The Closing Gap Between Dimensional and Surface Metrology

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The fields of dimensional and surface metrology have evolved through many centuries and many cultures. For the most part the changes in metrology have been driven by changes in the user's needs. Recently, the users of metrology have been pushing the field to become more generalized. This is shown in the development and advancement of general-purpose instruments such as CMM's as well as in the increasing capabilities of many other instruments once considered "special purpose".

This presentation looks at the field of metrology from historical, technological and economic perspectives in light of the current trend toward "harmonizing" the fields contained under the heading "metrology".

Introduction

The field of metrology has undergone many changes in its evolution. Many of these changes have been the result of the "demands of the time" and as a result, metrology technology has been closely connected to the "user technology". In most cases this has driven the development of specialized measurement technology – well suited for a given task.

In more recent years, there has been an increased emphasis on expanding the capabilities of measuring equipment. Instruments that were once used for measuring roughness are now measuring dimension. Instruments that once measured only dimension are now measuring form; and so on[1]. In the context of dimensional measurement, the most significant aspect is related to the measurement of surfaces and dimension. These two areas – dimensional and surface metrology, while sharing many common principles have had very little interaction in the past. However this culture is rapidly changing.

These changes can once again be attributed to changes in the culture in which metrology is applied. This presentation looks at this change or evolution "metrology culture" from historical, technological and economic perspectives and provides some insight into the future of metrology in the *information age*.

Instrument Origins

Historically, measurement technology has followed the user's technological needs. For example, in the time of the construction of Egyptian Pyramids, the cubit (and maintenance thereof) was adequate for the purpose. As technological demands increased, so did the demands on metrology[2]. In many cases and this has lead to a sort of *technology leapfrogging* – whereby product or manufacturing technology advances require measurement advances and measurement advances spawn further advances in product or process technology.

More recently, however, these technological needs are being considered alongside other needs such as *cost*, *ease of use*, *maintenance*, *up time* and *speed*. Thus, in many regards, the instrument drivers have historically been *technological* in nature whereas in today's marketplace technology is only one of the elements.

Instrument Overlaps

Historically, an instrument served one basic purpose: length-measuring instruments measured *length*, roughness instruments measured *roughness* and so on. However, advances in instrument technology have increased the *bandwidths* of most of today's metrology equipment. This has resulted in significant overlaps between the technologies.

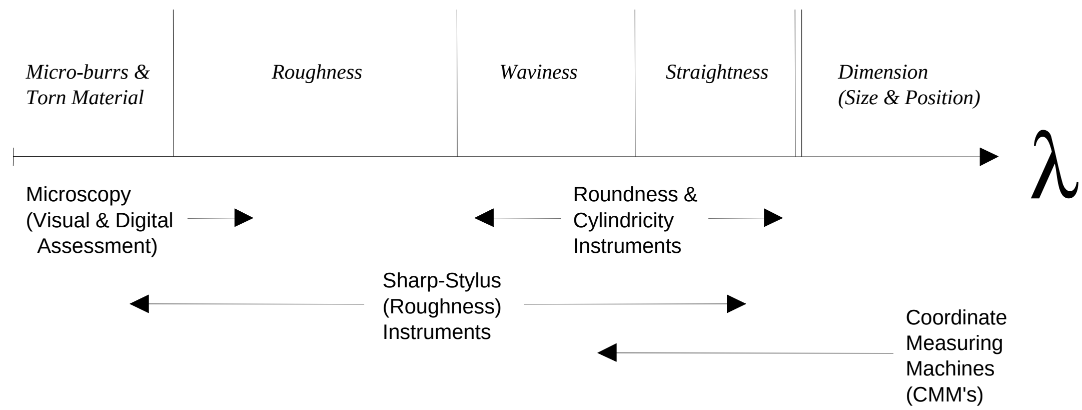

Figure 1. Instrument overlaps.

As an example of these overlaps, consider the measurement of *straightness*. There are many measurement approaches – ranging from small stylus roughness instruments to large-scale interferometric that will yield some kind of straightness. In many cases, these different measurement approaches have followed very different development and standardization paths, but they are, nonetheless, reporting the same measurand: "straightness".

Industrial Optimizations

Metrology is, in many regards, a "customer led" field as it can only provide data that used for some subsequent application. As a result, advances in metrology are mostly provoked by the culture of the metrology customers. Today's manufacturing and product development environment continues to be one of ever-shrinking tolerances. Thus, there is a corresponding push in the metrology field for lower and lower measuring uncertainties. Furthermore, the design community has continued to move dimensional tolerancing schemes in to smaller and small features[3, 4] (for example, micro-electronics and semi-conductors) and surface tolerancing schemes into larger and larger applications (for example, boat hulls and airplane wings.).

In addition to these technological issues, metrology faces another (perhaps *new*) major challenge in the current environment – that being one of "economics". In considering today's metrology user-base, we find many companies that are built upon manufacturing or producing some kind of "physical" good or product. However, the current economic trends indicate that this type of company (in very broad, general terms) is not receiving the attention of the fast moving internet-based or "dot-com" companies. This has driven the management of many metrology users to more carefully scrutinize the purchase of metrology equipment and the time spent using such equipment. After all, many business models consider activities such as measurement to be "non-value added"!

Information Overload

We a currently being bombard with more and more information in every aspect of our lives. This is typical of the abundance of television news channels with endless streams of "ticker" information as well as with the unimaginable size of the Internet. The field of metrology is also a party in the production of what has been coined as an "Information Overload"[5].

In the metrology context, the earliest origin of this "Information Overload" can be associated with the incorporation of computers into measurement equipment. Increased computation capabilities have made it possible to produce many different results based on a single, physical measurement. In addition, recent advances in data storage have made it possible measure more data points and compute still more results. In the end, the customer is often faced with a rather intimidating task of looking for the measurement result that actually means something relative to his task at hand. The customer of nearly every measurement technology faces this problem.

Improvement Opportunities

As the field of metrology considers its past, present and, more importantly, its future, we should recognize that metrology is an "enabling technology". Developments in metrology don't often have a direct impact on the daily lives people or society. However, developments in metrology can have a direct impact on areas such as medicine, transportation and communication. With this in mind, we in metrology can have the biggest impact in areas where we are best understood and applied. Thus, we must be able to provide measurement technologies suited for customer applications and we must be able to interact with users based on their needs rather than based on our technology. This will in most cases require education – on the part of both the customer and supplier.

"Harmonization"[6, 7] has been somewhat of a buzzword of the last few years and this is an essential topic for metrology. The customer of metrology does not care primarily about roughness, form or dimension – his concern is focused on his product or process. The metrology standardization community needs to accommodate this thinking as well as the instrument providers and in the end we need to come to a point where we have one "language" of measurement.

Finally, the metrology community must actively pursue collaboration between its various disciplines. This presents a precarious situation in that "*collaboration"* is often avoided due to fears of *"competition"*. Competition must be maintained, as it is a catalyst for advancement. However, collaboration is required to ensure that we are speaking the same language and providing comparable results. Ultimately, collaboration grows the metrology customer base – whereas the lack of collaboration can fragment it.

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