G Model
CIRPJ-384; No. of Pages 10

ARTICLE IN PRESS

CIRP Journal of Manufacturing Science and Technology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

journal homepage: www.elsevier.com/locate/cirpj

# Multiscale measurement of air foils with data fusion of three optical inspection systems☆

Jochen Schlobohm *, Yinan Li, Andreas Pösch, Markus Kästner, Eduard Reithmeier

*Institute of Measurement and Automatic Control, Leibniz Universität Hannover, Nienburger Straße 17, 30167 Hannover, Germany*

ARTICLE INFO

*Article history:*
Available online xxx

*Keywords:*
Blisk
Turbine blade
Inline measurement
Multiscale
Fringe projection
Borescope
Michelson interferometer

ABSTRACT

Measuring the geometry of machine parts with complex geometries creates new challenges towards measurement systems. Due to cost, fast inspection is nevertheless desirable. Additionally the characterization of a parts health and functionality requires geometric information in different scales. We have developed a set of optical measurement systems which together meet those requirements: A borescopic fringe projection system, a macroscopic fringe projection system using newly developed algorithms for fast inspection of turbine blades and a low coherence Michelson interferometer (LCI). The first can detect geometric variances in hard to reach areas, e.g. inside machines or in between parts with highly complex geometries like blade integrated discs (blisks). Using fully adaptable fringe patters, the second system can locate geometric variances with a single fringe pattern. These patterns lead to high sensitivity and high measurement speed. Afterwards the LCI further inspects the micro structure of defects and characterizes the surface structure of the air foil. The presented algorithms provide fast 3D reconstruction with a nanometer resolution and, compared to other systems, a large measurement range. Together, these three inspection systems are capable to detect and quantify defects or geometric variances of industrial parts in different scales. This information improves the prediction of the reliability of a part and helps extending its lifetime to reduce the maintenance costs of machines. As an example a turbine blade was measured with all three systems and the results are visualized in one dataset. Means to merge the measurements are discussed.

© 2016 CIRP.

## Multiscale metrology in product regeneration

With rising complexity of machines and parts, determining their reliability gets more challenging. Higher integration of each parts functionality leads to a higher per part investment. The regeneration of such parts is therefore getting more lucrative, while it strongly depends on information about the reliability. To generate such information, complete, fast and precise measurements of the geometry of the part has to be carried out. Fig. 1 shows an example of a very complex and hard to measure geometry. While state of the art tactile measurement systems often have a superior precision of single data points they measure with low lateral resolutions and measurement speed. They are designed for geometric inspection but are usually less suitable for the detection of stochastic surface defects. Further, some parts are sensitive to contact so that they cannot be measured by tactile means. There are several machines for X-ray inspection and X-ray computer tomography (CT) available on the market, which are capable of measuring turbine blades [1,2]. A CT measurement consists of cross sections which allow the user to evaluate the inside of the turbine blade. On the other hand, cross sections are not very useful to determine an objects outer shape, which is very imported for the aerodynamic properties of a turbine blade. Additionally, a CT is usually very expensive to buy, maintain and operate and has a relative low measurement speed.

Precise data with high point densities can be achieved with high speed using optical measurement systems [3]. NovaCam [4] uses a rigid borescopic interferometer to scan the surface of an object point by point with very high precision (about 1 μm). The measurement probe has to be positioned for each data point, so that the measurement speed and lateral resolution is comparable to that of tactile means. Another approach by Storz [5] is triangulating 52 laser points using a videoscope. While some aspects of this measurement systems are similar to fringe projection, it lacks the superior point density. Small cracks close to the surface and can be detected by thermal imaging while the

☆ An earlier version of this paper was presented at the Third International Conference on Through-Life Engineering Services held on 4–5 November 2014 at Cranfield University in UK.

* Corresponding author.
*E-mail address:* jochen.schlobohm@imr.uni-hannover.de (J. Schlobohm).

http://dx.doi.org/10.1016/j.cirpj.2016.07.006
1755-5817/© 2016 CIRP.

**Fig. 1.** A compressor blisk on display at the Paris Air Show 2013. This is a single-piece item, generated with 3D CNC milling. Source: Olivier Cleynen; license: CC BY-SA 3.0.

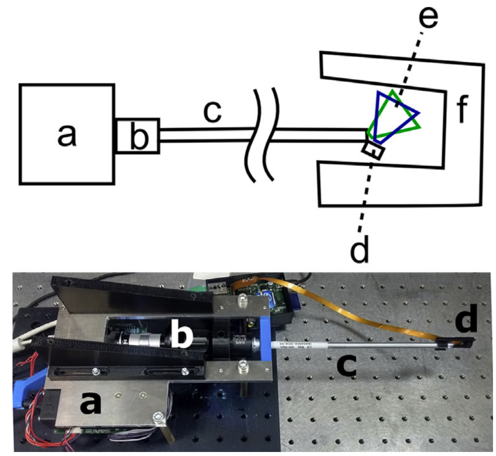


**Fig. 2.** Top: (a) projector; (b) borescope optics; (c) borescope shaft; (d) camera; (e) fields of view; (f) object. Bottom: borescopic fringe projection system with the projector (left), the borescope (middle) and the measurement head including the camera (right).

condition of protective coatings can be classified using eddy current testing [6]. Both methods do not give information of the blades shape. Classic fringe projection needs multiple patterns projected on the object [7] for a full phase unwrap. Most fringe projection systems are not capable of operating in very limited space. This paper introduces a borescopic fringe projection system with a very small measurement head as well as a ray tracing-based inverse fringe projection system to improve the measurement speed.

The roughness measurement of turbine blades has an important impact on the performance and is modeled in computational fluid dynamics (CFD) for simulation. The effects of surface roughness in gas turbines and the simulation of aerodynamic losses are studied based on the paper by Bons, Jeffrey and Zhang [8,9]. In order to acquire a non-contact microtopography measurement, the common optical measurement system like confocal laser scanning microscopes, vertical scanning interferometry and focus variation instruments are usually applied. In this paper we present a compact low coherence interferometer (LCI), which is based on a Michelson construction. With the help of a telecentric Lens, the LCI system can measure areas like the small space between two turbine blades which common microscope interferometers cannot reach due to their short working distance and geometric dimensions.

Through the paper a turbine blade is measured with all three measurement systems. While the inverse measurement in Section "High speed and high sensitivity geometry measurements" detects the defects on the blade, Section "Multiscale measurement of a blade" gives an overview of the measurement results using the endoscopic fringe projection system and the LCI.

## Advanced fringe projection systems

### *Inline measurements with a rigid borescopic fringe projection system*

A rigid borescopic fringe projection system was developed. With its very small measurement head, the system is capable of measuring in between parts of complex geometries (see Fig. 2). Our prototype was partly build from consumer electronics: a portable LED-beamer and a raspberry pi single-board computer along with a mobile phone 5 mega pixel camera. In later measurements a professional projector from Texas Instruments was used, that delivers linear light intensity. Additionally, we are also using a professional rigid borescope from *Storz* for the projection of the measurement patterns. The combination of a borescope with a chip-on-tip camera leads to a small, potable and cost efficient measurement system.

With the borescope, we are able to achieve high resolution and high contrast projections using standard components. The system is nonetheless capable of measuring in very limited spaces. It can for example be used to measure areas inbetween two blades of a blisk. Fringe projection systems usually have the size of a video projector and can therefore not be placed inside complex geometries. When using such a system to measure a blisk from a similar point of view, as shown in Fig. 1, the blades on the top right are mostly hidden behind other blades. The blades on the bottom right are not hidden, but the angle between the airfoils surface and the line of sight is very large. Large angles lead to a lower illumination and may demand the preparation of the object with an anti glare coating or similar. Additionally those large angles lead to a lower point density on the surface. The borescopic fringe projection system can reach into a complex object to be aligned in an optimal angle to improve the illumination condition and the lateral resolution of the measured points. Using state of the art camera calibration as shown in [10], influences caused by a mediocre lens and camera quality can be minimized. Based on this technique Pösch et al. [11] developed algorithms for the calibration of stereoscopic systems consisting of a camera and a projector.

Fig. 3 shows a closeup of a measurement of a 20 euro cent coin. The whole coin consists of 1.1 million data points. The field of measurement is approximately 30 mm × 30 mm with the coin having a diameter of approximately 25 mm. Using multiple lens

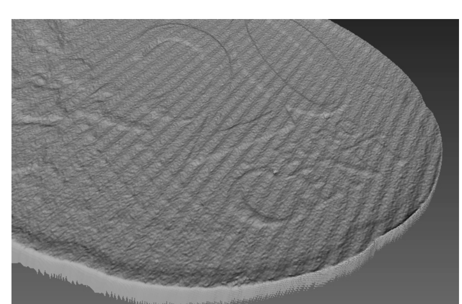

**Fig. 3.** Measurement with the endoscopic fringe projection system.

Download English Version:

https://daneshyari.com/en/article/5467078

Download Persian Version:

https://daneshyari.com/article/5467078

Daneshyari.com