DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity:	Development of measurement techniques for Additive Manufacturing
State of the Art:	The non-contact measurement technique known as "Digital image correlation" (DIC) is a well-known experimental method for analyzing the surface deformation field of samples and mechanical components for the development of high-performance data processing and image acquisition systems, with a large number of applications in experimental mechanics [1-2]. The thermoelastic measurement technique (TSA) [3-4] is usually used to study the stress field on the surface of samples or mechanical components. [5] On the basis of the fundamental law of thermoelasticity introduced by Kelvin [4], the temperature variation of a homogeneous, isotropic body, stressed in the linear field, is closely related to the tensional state that is generated on the surface of the body [6]. The DIC, on the other hand, is able to supply the entire deformation tensor, from which the stator component can be obtained, as the sum of the elements on the main diagonal of the tensor itself. These techniques are also used to evaluate the effectiveness of Additive Manufacturing (AM). The AM consists in the production of material components by the addition of layers one on the other in order to obtain the creation of complex geometries not obtainable with other types of technologies. Among these complex structures, one of the most used is the trabecular morphology, which results particularly versatile in the aeronautic and biomedical environment [7] thanks to the possibility to produce materials with reduced mass. The AM precision reaches by now high levels. Despite this, there are often dissimilarities between what is projected by software and what is effectively obtainable.
Short description and objectives of the research activity:	The proposed research has the objective, using the latest data acquisition and processing techniques, to analyze stresses and deformations on different materials in order to predict the dissimilarities between the project and the final object. To do that it is necessary to accurately study the properties of the materials and develop specific measurement procedures that are able to detect dimensional and surface characteristics, deformation and stress characteristics, dynamic and thermal properties, focusing in particular on non-contact and full-field measurement technologies.

	This is very important in the trabecular structures in fact, even if they also have important dimensions in the macro-scale, they are characterized by very fine structures in the micro-scale, so in practice creating these structures remains a challenge of accuracy. Furthermore, variations of the micro-scale could have unexpected effects on the macro-scale, since, although the individual trabeculae manages a small portion of the energies involved (whether mechanical, thermal or others), their even small modifications could have an important chain reaction. The trabecular structures, in addition to benefiting from the reduced mass characteristics, can be optimized to withstand specific mechanical loads, or to have good thermal performance, or for a defined vibrational behaviour, in fact they have the peculiarity of being optimized for the specific application, in particular as far as it is of interest for this study, for aeronautical and biomedical applications [7].
Bibliography:	1) Chu, T. C., Ranson, W. F., Sutton, M. A., Peters, W. H., Application of digital image correlation techniques to experimental mechanics. Experimental Mechanics. Vol 25, 232-244, 1985 2) Sutton, M. A., McNeil, S. R., Jang, J., Babai, M., Effect of subpixel image restoration on digital correlation error estimates, Optical Enginering. Vol 27, 870-877, 1988. 3) Weber, W., Uber die specifische Warme fester Korper insbesondere der Metalle, Ann d. Physik u. Chemie, vol. 96, pp. 177-213, 1830. 4) Thomson, W., "On the Thermoelastic, Thermomagnetic and Pyro-electric Properties of Matter", Phil. Mag., vol. 5, pp. 4-27, 1878. 5) Barone, Patterson, Full field separation of principal stresses by combined thermo and photoelasticity, Experimental Mechanics, Vol. 36 (4), pp. 318-324, 1986 6) N. Harwood, W. M. Cummings, A. K. Mackenzie, "An introduction to thermoelastic stress analysis", Ed Adam Hilgher, 1991. 7) Aversa, Raffaella and Petrescu, Florian Ion and Petrescu, Relly Victoria and Apicella, Antonio, Flexible Stem Trabecular Prostheses (2016). American Journal of Engineering and Applied Sciences, Volume 9, Issue 4 (2016). 8) G. Allevi, M. Cibeca, R. Fioretti, R. Marsili, R. Montanini, G. Rossi, "Qualification of additively manufactured aerospace brackets: Acomparison between thermoelastic stress analysis and theoretical results", Measurement, vol. 126, pp. 252-258, 2018, DOI: 10.1016/j.measurement.2018.05.068. 9) Marsili, R., Rossi, G., Mechanical components dynamic characterization using thermoelastic stress analysis and

	digital image correlation, (2018) Diagnostyka, 19 (1), pp. 3-9, DOI: 10.29354/diag/80861 10) Marsili, R., Rossi, G., Speranzini, E. "Study of the causes of uncertainty in thermoelasticity measurements of mechanical components", (2018) Measurement: Journal of the International Measurement Confederation, 118, pp. 230-236, DOI: 10.1016/j.measurement.2018.01.037 11) Ferdinando Cannella, Alberto Garinei, Roberto Marsili, Emanuela Speranzini, "Dynamic mechanical analysis and thermoelasticity for investigating composite structural elements made with additive manufacturing", 2018, Composite Structures, 185, pp. 466-473 , doi: https://doi.org/10.1016/j.compstruct.2017.11.029 12) Roberto Marsili, Gianluca Rossi, Emanuela Speranzini, Causes of uncertainty in thermoelasticity measurements of structural elements, Smart Structures Systems, Vol. 20, No. 5 (2017) 539-548, DOI: https://doi.org/10.12989/sss.2017.20.5.539
Scientific coordinator (s)	Roberto Marsili
Contact (s)	roberto.marsili@unipg.it