Extended Abstract:

Dimensional Metrology For Functional Control

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Mark C. Malburg, Ph.D.
mcmalburg@digitalmetrology.com
Digital Metrology Solutions, Inc.

The slides for this presentation can be found at:
www.digitalmetrology.com

In today's engineering settings, metrology, while being a valuable tool is, is commonly misunderstood and more commonly; is misapplied. This paper explores the role and value of dimensional metrology in the design, development and production of mechanical components in the 21st century. The paradigm of "metrology of function" is explored in the context connecting measurement data to functional performance.

Introduction

The typical role of dimensional metrology in industrial settings it is to determine the size or shape of some component. This measurement process is usually conducted with a "tolerance related" question in mind: Will this part meet my tolerances? What should my tolerance be based on this prototype? These tolerances are established as a means of controlling some "function", however the connection between "function" and "tolerances" is often difficult to establish.

In many subtle ways, two distinct thought processes are present:

1. The concept of "functionality" – how well will the part work.
2. The concept of "control" – the dimensional measurements of the part to ensure that it is properly produced.

The "Languages" of Engineering

One of the fundamental gaps between *functionality* and *control* is that these concepts each speak a different language. The "language of function" is a language of "verbs":

Will it <u>seal</u>?

Will it <u>fit</u>?

Will it <u>slide</u>?

Will it <u>vibrate</u>?

Will it <u>last</u>?

The terms used in functionality are terms related to either static or dynamic physical phenomena. Functionality is based on some kind of performance and performing is based on some kind of “action”.

However the language of dimensional metrology is a language of adjectives – describing:

It is a <u>big</u> part.

It is a <u>rough</u> part.

It is a <u>bent</u> part.

It is an <u>out-of round</u> part.

The terms used in dimensional metrology are typically “length-based” terms. Thus, these “length-based terms” are typically rather static in nature. The “action” of the component or the “interaction” with other components is not usually considered in the measurement of a component.

The “Metrology of Function”

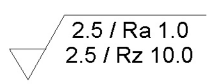
In geometric dimensioning and tolerancing we have a variety of measurands. Unfortunately, “sealing”, “contact pressure” and “friction” aren’t provided. Nonetheless, these performance-related measurands are actually what is required in the design of systems. The difficulty is in translating these functional requirements into dimensional attributes.

In some cases the translation of functional requirements into dimensional attributes requires many assumptions and the resulting tolerances may allow for the acceptance of some bad parts as well as the rejection of some good parts. What is needed, in some critical areas, is a more direct means of specifying function – without the intermediate step of dimensional tolerancing. These specifications would take on the form

“Cross-sectional leakage area must be less than X.XX $\mu m^2/mm$*”*

Rather than the traditional straightness and roughness callouts:

–	0.010



It should be noted that reference dimensions could be provided to support these function-based callouts. Thus providing a dimensional “starting point” for process development. However, ultimate product acceptance could be based on the functional requirements.

From a metrological standpoint, this paradigm shift would require the following elements:

The integration of functional modeling into the measurement system.
- This would also drive measurement system requirements such as sampling, filtering, etc.

The establishment and introduction of model parameters
- For example, pressures, temperatures, etc.

The standardization or at least “validation” of processing methods
- For example, an estimation of *model* uncertainty as well as *measurement* uncertainty.

Examples

Gasket Sealing:

Description:
A conformable component (gasket) is in contact with a rigid surface. Leakage must be controlled through the controlling surface and geometry of the rigid surface.

Measurand:
The leakage area between the gasket and the surface.

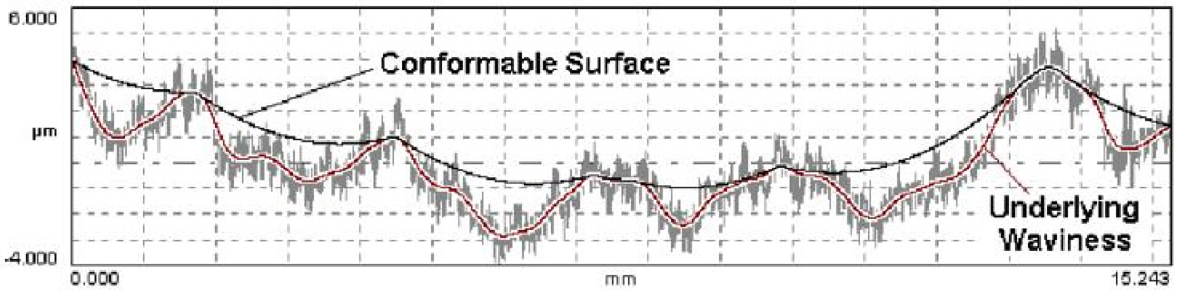


Figure 1.   *Conformable surface (e.g. gasket) sealing.*

Ball & Socket Loading/Contact:

Description:
A spherical ball is located in a “gothic arch” (i.e. offset radius) socket. The contact locations must be controlled.

Measurand:
The contact angles of a ball placed in the socket.

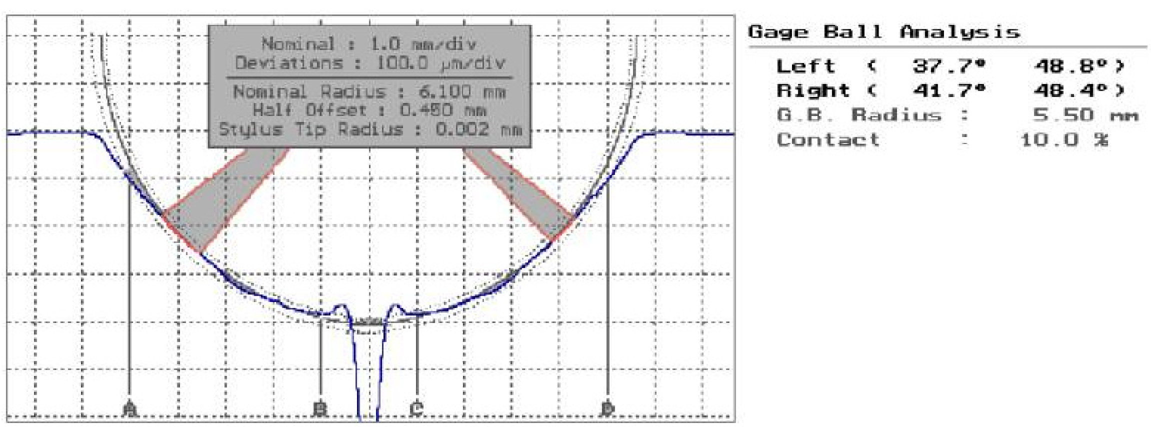


Figure 2.   *Ball & socket contact.*

Bushing conformability to rigid pin:

Description:
A semi-rigid bearing is in contact with a rigid pin. Localized waviness generates highly stressed areas.

Measurand:
Middle-wavelength waviness.

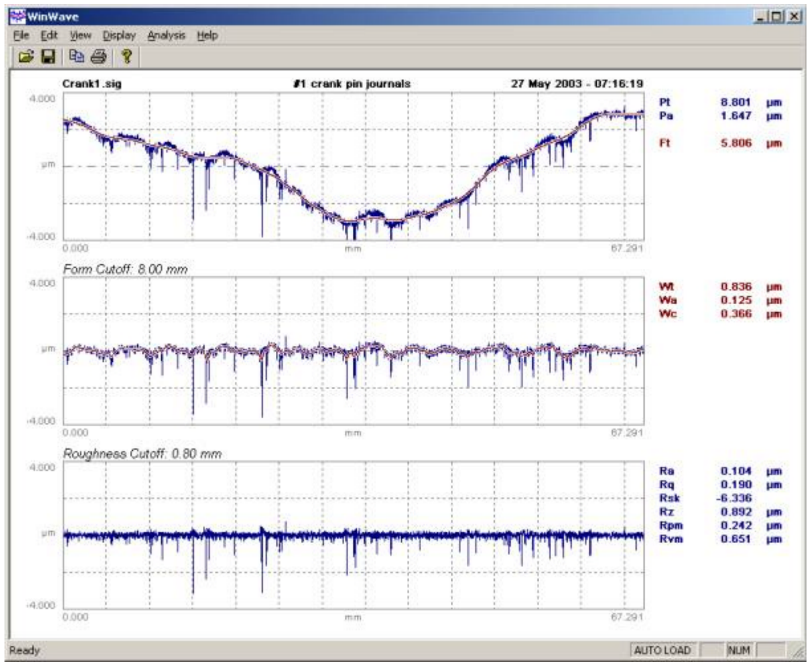


Figure 3. *Semi-rigid bushing sensitivity.*

Roller Contact Stress:

Description:
Crowned rollers are common used in highly stressed interfaces. The crown geometry must be controlled in order to reduce stress concentrations.

Measurand:
Maximum local contact stress under operating conditions.

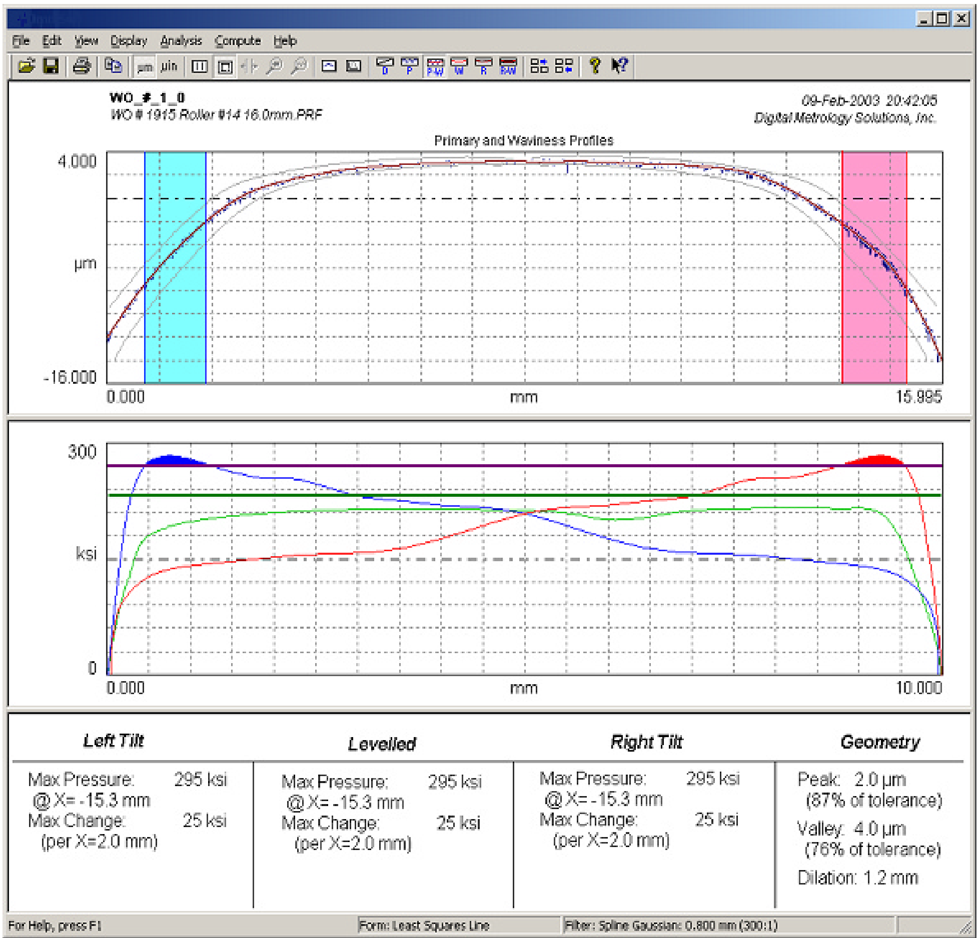


Figure 4. Local contact stress analysis.

Summary

For dimensional metrology to become more useful and thus more valuable to the engineering world, dimensional metrology must learn to "speak the language" of its customers. The measurement equipment of today provides an incredible amount of data concerning the measured component, however if that data cannot be translated into functional information, the data will never provide its full value. The next logical step for the field of metrology is to begin applying the appropriate analyses to the data in order to begin answering "*the functional questions that are being asked*" and answering them in the "*language of function*".