Sensors integration in additive DMLS metal parts

1c), the cable connected to the probe or sensor directly comes outside the component. In the second case (Fig. 1b), the standard 3-poles connector of Fig. 1d is integrated into the sample through the surface. The second solution is more complicated to build and requires additional fabrication complications, but it provides more reliable cabling of external wires and prevents local cable damage at the contact with metal.

III. Micrographic analysis

The insertion of foreign bodies into the metal may induce undesired alterations in the crystallographic structure and variation of mechanical properties of the material. The SLM process optimization provided for this technology also takes care of the prevention of material alterations. The validation of material properties is based on the micrographic analysis of 17-4PH steel samples. The samples are polished, incorporated into resin and subjected to chemical treatment on the inspected side. The first surface analysis is performed with 12.5x magnification factor to evaluate the material density. Then, another analysis with 200x magnification factor provided the surface microstructure analysis. The micrographs are reported in Fig. 2.

The material density is near 100%, internal pores and discontinuities have been totally removed in the optimized process. Only a slight shift of surface layers (right border in Fig. 2a) is present, but it is easily removed with the further mechanical surface tooling. In addition, the metal microstructure is homogenous and without defects or discontinuities.

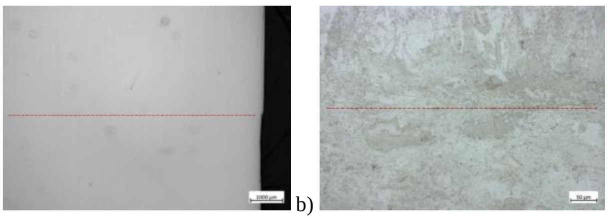

Figure 2: Surface micrographs at 12.5x (a) and 200x (b) magnification factors.

IV. Functional tests

The performances of thermal sensors are validated in terms of sensibility, repeatability and precision by functional tests after the integration process with portable analog-to-digital converter and heating plate (Fig. 3).

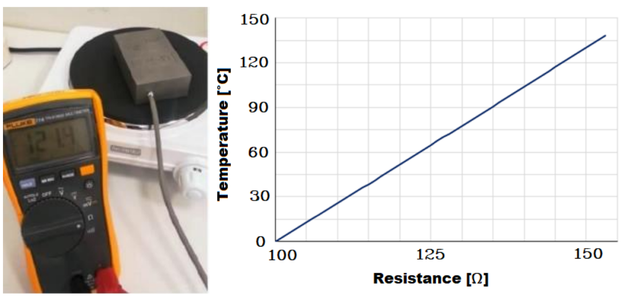

Figure 3: Functional validation of thermal sensors.

The output sensors curve is the same of the original sensors before the DMLS metal integration process (gain factor of 2.6 °C/Ω). The inertial sensor output is validated qualitatively.

V. Conclusions

The results synthetically exposed in this paper provides the overview of the potentialities of the technology for incorporating sensors into metal parts fabricated with DMLS processes. More generally, any kind of electronic device or circuit may be integrated similarly. At the same time, a more advanced electronic configuration of the transducer will improve the application to miniaturized and wireless components for the clinical and medical fields. In particular, the sensing of wearable systems customized on the characteristics of the individual subject is an attractive application for the near future.

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Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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