国外电子信息精品著作（影印版）

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Optical Measurement of Surface Topography

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内 容 简 介

本书介绍了表面形貌测量领域中一系列国际标准规范。复杂的准则都是基于新的测量技术而产生的。目前有很多用来测量表面形貌新的光学技术，每种方法都有其优点以及局限性。本书既适用于业界及学术研究领域的工程人员，也适用于相关领域的研究生及高年级本科生。

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《国外电子信息精品著作》序

20世纪90年代以来，信息科学技术成为世界经济的中坚力量。随着经济全球化的进一步发展，以微电子、计算机、通信和网络技术为代表的信息技术，成为人类社会进步过程中发展最快、渗透性最强、应用面最广的关键技术。信息技术的发展带动了微电子、计算机、通信、网络、超导等产业的发展，促进了生命科学、新材料、能源、航空航天等高新技术产业的成长。信息产业的发展水平不仅是社会物质生产、文化进步的基本要素和必备条件，也是衡量一个国家的综合国力、国际竞争力和发展水平的重要标志。在中国，信息产业在国民经济发展中占有举足轻重的地位，成为国民经济重要支柱产业。然而，中国的信息科学支持技术发展的力度不够，信息技术还处于比较落后的水平，因此，快速发展信息科学技术成为我国迫在眉睫的大事。

要使我国的信息技术更好地发展起来，需要科学工作者和工程技术人员付出艰辛的努力。此外，我们要从客观上为科学工作者和工程技术人员创造更有利于发展的环境，加强对信息技术的支持与投资力度，其中也包括与信息技术相关的图书出版工作。

从出版的角度考虑，除了较好较快地出版具有自主知识产权的成果外，引进国外的优秀出版物是大有裨益的。洋为中用，将国外的优秀著作引进到国内，促进最新的科技成就迅速转化为我们自己的智力成果，无疑是值得高度重视的。科学出版社引进一批国外知名出版社的优秀著作，使我国从事信息技术的广大科学工作者和工程技术人员能以较低的价格购买，对于推动我国信息技术领域的科研与教学是十分有益的事。

此次科学出版社在广泛征求专家意见的基础上，经过反复论证、仔细遴选，共引进了接近30本外版书，大体上可以分为两类，第一类是基础理论著作，第二类是工程应用方面的著作。所有的著作都涉及信息领域的最新成果，大多数是2005年后出版的，力求" 层次高、内容新、参考性强"。在内容和形式上都体现

了科学出版社一贯奉行的严谨作风。

当然，这批书只能涵盖信息科学技术的一部分，所以这项工作还应该继续下去。对于一些读者面较广、观点新颖、国内缺乏的好书还应该翻译成中文出版，这有利于知识更好更快地传播。同时，我也希望广大读者提出好的建议，以改进和完善丛书的出版工作。

总之，我对科学出版社引进外版书这一举措表示热烈的支持，并盼望这一工作取得更大的成绩。

王越

中国科学院院士

中国工程院院士

2006年12月

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1 Introduction to Surface Texture Measurement

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Abstract. This chapter introduces some of the concepts used in the measurement and characterisation of surface texture that will be used throughout the rest of the book. A short history of optical measurement techniques will be given, followed by descriptions of surface profile and areal surfaces. How surface texture sits within the ISO Geometrical Product Specification is discussed along with the current position with surface texture specification standards. Non-optical and optical surface texture measurement instrument types are summarised and some general advice is given on instrument choice.

1.1 Surface Texture Measurement

Surface texture plays a vital role in the functionality of a component. It is estimated that surface effects cause 10 % of manufactured parts to fail and can contribute significantly to an advanced nation's GDP. In the last century, surface texture was primarily measured by a method that involved tracing a contacting stylus across the surface and measuring the vertical motion of the stylus as it traversed the surface features. In most cases only a single line, or surface profile, was measured and this gave rise to enough information to control production, but was limited to identifying process change. Optical instruments closely followed the development of stylus instruments and had the benefit of being non-contact and potentially faster than stylus instruments (see Leach 2009 for a short history of surface texture measurement and Hume 1980 for a more thorough history of engineering metrology).

In the early and middle of the twentieth century several different optical instrument designs were developed for measurement of surface texture and form. These included conventional Michelson and Twyman-Green interferometers (Leach 2009), Schmalz light sectioning microscopes (Schmalz 1929), Linnik microinterferometers (Miroshnikov 2010), Tolansky multiple beam interferometers (1960), and fringes of equal chromatic order (FECO) interferometers (Bennett 1976). The interferometers produced very good fringe images that accurately tracked the peaks and valleys of the surface texture with high vertical resolution. However, it was not until the development of high speed computing that the analysis of fringes could be automated to the point where digitised topography profiles and images could be produced in an automated way that could enable optical instruments to rival the usefulness of stylus instruments. The first of these was the phase shifting interfereometric (PSI) microscope in the early 1980s (Bhushan et al. 1985, Greivenkamp and Bruning 1992, see Chap. 8), which was primarily useful for measurement of smooth optical surfaces. This was followed in the early 1990s by the coherence scanning interferometric microscope (Caber 1993, Deck and de Groot 1994, see Chap. 9), also called the vertical scanning interferometer or scanning white light interferometer, which was aimed at overcoming the roughness limitations of the PSI technique. The success of interferometric microscopes was matched by confocal microscopes (Schmidt and Compton 1992, see Chap. 11) in the 1990s. Nowadays, these two types of instruments dominate the market for optical surface topography instruments, but a number of other techniques have been developed as well. Many of these different types of optical instruments are discussed in the remaining chapters of the book.

1.2 Surface Profile and Areal Measurement

Surface profile measurement is the measurement of a line across the surface that can be represented mathematically as a height function with lateral displacement, $z(x)$. Areal surface texture measurement is the measurement of an area on the surface that can be represented mathematically as a height function with displacement across a plane, $z(x,y)$. Surface texture characterisation, both profile and areal, are not discussed here – this book concentrates on the methods used to capture areal surface texture data. The subsequent characterisation methods are presented in detail elsewhere (Whitehouse 2010, Leach 2009, Muralikrishnan and Raja 2008).

1.3 Areal Surface Texture Measurement

Over the past three decades there has been an increased need to relate surface texture to surface function and, whilst a profile measurement may give some functional information about a surface, to really determine functional information, a three dimensional (3D), or areal, measurement of the surface is necessary. Control of the areal nature of a surface allows a manufacturer to alter the way a surface interacts with its surroundings. By controlling the areal nature of a surface optical, tribological, biological, aerodynamic and many other properties can be altered (Evans and Bryan 1999, Lonardo et al. 2002, de Chiffre et al. 2003, Bruzzone et al. 2008).

The measurement of areal surface texture has a number of benefits over profile measurement (Blunt and Jiang 2003). Areal measurements give a more realistic representation of the whole surface and have more statistical significance. There is also less chance that significant features will be missed by an areal method and the manufacturer, therefore, gains a better visual record of the overall structure of the surface. The need for areal surface texture measurements resulted in stylus instruments that could measure over an area (a series of usually parallel profiles) and optical techniques. Optical instruments either scan a beam over the surface akin to stylus instruments, or take an areal measurement by making use of the finite field of view of a microscope objective. There are currently many commercial instruments that can measure areal surface texture, both stylus and optical (see Sect. 1.5).

1.4 Surface Texture Standards and GPS

Surface texture documentary standards are part of the scope of the International Organization for Standardisation (ISO) Technical Committee 213 (TC 213), dealing with Dimensional and Geometrical Product Specifications and Verification as well as many national committees. ISO TC 213 has developed a wide range of standards for surface texture measurement for both profiling and areal methods and has an ambitious agenda for future standards. Some of these standards are listed below.

1.4.1 Profile Standards

There are nine ISO specification standards relating to the measurement and characterisation of surface profile. These standards only cover the use of stylus instruments. The details of most of the standards are presented in Leach (2001) and summarised in Leach (2009), and their content is not discussed in detail in this book. It should be noted that the current ISO plan for surface texture is that the profile standards will become a sub-set of the areal standards. Whilst the basic standards and details will probably not change significantly, the reader should keep abreast of the latest developments in standards. The following is a list of the profile specification standards as they stand at the time of writing of this book:

- Nominal characteristics of contact (stylus) instruments (ISO 3274, 1996)
- Rules and procedures for the assessment of surface texture (ISO 4288, 1996)
- Metrological characteristics of phase correct filters (ISO 11562, 1996)
- Motif parameters (ISO 12085, 1996)
- Surfaces having stratified functional properties — filtering and general measurement conditions (ISO 13565 part 1, 1996)
- Surfaces having stratified functional properties — height characterization using material ratio curve (ISO 13565 part 2, 1998)
- Terms, definitions and surface texture parameters (ISO 4287, 2000)
- Measurement standards — material measures (ISO 5436 part 1, 2000)
- Software measurement standards (ISO 5436 part 2, 2000)
- Calibration of contact (stylus) instruments (ISO 12179, 2000)
- Surfaces having stratified functional properties — height characterization using material probability curve (ISO 13565 part 3, 2000)
- Indication of surface texture in technical product documentation (ISO 1302, 2002)

Note that there is only one specification standard (ISO 25178: 602 2011) that relates to the measurement of surface profile using optical instruments. However, in many cases where a profile can be mathematically extracted from an areal optical scan, the profile characterisation standards can be applied. It is important, however, to understand how the surface data is filtered, especially when trying to compare contact stylus and optical results (Leach and Haitjema 2010).

1.4.2 Areal Specification Standards

In 2002, ISO technical committee 213 formed a working group (WG) 16 to address standardisation of areal surface texture measurement methods. WG 16 is developing a number of draft 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. The plan is to have the profile standards as a sub-set of the areal standards (with appropriate re-numbering). Hence, the profile standards will be re-published after the areal standards (with some omissions, ambiguities and errors corrected) under a new numbering scheme that is consistent with that of the areal standards. All the areal standards are part of ISO 25178, which will consist of at least the following parts, under the general title Geometrical product specification (GPS) — surface texture: areal:

- Part 1: Areal surface texture drawing indications (2011)
- Part 2: Terms, definitions and surface texture parameters (2011)
- Part 3: Specification operators (2011)
- Part 4: Comparison rules
- Part 5: Verification operators
- Part 6: Classification of methods for measuring surface texture (2010)
- Part 70: Measurement standards for areal surface texture measurement instruments (2011)
- Part 71: Software measurement standards (2011)
- Part 72: Software measurement standards – XML file format (2011)
- Part 601: Nominal characteristics of contact (stylus) instruments (2010)
- Part 602: Nominal characteristics of non-contact (confocal chromatic probe) instruments (2010)
- Part 603: Nominal characteristics of non-contact (phase shifting interferometric microscopy) instruments (2011)
- Part 604: Nominal characteristics of non-contact (coherence scanning interferometry) instruments (2011)
- Part 605: Nominal characteristics of non-contact (point autofocus) instruments (2011)
- Part 606: Nominal characteristics of non-contact (variable focus) instruments (2011)

- Part 607: Nominal characteristics of non-contact (imaging confocal) instruments (2011)
- Part 700: Calibration of non-contact instruments (2011)
- Part 701: Calibration and measurement standards for contact (stylus) instruments (2010)

At the time of writing, a general standard on the calibration of all areal surface topography measuring instruments is being drafted, but is not yet a committee draft. The American National Standards Institute has also published a comprehensive documentary specification standard, ANSI/ASME B46.1 (2010) that includes some areal analyses (mainly fractal based).

1.5 Instrument Types in the ISO 25178 Series

ISO 25178 part 6 (2010) defines three classes of methods for surface texture measuring instruments (and see Fig. 1.1):

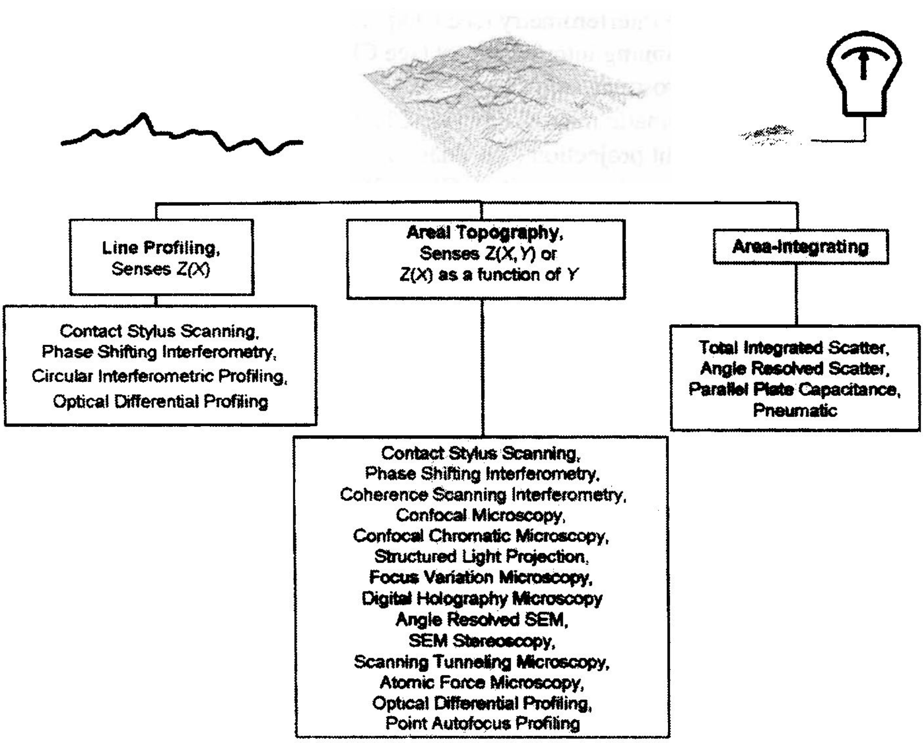

Fig. 1.1 A classification of surface texture measurement methods with examples, excerpted with permission (ISO 25178-6 2010)