Comparative assessment of documentation referred to surface roughness measurement

A A Vinogradova¹, M I Grichukha¹, E E Smirnova¹

¹Saint-Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

E-mail: vinogradova_aa@pers.spmi.ru

Abstract. The research relates to the field of metrological supervision, specifically to the control of surface roughness parameters. The authors analyzed the following regulatory documents: GOST R ISO 4287-2014 “Geometrical product specifications (GPS). Surface texture. Profile method. Terms, definitions and surface texture parameters”, GOST 25142-82 “Surface roughness. Terms and definitions”, GOST 2789-73 “Surface roughness. Parameters and characteristics”, GOST 9378-93 (ISO 2632-1-85, ISO 2632-2-85) “Roughness comparison specimens. General technical conditions”, GOST 27964-88 (ST SEV 6134-87, ISO 4287 / 2-84) “Measurement of roughness parameters. Terms and definitions”, GOST 19300-86 “Instruments for measurement of surface roughness by the profile method. Contact profilographs and profilometers. Types and main parameters”, GOST R 8.651-2009 ISO “State system for ensuring the uniformity of measurements. Contact (stylus) instruments for the measurement of surface roughness. Procedure of calibration”, GOST 9847-79 “Optical instruments for surface roughness parameters measuring. Basis parameters and types”, GOST R 8.700-2010 “State system for ensuring the uniformity of measurements. Method of surface roughness effective height measurements by means of scanning probe atomic force microscope”, which regulate the measured parameters of the surface roughness, instruments that measure these parameters. In the course of a comparative analysis of the values of the parameters of existing devices and the values of the parameters of devices prescribed in the standards, a summary table was formed, and the problem of controlling nanoparameters and nanocoatings was also identified. The existing instrument base for monitoring surface roughness allows measuring parameters with high accuracy and within wide limits, but the regulatory framework on the territory of the Russian Federation is outdated and does not allow the use of some modern types of instruments. In this regard, it is necessary to update the requirements of GOSTs for the modern capabilities of technology and control over roughness parameters.

1. Introduction

The requirements for surface roughness (according to one of the definitions, surface roughness is a set of surface irregularities with relatively small steps) of products are technical requirements that are important for modern industry [1], they are set according to the functional purpose of the surface in order to ensure the desired product quality. The methods and measuring tools are necessary to control the surface roughness after processing the product and after applying the nanocoating on it. Modern devices for monitoring surface roughness allow measuring parameters with high accuracy and within wide limits, while the regulatory framework in the Russian Federation is outdated and does not allow the use of some types of devices.
2. Comparative assessment of existing documentary standards

There are several standards that set the terminology and requirements for the measurement of roughness parameters. The fundamental standard is GOST R ISO 4287-2014 [2]. This standard provides terms, definitions and parameters for the measurement of surface structure (roughness, waviness and primary profile) using grading methods. The terms are divided into general terms related to surface profile and terms of geometric parameters of the surface, such as profile peak, profile element. In addition, the terms about the parameters of surface roughness are given in the standards GOST 25142-82 (it establishes the terms used in science, technology and production and definitions of basic concepts related to surface roughness) and GOST 2789-73 [3, 4].

However, having analyzed all three standards, we can see that there are inconsistencies in the notation and terms of the parameters [5]. In GOST 2789-73, in addition to terms on roughness parameters, there are data on the types of directions of surface irregularities (Table 1) and numerical values of roughness parameters (standardized and most preferred). The definition of roughness is also given as a set of surface irregularities with relatively small steps, selected using a basic length.

Since the 1980s a quick method was required during the production in order to compare visually and by sense of touch roughness obtained by cutting, polishing, electroerosion, etc. In 1993, the standard GOST 9378-93 was created [6], which contained images of surface roughness (comparison). The standard provides a classification of samples of various shapes and directions of surface irregularities. In addition, the series of nominal values are given for some roughness parameters.

### Table 1. Types of instruments for measurement of surface roughness

| Types of directions of surface irregularities | Explanation                                                                 |
|---------------------------------------------|-----------------------------------------------------------------------------|
| Parallel                                    | Parallel to the line depicting the surface in the drawing, for the roughness of which the requirements are established |
| Perpendicular                               | Perpendicular to the line depicting the surface in the drawing, for the roughness of which the requirements are established |
| Cross-angular                                | Crossing in two directions at an angle to the line depicting the surface in the drawing, for the roughness of which the requirements are established |
| Arbitrary                                    | Different directions with respect to the line depicting the surface in the drawing, for the roughness of which the requirements are established |
| Circular                                    | Approximately circular with respect to the center of the surface for the roughness of which the requirements are established |
| Radial                                      | Approximately radial with respect to the center of the surface for the roughness of which the requirements are established |

However, it is not always possible to visually and by the sense of touch determine the parameters of the surface roughness, and in this case, devices are used.

In GOST 27964-88 [7] terms for measuring instruments are given, using them we can measure parameters. After analyzing the standard, it is possible to give a classification of devices based on “contact with the surface” (Table 2): contact (with mechanical interaction with the measured surface) and non-contact (without mechanical interaction with the measured surface).
Table 2. Types of instruments for measurement of roughness parameters

| Contact devices | Non-contact devices |
|-----------------|---------------------|
| **Application** | **Accuracy** | **Contour section device** |
| Laboratory (stationary) | 1<sup>st</sup> degree | Light section device |
| Factory (stationary-portable to control the finished surfaces) | 2<sup>nd</sup> degree | interference measuring microscope |
| Factory (portable, intended for inter-operational control) | interference profilometer microscope |

What do these terms mean? In both cases the devices are based on the measurement of surface parameters by the profile method. The main difference between the devices is that the contact device mechanically probes the surface, while the non-contact device receives information about the shape without mechanical impact on the surface. Contact devices are profilograph-profilometers. Their main principle of operation is that mechanical vibrations of a diamond needle, probing the surface, are converted into electrical vibrations using an electromechanical converter. The signal received by the transducer is processed and analyzed, since its parameters characterize the irregularities of the profile.

According to GOST 19300-86 [8], which applies to contact profilographs-profilometers for measuring the profile and surface roughness parameters along the centerline system in accordance with the nomenclature and ranges of values, there are two classifications of profilograph-profilometers (Table 2): depending on the purpose and numerical values. The GOST 19300-86 standard also gives the main parameters for the profiler-profilometers, the requirements for the level of external vibration and surrounding conditions are also given:

- surrounding air temperature
- temperature change
- relative humidity.

In GOST R 8.651-2009 [9] it is indicated that the profilograph-profilometer can be influenced by such factors as noise, air flows and other external influencing factors. This GOST applies to contact (probe) devices for measuring surface roughness and establishes a method for their calibration.

Optical devices can be classified as non-contact devices. The GOST 9847-79 standard [10] regulates the requirements for optical devices, the operation of which is based on the principle of simultaneous transformation of the surface profile.

This standard specifies the types of optical devices (Table 2):

- contour section device (CSD);
- light section device (LSD);
- interference measuring microscope, the action of which is based on two-beam interference of light (IMM);
- interference microscope-profilometer, the action of which is based on the interference of light with the formation of bands of equal chromatic order (IMP).

Optical instruments / microscopes are used as supporting equipment for measuring the effective height of surface roughness with a scanning probe atomic force microscope (probe atomic force microscope with normalized metrological characteristics that generates an informative signal by scanning the surface with the tip of the probe) [11-13].

During the measurements, it is necessary to comply with such requirements as ambient temperature, relative humidity, atmospheric pressure, voltage and frequency of the power supply network. In GOST R 8.700-2010, the term “surface roughness (of a solid body)” means a set of surface irregularities with relatively small steps, identified using a scanning frame of a probe atomic force microscope.
The most important condition for measurements with any type of device is the absence of external mechanical vibration.

In the course of a comparative analysis of both the values of the parameters of existing devices and the values of the parameters of devices provided in the standards, we formed Table 3.

### Table 3. Result of a comparative analysis of the parameter values of existing devices and the values of the parameters of devices provided in the standards

| Device                  | Type of device                      | Roughness parameter | Limits of measurement |
|-------------------------|-------------------------------------|---------------------|-----------------------|
| Provided by the standards | contour section device              | Maximum profile height ($R_z$) | 40-320 μm            |
|                         | light section device                |                      | 0.5-40 μm             |
|                         | interference measuring microscope  |                      | 0.05-0.8 μm           |
|                         | interference profilometer microscope|                      | 0.05-0.8 μm           |
|                         | Profiler-profilometer               |                      | Not more than         |
| Modern promising        | 3D Scanning Laser Microscope        |                      | 10 nm                 |
|                         | Profilometer                        |                      | 0.1-400 μm            |

Thus, the study of the regulatory framework regarding the measurement of surface roughness parameters and the existing instruments for measuring these parameters set the following purpose to revise and develop regulatory documentation that would take into account a larger number of surface roughness parameters, including the possible nanoscale of measurements.

## 3. Conclusion

Surface roughness determines many functional properties of parts, affects the quality characteristics of mates, wear resistance of surfaces, etc. Usually a specialist is forced to work with archived technical documentation containing outdated terms of surface parameters.

The article describes the existing standards regulating the measured parameters of roughness and equipment for measuring the parameters of roughness. The comparative assessment of the existing normative documentation regulating the roughness parameters and the instruments for their measurement is given.

### References

[1] Protosenya A G, Verbilo P E, 2017 Notes of the Mining Institute 223 51-57 DOI: 10.18454 / PMI.2017.1.51

[2] GOST R ISO 4287-2014 Geometric characteristics of products (GPS). Surface structure. Profile method. Terms, definitions and parameters of surface structure. Introduction 2016 (Standartinform, Moscow)

[3] GOST 25142-82 Surface roughness. Terms and definitions. Introduction 1983 (Standartinform, Moscow)

[4] GOST 2789-73 Surface roughness. Parameters and characteristics. Introduction 1975 (Standartinform, Moscow)

[5] Zubkova O S, Pashkevich M M 2017 Technique and technologies: ways of innovative development pp 46-50

[6] GOST 9378-93 (ISO 2632-1-85, ISO 2632-2-85) Surface roughness samples (comparison). General specifications 1997 (IPK Publishing house of standards, Moscow)

[7] GOST 27964-88 (ST SEV 6134-87, ISO 4287 / 2-84) Measurement of roughness parameters. Terms and definitions 1990 (Publishing house of standards, Moscow)
[8] GOST 19300-86 Means for measuring surface roughness by the profile method. Contact profilometers-profilometers. Types and basic parameters. Introduction 1987 (Publishing house of standards, Moscow)

[9] GOST R 8.651-2009 GSI. Contact devices (probe) for measuring surface roughness. Calibration method. Introduction 2010 (Standartinform, Moscow)

[10] GOST 9847-79 Optical instruments for measuring surface roughness parameters. Types and basic parameters. Introduction 1981 (Publishing house of standards, Moscow)

[11] GOST R 8.700-2010 GSI. Methods for measuring the effective height of surface roughness using a scanning probe atomic force microscope. Introduction 2010 (Standartinform, Moscow)

[12] Boikov A V, Savelev R V, Payor V A, Erokhina O O 2019 CIS Iron and Steel Review, 17 doi: 10.17580

[13] Gogolinskii K V, Syasko V A, Umanskii A S, Nikazov A A, Bobkova T I 2019 J. Phys.: Conf. Ser. 1384 doi:10.1088/1742-6596/1384/1/012012