Edge measurement based on multi laser triangulation sensors

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This paper proposes a 3D edge measurement system based on two 2D laser profile sensors, which allows a 180° edge measurement in a single scanning. Using a specific calibration pattern, a geometric relationship between two sensors can be defined for the data matching. The calibration process and the measurement results of this sensor system are presented.

1 Introduction

The measurement range of common 2D laser profile sensors is not only limited by the field of view (FOV) of the detector, but also by the measurable spatial angle. Based on the well-known triangulation principle [1], the measureable spatial angle is limited by the angle of incidence between the receiving element and the projected laser line. Therefore, for the measurement of complex form samples with great curved surfaces (e.g. an edge), a single laser profile sensor from only one direction cannot scan the whole form of a sample. In this case, to measure a whole 3D edge a measurement system requires more than two times scanning from different directions. For this reason, using multiple laser triangulation sensors allows us to overcome the intrinsic limitations of single sensor. Fig. 1 shows the geometrical profile measurement of a turbine blade using a new developed edge measurement system.

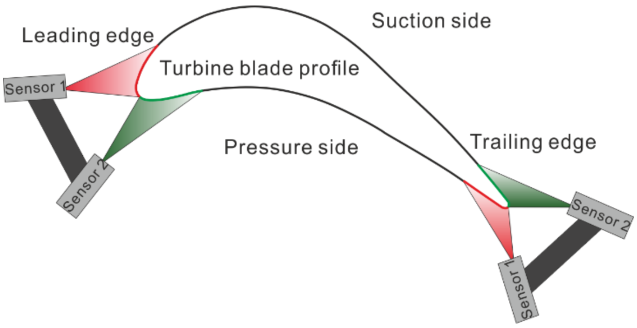

Fig. 1 *Edge profile measurement of a turbine blade*

2 Experimental setup

An edge measurement system was designed and built for scanning the whole 3D edge of the object. It is based on two industrial laser triangulation sensors with a vertical resolution of 0.015 mm, a horizontal resolution of 0.03 mm and a measuring frequency of 50 Hz. The sensor analyzes the acquired image of the projected laser line via the built-in DSP processor and provides geometrical profile as profile-coordinate data. The data communication and control signal via the TCP/IP interface between sensors and PC is realized by software components in python language. The sensors are configured with individual IP addresses. Utilizing the data access via fixed IP addresses, the host PC can acquire measurement data synchronously.

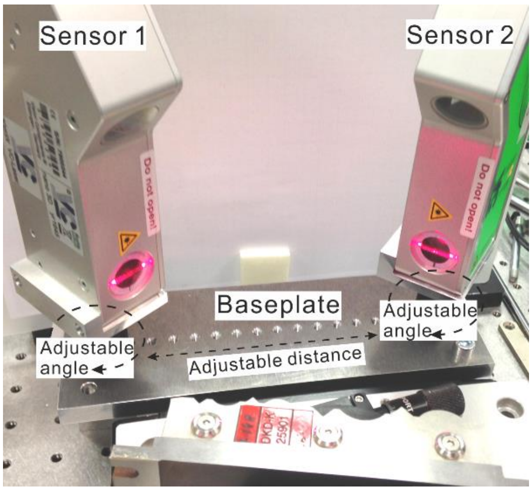

Fig. 2 *Experimental setup of the edge measurement system*

To allow the edge measurement from two different directions, the both sensors are built with an adjustable ball and socket mount on a base plate. The distance and angle between two sensors are adjustable to fit different geometrical edges. Each sensor projects an individual laser plane onto the target object to form a line in the x direction. If the two projected laser lines are not overlapped on the target object, the cross-laser line can lead to a large measurement error. Therefore, as a prerequisite for the measurement system setup, both projected laser lines must be adjusted using the ball and socket mount into an overlapping line. Fig. 2 shows the experimental setup of the edge measurement system.

3 Calibration of the edge measurement system

Two laser triangulation sensors are integrated in the system setup, where each sensor has a local sensor coordinate system (SCS). In order to integrate both SCSs into a new reference coordinate system (RCS), a calibration body was designed and fabricated. Fig. 3 shows the calibration body, which con-

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sists of a base plate with 6x5 matric holes and cylinders with different diameters of 15 mm and 30 mm respectively. Utilizing this calibration body, different calibration patterns can be combined flexibly with different cylinder sizes and distances, in order to fit and calibrate different measurement ranges of this system (see Fig. 4).

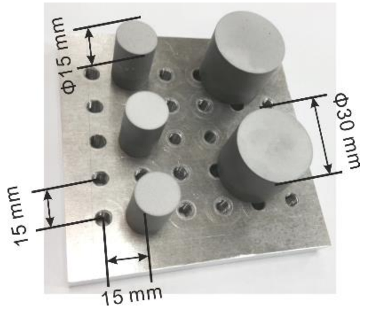

Fig. 3 *Calibration body*

For example, to determine the new RCS of this system, the position of a virtual sensor is defined as the coordinate origin of the edge system (see Fig. 4). The rotation angles α and β as well as the translation variables (t_x,t_y) can be calculated via the known calibration patterns.

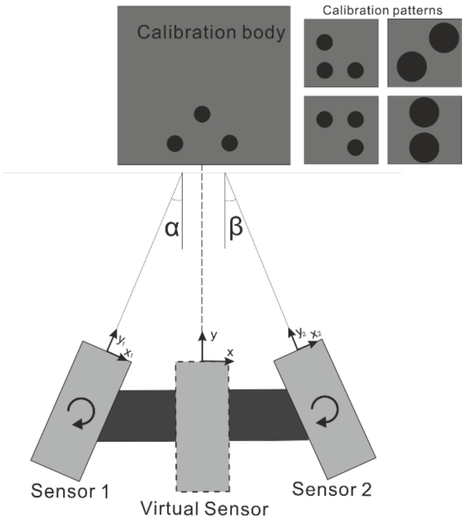

Fig. 4 *Calibration of the edge measurement system*

The transformation matrices for the RCS can be determined by

$$\begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix} + \begin{bmatrix} t_{x1} \\ t_{y1} \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} x_v \\ y_v \\ z_v \end{bmatrix} = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_2 \\ y_2 \\ z_2 \end{bmatrix} + \begin{bmatrix} t_{x2} \\ t_{y2} \\ 0 \end{bmatrix}, \tag{1}$$

where vectors (x_1,y_1,z_1), (x_2,y_2,z_2) are SCSs respectively and (x_v,y_v,z_v) is the new RCS. Due to the fact, that the measurement range of the laser profile sensors is only 2- dimensional, the z is mostly zero.

4 Experimental Results

To verify the accuracy of the proposed measurement system, a measured contour standard is compared with the known pattern size. The measurement deviation of our system is less than 40 µm. Furthermore, to evaluate the performance and applicability for measuring component edges, the measured leading edges and pressure edges of a turbine blade and a compressor blade are shown in the Fig. 5. The measurement range of the edge sensor can cover over 180° on the edges. The whole edge profile can be scanned with only one measurement.

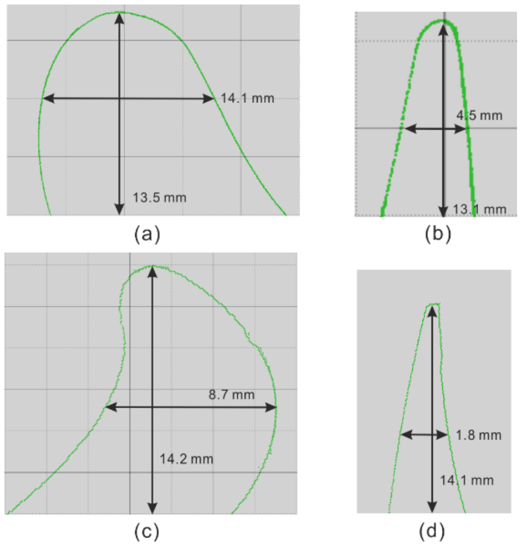

Fig. 5 Measurement of edges of a turbine blade and a compressor blade

5 Summary

Based on two 2D laser profile sensors, a new edge measurement system is proposed in this paper. A specific calibration pattern, whose size is adjustable flexibly for measurement range, is used to calibrate this system. The calibrated measurement result is in good agreement with the comparison with a contour standard.

6 Acknowledgements

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