Managing uncertainty in the new manufacturing era

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Abstract

The new manufacturing era is characterized by a relevant shift of manufacturing from the physical to the digital world. In this context the proper management of product and manufacturing information is fundamental. The CIRP CAT provides a technical forum for researchers, industrial practitioners, and policy makers to exchange ideas, share research findings, and discuss the various issues in the fields of dimensional and geometrical tolerancing, dimensional metrology, uncertainty management, standardization.

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1. Introduction

The new manufacturing era, that we may name Smart Manufacturing, Intelligent Factory, or Industry 4.0, is characterized by a relevant shift of manufacturing from the physical to the digital world, so that products exist in the memory of computers before, in parallel, and after the existence of their physical counterparts. The main actors of this shift are the Cyber-Physical Systems (CPS), which are systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the Internet [1]. The application of the CPS in manufacturing are named Cyber-Physical Production Systems (CPPS).

In this context the proper management of product and manufacturing information is fundamental. Among this, in the field of mechanical engineering, dimensional and geometric tolerances are the most relevant, in order to properly deal with uncertainty from the conception to the end of life of a product [2–4].

This is the motivation of the scope of the 15th CIRP CAT, where the management of the uncertainty in whole manufacturing is considered. In particular, the link between product geometrical specification and its verification is fundamental, because, if manufacturing opens the loop by converting digital parts into physical parts, geometrical verification closes the loop by turning physical parts into information. The CIRP Conference on Computer Aided Tolerancing focuses on the progress in the fields of dimensional and geometrical tolerancing, dimensional metrology, uncertainty management, standardization. It provides a technical forum for researchers, industrial practitioners, and policy makers to exchange ideas, share research findings, and discuss the various issues they encounter. The CIRP CAT refers to the Scientific Technical Committee Design (STC Dn) of the International Academy for Production Engineering (CIRP), who has been supporting contributions in the areas of design theories, methodologies, IT tools and their practical applications over the past decades.

From this starting point, the CIRP CAT 2018 conference has been focused on:

- Robust Design and Uncertainty
- Functional Tolerancing
- Tolerance Specification
- Tolerance Analysis
- Form Deviation in Tolerance Analysis
- Actual Mating Conditions
- Tolerance Verification
- Quality
- Additive Manufacturing
- Micro-Manufacturing

In the following three of these main topics are highlighted as special one for the CIRP CAT 2018.

1.1. Robust Design and Uncertainty

Robust Design is a well-acknowledged design approach that strives for designing products, devices and production equipment so that their performance and function is insensitive to the variability and uncertainty inherent in manufacturing, as-
1.2. Additive Manufacturing: A new challenge

It is well established that additive manufacturing (AM) is a historical breakthrough in manufacturing and deeply impacts the overall design and manufacturing process chain as well as the entire life cycle of a product [5]. The greater benefits of AM come from the fact that by adding material point-to-point and layer-by-layer, it is possible to control both the shape and material complexity of a product. This complexity for free requires alterations to current methods to describe and communicate complex design. This need is particularly true and well recognized with respect to the development of methods to tolerance complex freeform surfaces [6]; to communicate and tolerance heterogeneous materials and internal features; and to verify dimensioning and tolerancing requirements of the additively manufactured parts.

1.3. Micro-Manufacturing: Specification and Verification

Nowadays, many manufacturing processes are available capable of manufacturing components whose size is well below 1 mm. However, the correct definition and inspection of such components is still a difficult task: at micro-scale level the geometry of the part influences the functionality not only in terms of mating and movement. Then, the question arises whether or not the current GD&T and GPS practices are still adequate [7]. Therefore, new techniques for tolerance analysis, synthesis, and allocation are needed. Verification also needs to be harmonized with the new tolerancing techniques, but in this field an additional challenge is present. In general, inspection systems for micro metrology are non-contact measuring systems. A complete infrastructure guaranteeing the traceability of non-contact micro-measuring systems like quantitative microscopes still needs to be developed and implemented, including instruments calibration and verification, and measurement uncertainty estimation.

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