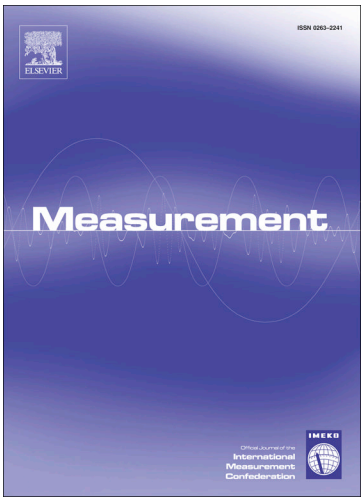

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A clearance measurement system based on on-component multilayer tri-axial capacitive probe

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Abstract – In this paper the authors propose the design of a complete measurement system of clearance based on an "on-component" triaxial capacitive probe for static and dynamic measurement of distance. The capacitive probe is designed to be deposited onto machinery components or complex structures and is aimed at reducing the impact of probe mounting on the monitored component. The problem is discussed from a theoretical point of view and then supported by the realization of a sensor prototype in screen printed technology and of two possible and alternative conditioning systems. The results prove the feasibility of this innovative measurement system.

I. INTRODUCTION

'On-component' sensors, printed or deposited onto machine components have many obvious advantages: a negligible mass, accurate placement, applicability to a variety of materials including ceramics, capability for operation to very high temperatures (>1000 °C), minimal structural disturbance (minimal machining) and finally an intimate sensor to substrate contact. The use of such sensors, instead of traditional 'bulk' devices, allows for preserving the integrity of the components, not perturbing the operating conditions and the operation of the whole system, and accordingly permitting to ensure a greater reliability. Some solutions based on the deposition of thin films have been since a long time the subject of studies in the field of avionics. In this context, NASA has produced prototypes of sensing films for the measurement of temperature, and flow sensors based on thermocouples and resistive strain gauges [1-6]. In different studies reported in the literature, materials and deposition techniques suitable for particularly hostile operating conditions have been identified, especially in terms of temperature (up to 1100 °C). Both conductive and insulator ceramic materials for this application have been identified: the latter are able to maintain high insulation at temperatures up to 700 °C with a film thickness even less than 10 μm, and can be deposited on either steel or similar alloys. The feasibility of multi-layer structures was also proven.

These results constitute a solid basis for the study and the realization of capacitive sensors deposited directly onto turbomachinery components. In particular, in this paper we explore the possibility of realizing triaxial capacitive probes for clearance measurement (static and dynamic measurements of distances). The structure to be achieved is quite complex, since it requires the construction of sensors consisting of a large number of layers of different materials. The problem is discussed from a theoretical point of view and then supported by the development of a prototype of a film-based triaxial capacitive sensor in screen printed technology. The proposed structure is designed, studied through electric field simulations and finally realized and tested.

The measurement of clearance based on capacitive sensing is a complex problem due to the presence of parasitic capacitances. The sensor capacitance is grounded and has a small value (at most some pF): in order to grant a sufficient sensitivity the parallel of this capacitance with the large capacitance of the cable, which in industrial environment can be many meters long, has to be avoided [7-9]. It is well known that the guarded structure provided by a triaxial capacitive probe wired with a triaxial cable is the only possible solution to this problem, provided that a suitable driving system for the