

Design for Precision: Current Status and Trends

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Abstract

'Design for Precision' reviews the status quo in Precision Engineering and concludes that today's precision engineers put repeatability at the top of their list. The design rules, patterns or principles, quoted here from various authors, are all time-proven insights, to get reproducible results with ultra precision machines and instruments. Modelling and analysis of different concepts, systems, and components is required to adapt the progressing design or to confirm its adequacy. Expenditure on such analysis is worthwhile to avoid realisation of an inadequate design. However, creativity is more important in keeping the cost down by finding other than locally optimised solutions. World-wide, precision engineers agree on design principles, the challenge is to apply them creatively to obtain a thought-out design. In today's most accurate machines, advanced techniques are applied for compensation of e.g. residual geometric errors, errors caused by machine dynamics, or thermo-mechanically induced errors. Future developments in Precision Engineering require nanometre- or even subnanometre positioning- and measuring accuracy, demanding new design concepts with integrated control and error compensation systems.

Keywords: Design principles and features, predictive design, accuracy, repeatability, reproducibility.

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1. Introduction

Currently, many activities employed in industry and institutes are aimed at creating high precision products and involve high precision processing. The manufacturing of these products demands a highly specialised science called Precision Engineering, which is based on the following disciplines:

- Design for Precision
- Optical and Mechanical Metrology
- Precision Manufacturing

'Design for Precision' here is meant as total design including materials, mechanics, electronics, control, thermo-mechanics, dynamics and software. It may be indicated as high precision mechatronic design. Design for higher precision is becoming more and more important due to the rapidly increasing need for high accuracy machines, instruments and consumer products. [McKeown, 1987], [Evans, 1988], [Gardner, 1991], [Nakazawa, 1994]. Today, this tendency is highly influenced by developments in computer technology, data processing and data storage. This process started in

1958, when the integrated circuit was invented. The need to have more and more transistors on a chip [Hutcheson, 1996] demanded special machines with an extremely low positioning uncertainty of a few nanometres. An example of such a machine is the waferstepper, used to position the image of the IC on the surface of a silicon wafer. Such a machine can be achieved only by highly developed design- and manufacturing technologies. Also the increasing need for high density optical recording systems (DVD), and as a result for optical disk mastering systems, asks for advanced machines with nanometre uncertainty. The parts used in these machines, like bearings, drives and beam shaping optics, have to be manufactured to submicron accuracy. For the manufacturing process, machines with submicron even down to nanometre accuracy have to be developed.

In Metrology, the technology for high precision measurements is developed e.g. measurement software, error modelling [Soons, 1993], measurement techniques and measurement strategies. To measure parts and products with sufficient accuracy, measuring machines for submicron to nanometre accuracy have to be developed, demanding new design skills since existing design-methods for high precision hardly allow to reach these levels [Teague, 1989, 1997]. Therefore, Metrology as a basic discipline has faced an enormous growth resulting in accurate co-ordinate measuring machines, laser interferometers and nanosensors such as STM and AFM. Additionally much analysis software and software for error compensation was developed and implemented.

Precision Manufacturing concerns the realisation of products with high shape accuracy and surface quality. The accuracy may be at the nanometre level, so both machine design and process behaviour must be well understood as well as the interaction between process and machine, i.e. the interaction between tool and

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