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A Pseudo-Abbe comparator and double form measurement machine for high precision diameter and form calibrations

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Abstract

A concept for a novel diameter and form measuring instrument is described. The concept utilizes two independent z-axes towers on a common x-axis which each carry their own y-axis and tactile probes. The X- and Z-axes are equipped with metrology frames for compensating guide errors. An additional length metrology frame serves as reference for 8 interferometers which realize the length scale for measuring diameters and to compensate guide errors.

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Keywords: Form measurement; diameter measurement; interferometry; metrology frame; seudo Abbe concept

1. Introduction

Cylindrical and spherical dimensional standards together with end gauges are the most important reference standards for ensuring the traceability of form measurements and coordinate machines measurements. These standards are referred to in many written standards. Whereas end gauges may be calibrated by direct e. g. phase-shifting interferometry, cylinders and standard spheres are calibrated by tactile probing. Some special applications like the realization of the traceability chain for pressure, even require the direct calibration of the thereby utilized piston-cylinder assemblies. This was also an important milestone within the project dealing with the new-definition of the Boltzmann constant, where 3D cylinder surface point cloud uncertainties in the range of U = 20 nm were

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required [1]. Some few special measurement machines for these tasks have already been developed. Their common approach is a one-dimensional Abbe comparator design with interferometrical length measurement and the utilization of two probes instead of one to minimize or eliminate the influence of the probing sphere diameter calibration uncertainty [2-4]. However, these instruments are mainly focused on improving outer diameter measurements. The additionally required inner diameters and form measurements are realized with higher uncertainties or even on different machines, which implies additional measurement uncertainties, because of the additional setting procedure.

Therefore, a novel measurement machine has been developed, which can measure both inner and outer diameters with low uncertainty, the form measurands roundness, straightness, and cylindricity, and additionally parallelism with uncertainties in range of U = 10 nm … 50 nm without considering the limitations of the older designs. This machine was called KOLD (comparator for length and diameter).

2. Mechanical measuring machine concept

The machine concept which was developed in tight cooperation with the Mahr company can be described as two cylinder form and length measurement machines which share a common rotary table with centering and leveling unit [5]. The center of the rotary axis servers as datum for all measurements. Both sides of the machine are equipped with two towers (left and right, see Fig. 1), each carrying a Z- (i. e. vertical) and a Y- (i. e. transverse) axis with a tactile probe system. All axes are equipped with high precision length scales, which are mainly needed for positioning and scanning of the probes. The Z-axes towers can be positioned independently on a common machine bed. The Z- and X-axes are equipped with reference rulers forming a metrology frame equipped with a capacitance transducer based monitoring system, which measures and compensates guide errors. These axes and probes enable the machine to realize form measurement modes, like roundness and straightness measurements at generatrices of cylinders. The probes can touch each other in a reference position, e. g. above the center of the rotary table. For outer diameters measurements, this position deals as datum. Therefore, no probe diameter calibration is necessary. The shafts of the probes encompass a small angle which enables the probe to probe contact for the first time additionally in the opposite position of the probing spheres. This is a prerequisite for realizing the reference based double probing measurement procedure also for inner diameters.All figures should be numbered with Arabic numerals (1,2,3,….). Every figure should have a caption. All photographs, schemas, graphs and diagrams are to be referred to as figures. Line drawings should be good quality scans or true electronic output. Low-quality scans are not acceptable. Figures must be embedded into the text and not supplied separately. In MS word input the figures must be properly coded. Preferred format of figures are PNG, JPEG, GIF etc. Lettering and symbols should be clearly defined either in the caption or in a legend provided as part of the figure. Figures should be placed at the top or bottom of a page wherever possible, as close as possible to the first reference to them in the paper. Please ensure that all the figures are of 300 DPI resolutions as this will facilitate good output.