used to define the twist of the surface:

$$a_m = \frac{a_1 + a_2}{2}.$$

The surface can be considered twist free if the a_m value is smaller or equal to 0.5 mm [2].

5. RESULTS

The results are summarized in Fig. 3. There are major differences between the measured values on the same surface using different lines.

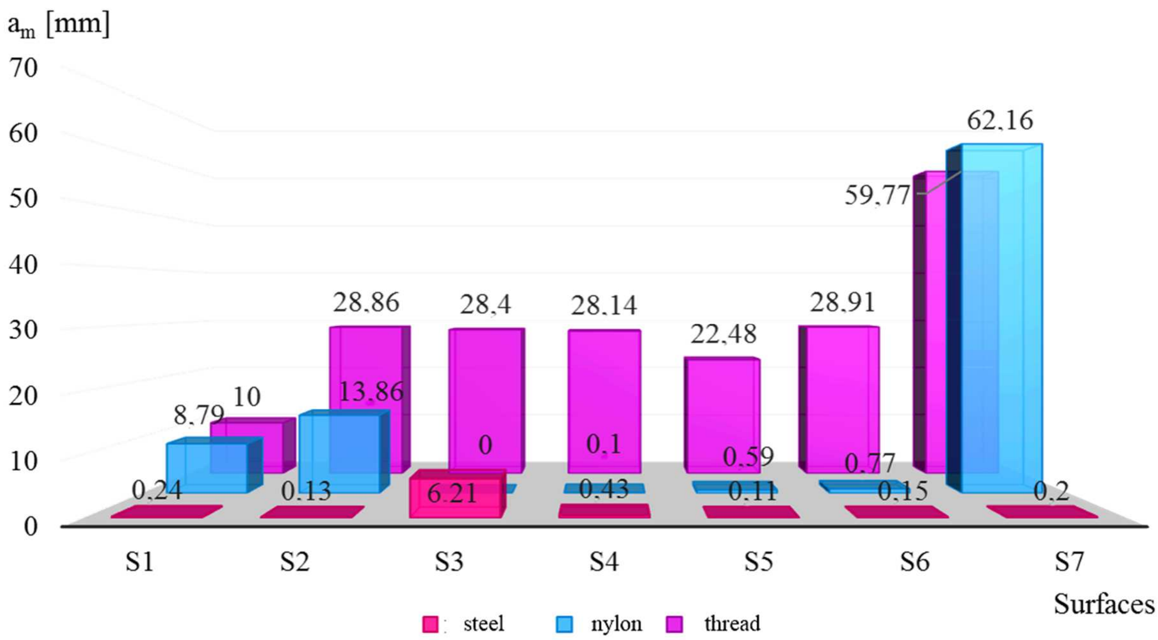

Fig. 3
Results of measurements [8]

Twist was found for all 7 surfaces using braided line. In three cases we obtained large values using monofilament line, similarly to the braided line values. Two surfaces (S3 and S4) were measured as twist free with monofilament.

The values measured using steel were much lower than those measured by the braided line. We measured a greater value than 0.5 mm only for the S3 surface using steel. We measured the highest value with the braided line for all surfaces except S7. The difference between the measured results is major, which can have several explanations. We can assume that the measurement is heavily affected by the parameters of the line (diameter, material and mechanical properties). Due to this fact, the standard should define also the measurement line material, diameter and mechanical properties as well, as recommended in [9].

6. SUMMARY

The demand for an increased lifetime of structures requires creation of the most effective surface topology for application in manufacturing. In our case this means that we strive to reduce the twist topology on machined surfaces.

We can assume that twist can occur either on single-point cutting tool machined surfaces or on abrasive machined surfaces. The level of twist can be decreased on surfaces manufactured with well-defined tools. In this case the modification of the parameters such as kinematics and tool geometry needs to be selected carefully.

During the abrasive machining the usage of a dressing block instead of single-point diamond tool and grinding with in-feed and with oscillation can decrease the surface twist.

This study illustrates that the measurement of twist parameters in the industry needs to be further developed. In practice the thread run test can provide reliable results only if the conditions, which are set in the standard are strictly kept. Standards should include a specifications of the line used when performing the thread run test.

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