Temperature Stabilization of an In-process Measurement System Based on Laser Triangulation and Applied at a Furnace

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Abstract

This paper presents a method to stabilize the temperature impact on an optical measurement system based on laser triangulation. The system was developed to provide geometrical information of steel rings obtained in hot environments (temperatures up to 900 °C) for the verification of heat treatment simulations.

The approach for temperature stabilization mainly consists of a fiber coupling with the laser source and a minimization of the frame which holds the optical components. Due to this modification, the systematic deviation could be reduced to the level of noise. The results achieved with the modified measurement system will be discussed and compared with previous findings.

1 Introduction

Heat treatment is one of the last production steps in an industrial process chain for steel components. Its purpose is the adjustment of material attributes, frequently within a near-surface zone (e.g. hardness). However, the heat treatment often leads to a spurious geometrical deformation of the workpiece. This deformation is known as “distortion” and is caused by the release of “distortion potential”, induced by preceding production steps. Distortion is an undesired effect and can presently be minimized by costly finishing treatments like grinding. The Collaborative Research Center ‘Distortion Engineering’ (SFB570) of the German Research Foundation is investigating the origin and the cause of distortion along the entire production chain. The investigation was initially focussed on elementary geometries like ring, shaft and disk and is actually extended to gear wheels. One of the major goals of this project is

to compensate unavoidable distortion by inducing thermally generated "counter" deformation during heating or quenching [1].

To achieve this goal in case of ring geometry, a heating furnace was specially designed [2]. It consists of six separately controlled heating elements, which enable a selective symmetrical or asymmetrical heating process. To avoid overcompensation, a laser triangulation system was developed allowing non-contact geometry measurements during the heating process (Figure 1).

Referring to vibration and electronic noise, the spread of measured deviations amounts to several micrometer. But, during a long-term measurement in a shop floor with varying ambient temperature, it exhibits a temperature dependent systematic deviation up to 0.2 mm. Thus, for absolute measurements of the roundness change, the dependence of the system on the hall temperature outside the furnace should be minimized first.

After a brief description of the measurement system, this paper will describe the approach to solve the temperature problem explained above.

2 Experimental setup

The laser triangulation system provides six evenly distributed sensors around a ring, measuring the radial displacement *dX* of the outer ring diameter (Figure 1).

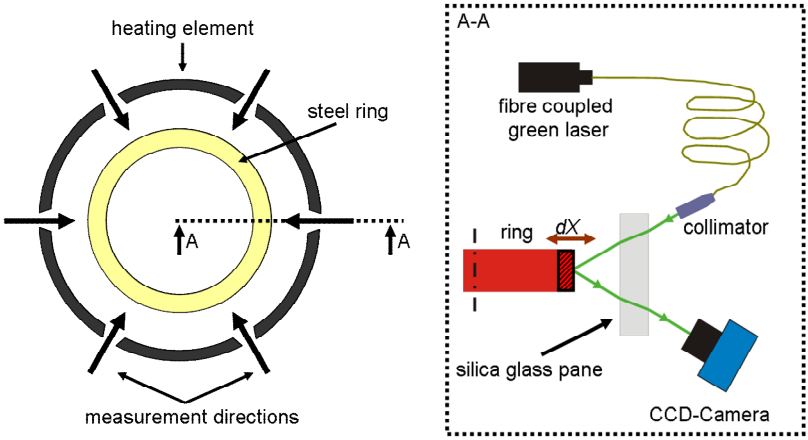

Figure 1: Schematic view of the measurement system with a cross-section along one measuring direction [3]

By combining the obtained displacements of all six measuring directions, the relative change of the ring's roundness can be measured in hot environments, i.e. at

temperatures up to 900 °C. A former publication describes in detail the furnace as well as the measuring technique applied and its calibration [3].

3 Measurement problems and their solution

The problems concerning the realization of in-process measurements are essentially caused by the accessibility to the workpiece and the environmental conditions around the sensor or the measurement system. In case of measuring hot workpieces, the enhanced ambient temperature represents the main disturbing influence. It causes an expansion of the measurement setup frame and affects the electronics. The influence of the former on the measurement results is minimized by building a small symmetric frame, which forces the thermal expansion to a known priority direction. So, this effect can be corrected easily.

Concerning the electronic part, the repeatability of laser triangulation measurements is highly sensitive to the pointing stability of the laser source. This attribute describes the stability of the laser beam direction. The data sheets of lasers specify the pointing stability as a temperature dependent value, quantified in the unit rad/°C. Therefore, a varying ambient temperature causes laser spot movements on the workpiece surface that can be misinterpreted as workpiece displacement.

To avoid the influence of the beam pointing stability on the measurement results, fiber coupling was realized to act as laser source. The radiation leaving the fiber is always divergent and its direction does not depend on the angular coupling of the entering laser beam. Thus, temperature dependent pointing stability theoretically should not affect the beam direction.

4 Results

To verify the approach explained above, the laser triangulation system continuously measured the mean radius of a steel ring for at least two days. The results exhibited deviations in the one-digit micrometer range. Comparing them with ambient temperature data, the measured deviations can be explained by the thermal expansion of the ring.

Figure 2 shows results from an in-process measurement of a ring, obtained during one heating/cooling cycle. The ring was symmetrically heated up to 700 °C. After a certain retention time at this temperature, the heating elements were shut off, and the ring cooled down. The results exhibit an uncertainty two times lower than presented

in a previous publication [3]. The uncertainties are estimated by the standard deviation σ.

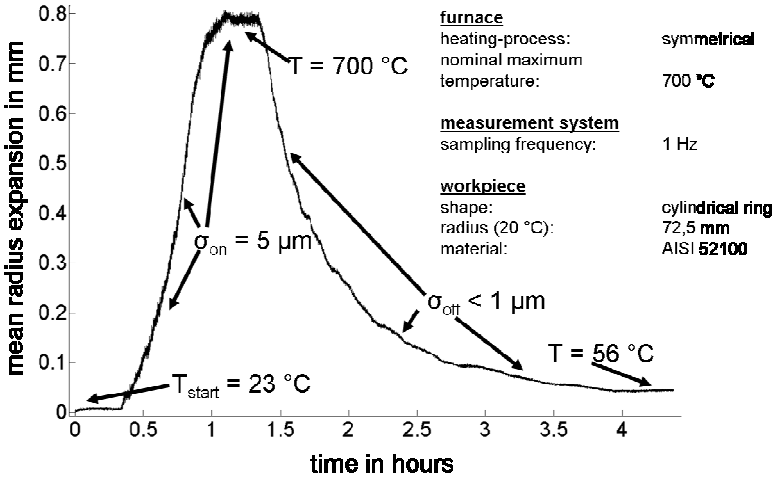

Figure 2: Mean radius thermal expansion of a steel ring during a heating process

5 Conclusions

With the modifications described in this paper, varying ambient temperatures have no measurable influence on the laser triangulation system. Compared with former results, these modifications also lead to lower uncertainties.

Acknowledgements:

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References:

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