Calibration of the Optical Axes of an Image Derotator Using Image Processing and a 6-Axes Parallel Kinematics

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The analysis of rotating objekts during operation needs as a prerequisite the calibration of the derotator with respect to the measured object. The optical axis of the derotator has to be coaxial to the rotational axis of the measured object. Ensuring this condition an calibration strategy is presented, which allows a defined positioning of the derotator on the basis of image processing data.

1 Introduction

Using non-contact measurement methods for the analysis of rotating objekts a derotator is required. [1] discribes the disadvantages of a derotator with a rotating dove prism and presents a new concept, which is based upon a rotating mirror body assembly. [2] uses this derotator to investigate the vibrational behaviour of a model blisk. He identifies the effects of typical phenomena occurring to rotating objects such as centrifugal stiffening of blades.

To ensure a stationary optical imaging it is necessary that the optical axis of the derotator is coaxial to the rotational axis of the measured object. In the present work a model of the optical imaging is explained. Based on this model a calibration strategy is developed including the identification of the positioning error with industrial imaging algorithms.

2 Experimental Equipment

The basis of the optomechanical image derotator is the rotating mirror body assembly shown in figure 1. This assembly called mirror dove is installed in a hollow shaft motor, which is rotating at half of the speed of the measured object.
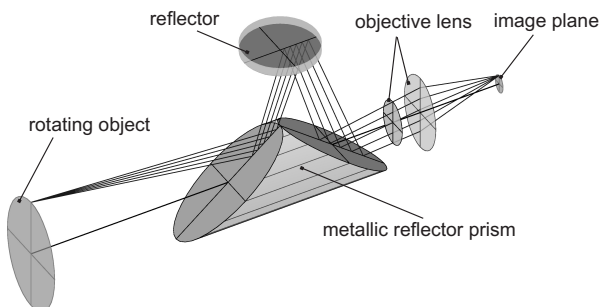

Fig. 1 *Key element of the optomechanical image derotator,* ©*IMR*

The complete experimental setup can be found in figure 2. The camera and the derotator are rigidly connceted together and can be positioned with the hexapod. For the calibration the image processing data is transfered to a realtime system where the computation is taking place. Based on those results correcting variables for the hexapod are generated.
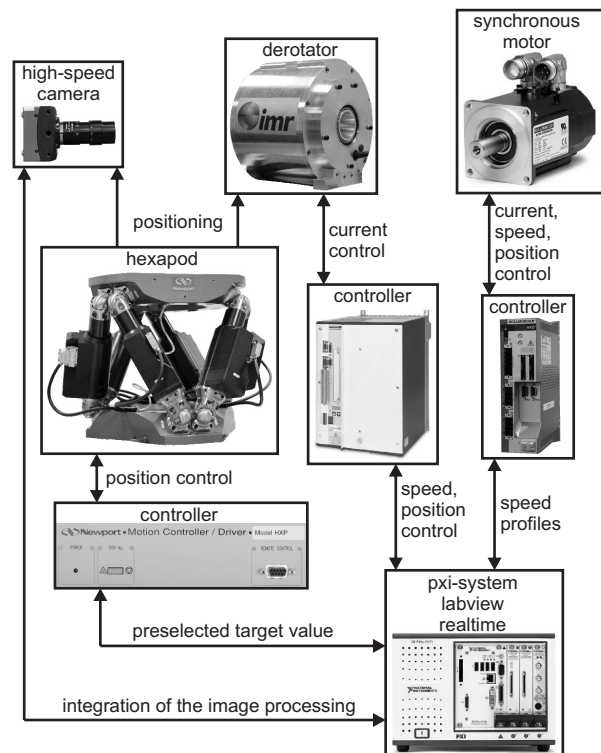

Fig. 2 *Complete experimental setup,* ©*IMR*

3 Modelling of the Optomechanical Image Derotator

Using geometrical optics it is possible to neglect the effects of wave optics cause the diameter of the modelled light beam is significantly larger than the wavelength of the visible light. The mathematical model explains the total beam path through the derotator and a simplified camera model with a so-called thin lens. On the basis of the two-dimensional image equations different situations can be analysed.

An ideal optical imaging is achieved, if the optical axis of the derotator is coaxial to the rotational axis of the measured object and the rotational speed of the derotator is at the half of the speed of the measured object. In this state a rotating point can be viewed stationary in the image plane.

If the optical axis of the derotator is shifted parallel to the rotational axis of the measured object, it can be demonstrated by simplifing the image equations that the point is moving on a circular path in the image plane. The radius of the circle is corresponding to the distance of the two axes. This movement can also be created tilting the optical axis in relation to the rotational axis. Based on the image it is not possible to distinguish between tiltings and shiftings. Thus, it is possible to reduce a movment resulting from a parallel shift with a tilting. [3] describes this situation as off-tune justified state.

To get a more detailed model of the derotator it is necessary to consider an adjusting error. This error occurs because the parts of the rotating mirror body assembly can not be perfectly aligned. The result is a circular movement in the image plane.
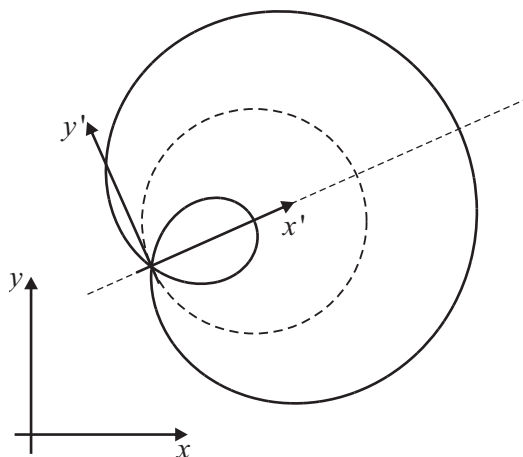

Fig. 3 *Orientation of the Limacon of Pascal, ⓒIMR*

In reality all these effects are overlapping. Assuming a rotating point on the measured object the movement of the optical image is similar to a so-called Limacon of Pascal a special case of a general con-choid, shown in figure 3. The mathematical model can be reduced to a formulation according to the parametric representation of the Limacon of Pascal. This curve is determined by two parameters. The first parameter results from the previously described adjusting error. The influence of this error can not be rectified, but reduced with an accurate justification of the mirror body assembly. With the second parameter the deviation of the optical axis and the rotational axis can be identified.

These results correspond to the considerations in [3] about a different derotator. Thus, the same conclusions with respect to an incorrect calibration can be drawn. The symmetry axis of the Limacon of Pascal is aligned to a plane spanned by the optical axis of the derotator and the rotational axis of the measured object.

The calibration approach consists of the identification of the orientation of the limacon of pascal and the second parameter. In the next step the derotator is moved by the hexapod along the symmetry axis of the Limacon of Pascal. The norm of this parallel shift corresponds to the second parameter. An ideal calibration can not be ensured because of the substitutability of tiltings and shiftings described above. Further studies will deal with the experimental validation of the calibration strategy and the implementation of an image processing tool which also identifies tiltings.

References

[1] S. Mirzaei, "Entwicklung und Erprobung der Bildderotator-Messtechnik am Beispiel der Schlupfmesung von Waelzlagern." Ph.D. thesis, Leibniz Universitaet Hannover (2011).

[2] B. Rohloff, S. Schwarzendahl, J. Wallaschek, and E. Reithmeier, "Schwingungsanalyse von rotierenden Objekten mit einem optomechniaschen Bildderotator," in *3. VDI-Fachtagung Schwingungsanalyse & Identifikation, Leonberg, S. 203-211, ISBN 978-3-18-092191-4* (2013).

[3] J. Miesner, "Beitrag zur kontinuierlichen interferometrischen Untersuchung der Eigenschwingformen rotierender Bauteile," Ph.D. thesis, Carl von Ossietzky Universität Oldenburg (2004).