Calibration and Characterization of a CW Radar for Blade Tip Clearance Measurement

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***Abstract*— The calibration and characterization of a blade tip clearance sensor is proposed for gas turbine applications. This sensor is based on continuous-wave microwaves that operates at 6GHz in the version for large frame turbines. The calibration of such a sensor is a difficult problem because of the complex interaction between the microwaves and the blade tip geometry. Different geometrical parameters can influence the calibration results, which drives us towards using both the actual blade geometry and probe positioning. This study presents the calibration process of this sensor using a precision test setup. Moreover, the optimization of probe positioning is discussed in order to limit the measurement errors due to axial shift of the rotor during engine operation, which is the major source of errors for tip clearance measurement. Finally, the measurement error corresponding to an optimal probe positioning is characterized.**

I. Introduction

Gas turbines, like jet engines or large frame power generation turbines have to be at the same time, safe, efficient and reliable. The operating cost of these machines greatly depends on fuel consumption and on the amount of needed service. Both of points can be improved by precisely controlling the clearance between the tip of the rotating blades and the surrounding casing. Indeed, the efficiency of the engine is directly related to the blade tip sealing which in this case, is desirable to be as tight as possible. On the other hand, blade/case rubbing causes premature mechanical deteriorations which affects the engine reliability and increases the service need. These facts have pushed engine manufacturers to control clearance values since the early days of gas turbine manufacturing [1]. Many passive clearance control systems, based on smart designs of the engine assembly, are used but the clearance values are far from being optimized because of the diversity of clearance variations sources (ex: thermal expansions, centrifugal forces or blade load). In order to compensate the lack of passive systems, several active systems have been also developed. For example, some are based on active cooling that make the turbine case shrink when activated. To operate, active systems need information feedback on the clearance values from physical models using indirect measurements of engine parameters, like rotation speed or temperature, or from direct clearance measurement.

Obtaining direct blade tip clearance measurements is a difficult problem because the engine interior is within a harsh environment (high temperature and high vibration levels) with dirt and combustion products and the system needs to measure clearance at very high speeds for individual blade tip clearance measurements.

Many technologies for clearance measurement exist but are predominantly used on test engines because of long term operational difficulties such as heat resistance and survivability of the probe or metrological characterization of such systems. Within this framework, Meggitt Sensing Systems has developed a short range continuous-wave microwave system with a high temperature probe design. When the blades are passing in front of the microwave probe, they interact with the electromagnetic field of the probe. This interaction generates a phase modulation on the returned wave, which is measured and used for clearance measurement. Because of the importance of geometrical parameters on the behaviour of this interaction, a calibration of the system is performed using the actual blade geometry, actual blade motion and actual probe positioning as closely as possible [2].

This paper discusses the calibration and the characterization of the 6GHz version of this microwave sensor using a high precision facility. Model blades are used in order to explain the calibration process and to demonstrate the measurement performances of the system. The first section will remind the reader on the functioning of the sensor including a system architecture description. In the second section, the calibration of the sensor for a given probe positioning and the associated error characterization will be discussed. Finally, the third section will show that the measurement error can be reduced by optimizing the probe positioning.

II. Measurement Principle and System Architecture

A. System overview

The measurement system is based on a microwave probe (Fig. 1) which is mounted through the engine casing such that its tip is oriented towards the blades (Fig. 2).