

## HOTGAUGE – Measurement of complex and freeform shaped parts at elevated temperature

Geometrical distortions due to inappropriate setting of process parameters are one of the main causes of variability in manufacturing high-valued hot forged thin freeform parts e.g. turbine blades. Their identification and quantification at the earliest steps of the process chain may permit well-timed setting of the process parameters, with significant benefit in case of small batch production. DII and partners of the international research project HOTGAUGE developed and tested an innovative Coordinate Measuring System (CMS) for fast inspection of freeform parts at elevated temperatures through high-speed laser triangulation, using multiple sensors and intelligent data fusion and illustrated in the figure below. The system can scan the entire geometry of a hot part a frequency of 320 Hz, thus generating  $10^6$  points/s for a 800 mm long blade in less than 8 sec. Due to the harsh environment conditions, laser triangulations sensors were placed inside a shielded and isolated housing (2.6 x 2.5 x 1 m), where the temperature is kept steady at  $20 \pm 1^\circ\text{C}$  while a part at  $800^\circ\text{C}$  is moved through. Additionally, two pyrometers are installed in the top of the housing in order to acquire part surface temperature. Main error sources were identified and minimized using appropriate techniques, including a new method for the correction of systematic errors due to imperfect laser planes alignment. A new procedure for testing the prototype CMS in hot conditions was also developed. The procedure uses glass-ceramic plates, featuring nearly zero Coefficient of Thermal Expansion (CTE), mounted on a fixture over a hot billet. Test results demonstrate that the prototype CMS, after more than one hour of operation in hot conditions, is measuring with bidirectional length measurement errors in the order of 0.05 mm.

The prototype was extensively tested in the forging plant of an Italian manufacturer of turbine blades and demonstrated to be an effective tool for reductions of wastes in small batch production of high-valued hot forged thin freeform parts.



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Main research topics:

- Manufacturing systems and processes
- Micro-technologies and precision technologies
- Shaping of metallic materials
- Processing of polymeric materials
- Geometric metrology