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THERMAL AND MAGNETIC CORRELATION IN APPARENT STRAIN DOWN TO 1,53 K AND UP TO 6 T ON STRAIN GAUGES

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Abstract— **In recent years the exceptional development of cryogenic technology in connection with applications in the fields of superconductivity, research concerning particle acceleration, thermonuclear fusion and in the spatial sector, has clearly shown the necessity of characterizing materials and transducers suitable to operate in the range from room temperature to that of super-liquid helium (4,2 K). Besides fulfilling its institutional tasks of the realization and maintenance of the primary standards of thermal and mechanical quantities, the Istituto di Metrologia "G. Colonnetti " (IMGC-CNR), now Istituto Nazionale di Ricerca Metrologica (INRIM) carries out also work concerning the metrological characterization of sensors and transducers. In particular was undertaken a work for the characterization of stress/strain sensors to be used at cryogenic temperature and in high magnetic fields.**
The present paper describes the IMGC facilities for strain gauge characterization from room temperature down to 1.53 K. Apparent Strain and Gauge Factors (K) are given from 293 K to 4.2 K and for high magnetic fields (from 0 T to 6 T)

Keywords— strain gauges, cryogenic, magnetic field, apparent strain

I. INTRODUCTION

The construction of large structures applying superconductivity systems (high field magnets, nuclear fusion apparatus) for example, in the development of the LHC accelerator (LARGE HADRON COLLIDER) at the CERN or in spatial sector for instance, in satellites for astronomical (IRAS, ISO) and astrophysical observations (ASTRO), have made it necessary to characterize electrical strain gauges working under cryogenic conditions and in high magnetic field.
The use of strain gauges (SG) to construct transducers suitable to operate at cryogenic temperatures and in high magnetic fields has required deeply investigations at IMGC concerning l) the choice of suitable strain gauges (grid material, length), substrate, adhesive, wires, soldering materials and so on; 2) the choice of appropriate electric circuitry; 3) the definition of measurement methods, the design and construction of testing equipment for strain gauge characterization in conditions approaching those of use as much as possible

The purpose of the investigation on the most suitable type of strain gauge is to find materials having minimal apparent strain (AS), a very low resistance temperature coefficient (CTR), and exhibiting minimal variations in the gauge factor in temperature intervals between room and liquid-helium temperatures, in the presence of temperature gradients and of high magnetic fields (from 0 T to 6 T)

Whatever the type of strain gauge selected from those commerciallly available, it is necessary to separate resistance variations of the gauge caused by the deformation to be measured, from variations deriving from other f actors

The choice of a particular alloy (Karma. Nichrome V, Armour D), of the adhesive. of special gauges (composite strain gauges), and of particular electrical devices or precautions (dummy gauges, half or complete bridges) , must have the purpose of minimizing if possible, the effect of influencing quantities. Minimizing does not mean annulling. It is therefore necessary to make corrections for variations of apparent strain and sensitivity caused by temperature and magnetic field.
Systematic investigations of alloys and materials suitable for work at cryogenic temperatures began a few decades ago. Let me mention here the work of McClintock, Chiarito, Kaufmann, Kemp, Nichols, which were prompted by growing requirements in the industrial field.

Kaufmann, and Telinde, Walstrom, Freinick et alii were the first to synthesize results and select the alloys more suitable for the construction of strain gauges to be used at cryogenic temperatures. They analyzed the following strain-gauge alloys: Advance, Karma, Modified Karma, Budd Alloy, Nichrome V, Armour D, V-Pt .

Of the investigated alloys used for commercial-type strain gages, two are the most suitable to work in cryogenic conditions, namely : iron-chromium-aluminum alloys, such as