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The standards rash – is there a cure?

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Abstract. In recent years there has been a proliferation of proposed specification standards for surface texture measurement and characterisation as part of ISO 25178. This note will discuss the background behind this proliferation and ask whether such a large number of standards is strictly necessary. An alternative framework will be suggested, which should keep the number of standards down to a minimum.

Keywords: Specification standards, surface texture, surface measurement

1 Introduction

In 1982, Whitehouse published a paper entitled "The parameter rash – is there a cure?" in which he put forward the argument that the number of surface texture parameters was becoming too large [1]. Inspired by this example, we offer a similar argument for the current set of published and proposed surface texture specification standards. After reviewing the status of the ISO 25178 series of documents, we reconsider the rationale for creating standards in the first place, and put into question the current trend in document creation, which has the potential for generating over thirty separate parts for ISO 25178 in the near term.

This editorial note represents our views on the subject and aims at stimulating thoughtful reflection and debate among our colleagues in this important and demanding work, especially those involved in preparing and proposing new standards, as well as input from technology developers and the user community. A response from those with different opinions is both desired and encouraged.

2 Background

Surface texture measurement and characterisation has been carried out for well over one hundred years and is now an essential part of modern manufacturing (and many other disciplines) [2, 3]. In many cases, there is an established link between surface texture and the function of a component [4, 5], and a number of techniques mathematically link surface texture with function [6–9]. To control the manufacture of a surface and, therefore, in many cases to control function, a suitable quality system is required, and such a quality system should be backed up by an infrastructure of internationally-recognised specification standards. The International Organization for Standardization (ISO) has been developing such an infrastructure since the 1950s, and published its first standard relating to surface texture in 1966 [10], although there were several national standards published prior to this.

Surface texture specification standards are part of the scope of the ISO Technical Committee 213 (TC 213). This committee deals with Dimensional and Geometrical Product Specifications and Verification (as do many national committees). ISO TC 213 has developed a wide range of specification standards for surface texture measurement for both profiling and areal methods and has an ambitious agenda for future standards.

Up until fairly recently, stylus instruments dominated surface texture measurement by means of the profile method of characterisation (see [2, 3] for historical accounts, and details of stylus instruments and the profile method). TC 213 has developed nine profile-specific standards [3]. These standards are primarily for the stylus method, although they can be adapted to optical methods with a little thought. It is quite feasible to set up a basic quality system only using around four of the profile standards, so there is no standards rash here, at least when only using the basic parameters and filtering method. Note, however, that another rash of filtering standards is being developed as the ISO 16610 series that may confuse this situation in the future. It should be noted that the current ISO plan for surface texture standards is that the profile standards will become a sub-set of the areal standards.

Whereas the profile method may be useful for showing manufacturing process change, an analysis of the areal surface texture provides much more functional information about the surface [7]. There are a number of significant differences between profile and areal analysis. Firstly, whereas it may be possible to use the profile method to

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Table 1. Current status of ISO 25178 areal specification standards. Key: WD – working draft, CD – committee draft, or later stage, of ISO balloting, NS – not started, PS – published standards.

Part	Title	Status	Date
1	Areal surface texture drawing indications	CD	2014
2	Terms, definitions and surface texture parameters	PS	2012
3	Specification operators	PS	2012
4	Comparison rules	NS	–
5	Verification operators	NS	–
6	Classification of methods for measuring surface texture	PS	2010
70	Measurement standards for areal surface texture measurement instruments	PS	2014
71	Software measurement standards	PS	2012
72	Software measurement standards – XML file format	CD	2012
600	Nominal characteristics of areal surface topography instruments	WD	2014
601	Nominal characteristics of contact (stylus) instruments	PS	2010
602	Nominal characteristics of non-contact (confocal chromatic probe) instruments	PS	2010
603	Nominal characteristics of non-contact (phase shifting interferometric microscopy) instruments	PS	2013
604	Nominal characteristics of non-contact (coherence scanning interferometry) instruments	PS	2013
605	Nominal characteristics of non-contact (point autofocus) instruments	PS	2014
606	Nominal characteristics of non-contact (variable focus) instruments	CD	2012
607	Nominal characteristics of non-contact (imaging confocal) instruments	WD	2014
700	Calibration of areal surface measuring instruments	WD	2014
701	Calibration and measurement standards for contact (stylus) instruments	PS	2010

control quality once a machining process is sufficiently stable, problem diagnostics and function prediction often require an areal measurement. Also, with profile measurement and characterisation, it is often difficult to determine the exact nature of a topographic feature. Lastly, an areal measurement will have more statistical significance than an equivalent profile measurement, simply because there are more data points and an areal map is a closer representation of the full surface structure.

In 2002, TC 213 formed working group (WG) 16 to address standardisation of areal surface texture measurement and characterisation methods. WG 16 is developing a number of standards encompassing definitions of terms and parameters, calibration methods, file formats and characteristics of instruments. Several of these standards have been published and a number are at various stages in the review and approval process. All the areal standards are part of ISO 25178, which will consist of at least the parts shown in Table 1 (correct at the time of publication), under the general title Geometrical product specification (GPS) – Surface texture: Areal.

Details of the various parts of ISO 25178 can be found elsewhere [3].

Parts 601 and 701 were published in 2010. Part 601 relates to the metrological characteristics of stylus instruments and part 701 relates to the calibration of stylus instruments. A number of standards have been published or are in preparation related to specific instruments, referred to here as the 6XX series, as indicated in Table 1 as parts 601 through 607. One can readily imagine, given the granularity of the technology selection, that there may be a danger in the future of exhausting the ninety-nine available numerical designations for specific technologies. The 6XX series codifies, for example, phase shifting and coherence scanning interferometers as entirely separate instruments. Focus variation and point autofocus microscopes are similarly distinguished, and there are separate standards for chromatic confocal as opposed to imaging confocal methods. The list does not yet include such well-known methods as wavelength shifting interferometry, optical coherence tomography, moiré interferometry, triangulation, deflectometry, digital holography, speckle interferometry and a host of other methods both current and future. The existence of standards for certain methods may give the impression that any other methods are "not standardised", and not feasible for quality control in production. This may apply pressure to manufacturers of instruments, using technologies that are not yet explicitly given a place in the standards infrastructure, to have their method "standardised". Together with the fact that each of these techniques has subclasses and divisions, this potentially leads to a high number of individual standards for any technique, requiring years of effort without significant added value.

3 When should we write a standard?

At the present chapter in the story, it is worth taking a look at the primary purposes of a standard. The following are the most common reasons for producing a standard [11,12]:

- to define terms that are not used elsewhere or where there may be some ambiguity;
- to provide a way of specifying the performance of an instrument that is manufacturer-independent;
- to detail a method for demonstrating that an instrument meets its specification;
- in some cases to make sure an instrument is safe to use;

– it might suggest how an item should be manufactured (e.g. gauge blocks) and specify grades of instrument; and
– it might suggest how the performance is monitored after installation (re-verification and interim checks).

As corollaries to these propositions, most would agree that well-founded standards documents are:

– concise;
– widely accessible;
– timely (up to date);
– devoid of extraneous material;
– neutral to specific technologies, artefacts or manufacturers; and
– open to continued technological progress by avoiding the unnecessary codification of mandatory methods or procedures.

To summarise, we would argue that the proliferation of unnecessarily lengthy or multi-volume standards reduces their accessibility, given their cost, time to prepare and publish, and density of additional information best treated elsewhere. Also it may give the impression that any technology not explicitly mentioned is "not standardised" and lacks validity.

4 Standards rash – the 6XX series

With these points in mind, the 25178-6XX and proposed -7XX series of documents (see later) merit review. Serious work has gone into preparing the instrument-specific 6XX series, including high-quality informative sections that read like authoritative review articles. In the development of these documents, common features have emerged related to terms and concepts worthy of standardisation. Several members of TC 213 proposed a simplification, in which a unified set of metrological characteristics that were instrument-independent would provide a core set of terminology and concepts that would appear in 25178-600 and would be echoed in all of the 6XX series documents. Three published papers provide the basis for this set of metrological characteristics [13–15], and with a little adjustment these ideas were adopted by WG 16 in 2010.

There is continued refinement of the metrological characteristics, particularly for lateral resolution and the non-linear nature of many instruments (currently referred to as "topography fidelity" [16]), but there is now one part 600 at the draft international standard stage that covers the metrological characteristics of all areal surface topography instruments, be they optical, mechanical, or any future method with a comparable set of targeted measurands. Part 600 further clarifies terminology found in the VIM [17] or GUM [18] in the context of topography measurement, up to the limit of avoiding unnecessary duplication. Additional published work has illustrated the effectiveness of using the common metrological characteristics found in part 600 for the development of an instrument-specific list of performance specifications [19].

What, then, is the additional added value today of the instrument-specific 6XX series beyond part 600? The answer is:

– a handful of instrument-specific terms;
– informative (as opposed to normative) theory and example sections; and
– a list of influence quantities related to the metrological characteristics.

We shall evaluate these points one by one.

The value of instrument-specific terms is debatable. As an example, it is not clear that it matters, from the standards perspective, whether we refer to a feature of a white-light interference signal as the contrast envelope, the modulation function, the fringe visibility, or the degree of mutual coherence. The most useful technical term will emerge from usage in scholarly papers, according to the context of the instrument study. It is not a great concern to the instrument user, while at the same time it is unlikely that a scientist would care about official ISO terminology when describing theoretical measurement principles. Further, instrument-specific terminology evolves as research advances, and contemporary instruments will have variations in the operation, hardware or software that frustrate the alleged standardisation of instrument terminology. Indeed, given the length of time that it takes to approve a standard, it seems inevitable that some of the instrument-specific terminology is almost certainly be out of date at the moment of publication. A manufacturer may also choose to measure or process data in a proprietary way that is not disclosed and so cannot be captured by a standard. Terms that are likely to endure, such as numerical aperture, are now incorporated in part 600. Any later 6XX standards will not include them, and the 6XX standards published earlier will be modified to eliminate them.

A similar argument applies to the theoretical review portions of the instrument-specific 6XX series – the theory is almost surely lagging the state of the art when published by ISO, unless it is so well established that it is already integrated into existing published journal articles and textbooks. In any case, the historical precedent established by previous standards work does not support the idea of publishing theoretical review articles as major components of ISO standards. Nowhere in [11] (or [12]) is it suggested that the theory of an instrument should be standardised.

The 6XX series does provide potentially useful compilations of influence factors that may be instrument specific. For example, although topographic lateral resolution is the general metrological characteristic for all areal surface topography instruments, the optical imaging lateral resolution and camera sampling may be recognised as optics-specific factors that relate to topographic lateral resolution, as illustrated in Figure 1. However, the most significant and defensible listing of such factors is, or should be, in part 600, either as standardised terminology or as examples to clarify the meaning of an influence factor as it relates to the general metrological characteristics.

Finally, given that the existing and proposed set of 6XX series documents will always be incomplete with

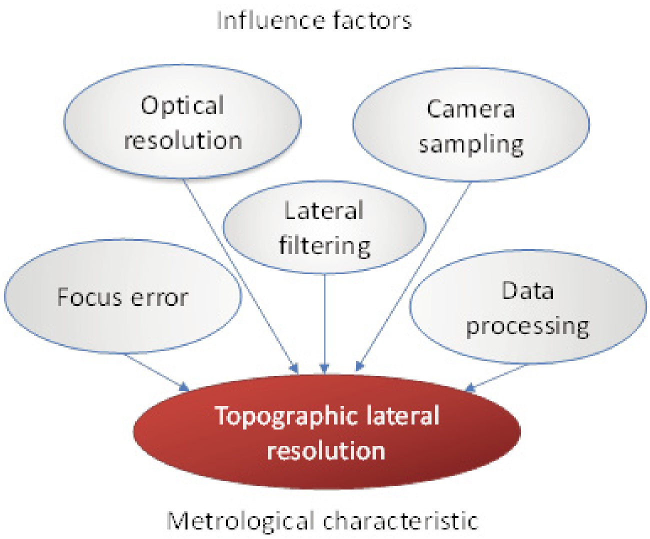

Fig. 1. Relationship of instrument specific factors to a metrological characteristic, in this case, for topography lateral resolution in optical 3D metrology.

respect to the universe of possible instrument technologies applicable to areal surface texture measurement; we should take a moment to question the basic logic of this series. If properly crafted, ISO 2518-600 should allow us to specify and verify the performance characteristics of technologies yet to be recognised by TC 213 as deserving of standardisation. As an example, we could test moiré interferometry against part 600 to see if it fits within the general scheme of things. If it does, then there is no need for a special standard for this technology. If it does not, we need to fix part 600 since there are no plans today to cover moiré interferometry in a specific document. Either way, the concept of instrument-specific standards is questionable.

5 Standards pandemic – the 7XX series

Having brought into question the multi-volume 6XX series, we now move to what has the potential to be an even greater proliferation of unnecessary and possibly damaging standards.

ISO 25178 part 700 is at the committee draft stage and concerns the calibration and performance verification of surface texture instruments. Part 700 will outline how to determine the metrological characteristics listed in part 600. Performance verification will not be discussed here – the concept with regards to surface texture measurement is still not clear and needs much more discussion. The most recent draft of part 700 describes methods to determine the metrological characteristics using material measures (otherwise known as calibration or transfer artefacts). Although this is a useful set of examples of how to perform this kind of calibration, the language of part 700 includes repeated uses of the phrase “shall be” in normative sections that seem to imply that no other approach to calibration is acceptable to ISO and is invalid. There is a danger that issuing this standard will have the unintended consequence of freezing technology to a fixed point of time, prohibiting innovative methods and procedures on the grounds that they are “not in the standards”.

An example of the danger presented by part 700 is the calibration of the amplification coefficient – a metrological characteristic defined in part 600 related to the scaling factor for height measurements. Part 700 is likely to stipulate the use of traceable step height standards to calibrate the axial response [14]. However, there are many other ways to calibrate the amplification coefficient. A simple example is a Fizeau interferometer employing a HeNe laser light source [20, 21]. Another example is a moving platform that can generate any step height or periodic pattern, with a displacement that is measured directly traceable to primary wavelength standards [22]. It would be senseless to adjust such an instrument to match exactly the stated value for a mechanical step height standard, or use a mechanical step height standard that is calibrated elsewhere, as this would only degrade the uncertainty. Likewise, many instruments include built-in calibrations using capacitance gauges or even laser interferometers [23, 24]. For other metrological characteristics, there are opportunities for self-calibration using reversals, averaging and other techniques, without relying on any sort of traceable artefact [25].

An approach to solving the problem of diverse calibration methods would be to enumerate every possible “recognised” method of calibration for all of the metrological characteristics. This would be a significant task that would always fall short. Alternatively, and more realistically, ISO should provide informative guidance on how to calibrate an instrument, including specific informative (as opposed to normative) examples. Mandating specific techniques could lead to disputes as one type of commercial material measure is favoured over another. There are many different ways of determining each type of metrological characteristic and, provided they can be demonstrated as effective and suitable uncertainties estimated, they are all equally valid if consistent with the GUM.

It has also been proposed in TC 213 that there should be instrument-specific standards on how to calibrate and verify instrument performance for each of the available technologies related to surface form and texture analysis. Given the now questionable purpose of the 6XX series with the benefit of hindsight, we should learn from history and have the foresight to abandon the idea of a 7XX series before it has a chance to gain momentum.

6 Summary

When developing standards, we primarily need to consider what the industrial user wants. They will not appreciate long lists of standards and lengthy technical descriptions. Also, optics is a difficult subject and most users do not understand it (especially complex nuances such as transfer). We could produce succinct, helpful standards that are independent of the operation of the instrument, not complex technical descriptions of instruments with myriads of terms and influence quantities. Standards are expensive. We should produce the minimum number of standards that cover all that is necessary to make "standard" measurements.

The following, for the sake of discussion and refinement, is one possible path forward:

1. Complete ISO 25178 part 600 – it is currently a draft international standard and has to be reviewed by industry before being published as a standard.
2. Finalise and publish 601 to 607, given the many hours of work already invested in these documents.
3. Stop the further proliferation of 6XX series standards and do not add any more instrument-specific documents. Revised versions of these documents should fully incorporate and in turn, inform part 600 if there are deficiencies in the latter.
4. Continue part 700, but with any specific techniques for calibration being informative examples rather than inflexible, normative mandates.
5. Stop work on the 7XX series until it is clear what its purpose is or if it is required at all.

The fight against the standards rash is a lonely fight. The natural tendency of standards committees is to produce more standards. But, perhaps in this instance, we need to take a step back, look at the bigger picture and produce a small number of useful standards that can be accepted by everyone.

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