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Measurement of radial expansion and tumbling motion of a high-speed rotor using an optical sensor system

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ABSTRACT

In order to investigate the load capacity and the strength properties of high-speed rotors, dynamic deformation and vibration measurements are of importance, in particular at lightweight composite devices which cannot be simulated reliably. This is a challenging task in metrology since non-contact inspection techniques are required which offer micron uncertainties and high temporal resolution simultaneously, also under vacuum conditions. In order to meet these requirements, a non-incremental laser Doppler distance sensor system was developed using fiber and diffractive optics. In this paper we present for the first time high-speed deformation measurements of a cylindrical steel rotor using this novel sensor system. The radial rotor expansion of only some microns was determined despite the presence of an unsteady tumbling motion of the rotor, which was measured simultaneously. Future prospects are discussed including the possibility to measure non-metallic devices such as fiber-reinforced composites.

1. Introduction

1.1. Measurement task

Deformation measurements of rotors are indispensable particularly in composite materials such as fiber-reinforced plastics since they cannot be simulated reliably. These stability measurements are performed in a high-speed rotor test rig, whereas the device under test is accelerated up to the failure of the device in extreme cases. In addition to the investigation of the moment of failure, the radial expansion due to centrifugal forces before the failure is of particular interest. Thus, elastic and plastic deformations in dependence of the rotational speed can be studied. Due to the very high surface speed up to some hundred meters per second and the radial expansion of only some tens of microns, a fast, non-contact and precise distance measurement technique is necessary. Because the measurement object is only unilaterally mounted, an additional tumbling motion occurs, see Fig. 1. Thus, the distance variation measured by a distance sensor positioned perpendicularly to the object surface is not only affected by the radial expansion but also by the tumbling motion. Hence, one distance sensor is insufficient for this measurement task since the radial rotor expansion cannot be determined unambiguously without further information. Consequently, to measure the radial expansion and the tumbling motion

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