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XXXIII Cycle

Study and design of hollow core wave guide for LASER beam propagation

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Research context and motivation

The joint of plastics plays an important role in all major industrial sectors such as automotive technology. There are various techniques: forming, gluing, screwing or welding. There are three reasons to join the plastic:

- The production of the entire component is uneconomical from the point of view of production or assembly;
- By separating a component unit it is possible to prevent complex prototyping and expensive tools
- Allows the use of different material.

The continuous development of products entails increasingly higher demands in mechanical terms. Multicomponent systems and the use of different materials for different components allow the optimal material to be used for each individual function. Riveting of plastics is a technically and economically important joining process to produce permanent connections. Low costs, short cycle times, design freedom make riveting an important alternative to welding, gluing or screwing.

Addressed research questions/problems

The first year the research activity has been dedicated to study of hollow core wave guide for LASER beam propagation directly into the polymers to be joined. According to Through- transmission Laser Welding, a simultaneous machine was developed. Several pairs of materials have been tested and joined: PMMA-ABS; PA66; PC-ABS, PBT.

The second year more attention was payed on several polymers laser welding applications in collaboration with my colleagues interested in fabrication of such devices to be applied in different sectors such as additive manufacturing and lab-on-chip.

Most of my activity has been devoted to the study of the riveting methods in order to design a new approach by laser in thermal riveting.

Rivet made of thermoplastic material is heated on the front side and deformed by a forming punch (Figure 1). The shape of the rivet head is determined by the shape of the punch.

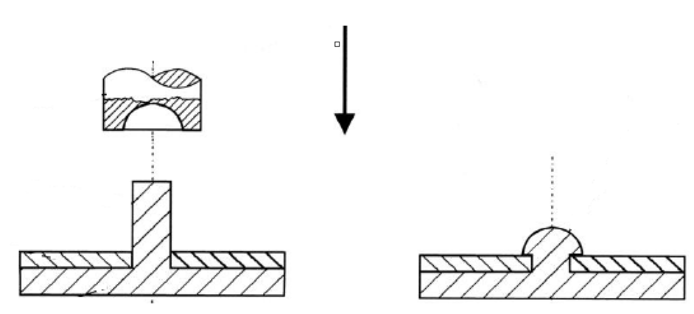

Figure.1 *– Schematic representation of a riveting operation with conventional heating*

The entry of heat into the rivet body is made contactless by laser radiation. Heating material permits to have not welding lines and the relaxation effects are greatly reduced by the cooling under the cold punch. The times are short and there are no dust or residual particles.

Submitted and published works

- V. Bertana, G. De Pasquale, S. Ferrero, L. Scaltrito, F. Catania, **C. Nicosia**, S. L. Marasso, M. Cocuzza and F. Perrucci - 3D Printing with the Commercial UV-Curable Standard Blend Resin: Optimized Process Parameters towards the Fabrication of Tiny Functional Parts – Polymers Vol.11 No.2, 2019
- M. Periolatto, F. Catania, **C. Nicosia**, L. Scaltrito, M. Cocuzza, C. F. Pirri, S. Ferrero - Spectrophotometric detection and monitoring of heavy metals in sea water, near offshore sites.
- I. Roppolo, F. Frascella, M. Gastaldi, M. Castellino, B. Ciubini, C. Barolo, L. Scaltrito, **C. Nicosia**, M. Zanetti and A. Chiappone - Thiol-yne chemistry for 3D printing: exploiting off stoichiometric route for selective functionalization of 3D objects - Polymer Chemistry, 2019
- M. Parmeggiani, P. Zaccagnini, S. Stassi, M. Fontana, S. Bianco, **C. Nicosia**, C. F. Pirri, A. Lamberti - PDMS/Polyimide composite as elastomeric substrate for multifunctional laser-induced graphene electrodes - ACS Applied Materials & Interfaces Vol.11 No.36, 2019
- V. Bertana, G. Scordo, S. Romano, **C. Nicosia**, S. L. Marasso, M. Cocuzza, S. Ferrero, C. F. Pirri, L. Scaltrito - Electrical connection enhancement of conductive 3D printed parts based on PEDOT:PSS by metal plating – MNE 2019, Rhodes

List of attended classes

- 01LEXRP– Strumenti e tecnologie per lo sviluppo del prodotto (08/05/2018, 5)
- 01NYCPE – Physics of technological processes for Micro & Nano systems and Micro & Nano systems (28/06/2018, 12)
- 01QORRV –Writing scientific papers in English (23/05/2018, 3)
- 03LCLRV – Epistemologia della macchina (13/04/2018, 4)
- 01NTQOD – Tecnologie per le nanoscienze (20/07/2018, 6)
- 01SHFRO Vibration Based Statistical Time Series Methods for Structural Healt (26/10/2018, 2)
- 01SCWRO - Giunzioni strutturali : progettazione, processi e tecnologie (06/11/2018, 6)

Novel contributions

Optical setup for the characterization of the laser beam, design of an optimal metallic hollow core waveguide, for the laser system, has been achieved (Figure.4) . Different set-up to heat the rivet was tested (Figure.2) , on its side surface or both in the top and side.

The effect of energy density distribution was studied, in order to guarantee the minimum power requested to have a good heating (Figure.3).

Different materials and geometries of rivets (Figure.5) was tested. Tests have shown that the riveting with laser effect is very suitable for colored and filled plastic materials.

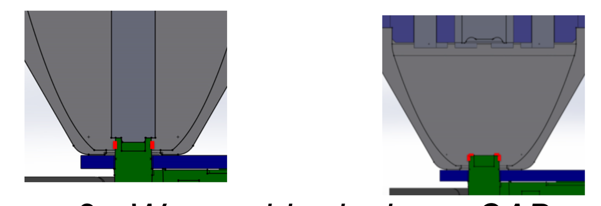

Figure.2 *- Waveguide design – CAD model*

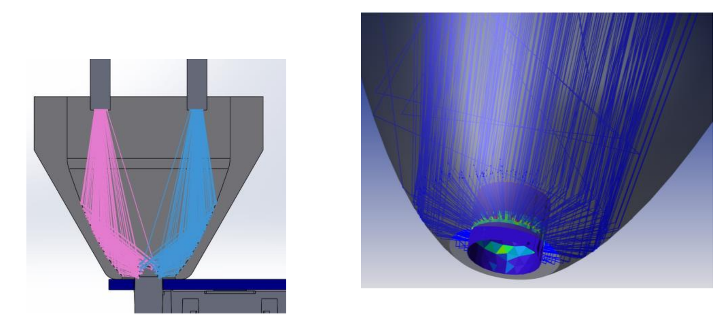

Figure.3 *– Irradiation distribution*

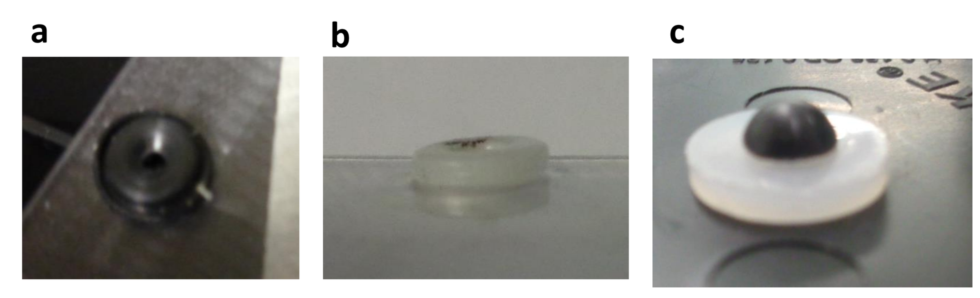

Figure.5 *- Tests a. PA66-GF30 hollow pin; b. POM natural hollow pin; c. PA66- GF30 solid pin*

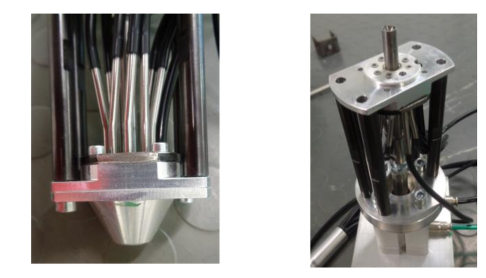

Figure.4 *– Staking system*

Adopted methodologies

Using a raytracing software ZemaxOpticStudio (Figure.6) a model of the system was obtained (Figure.7).

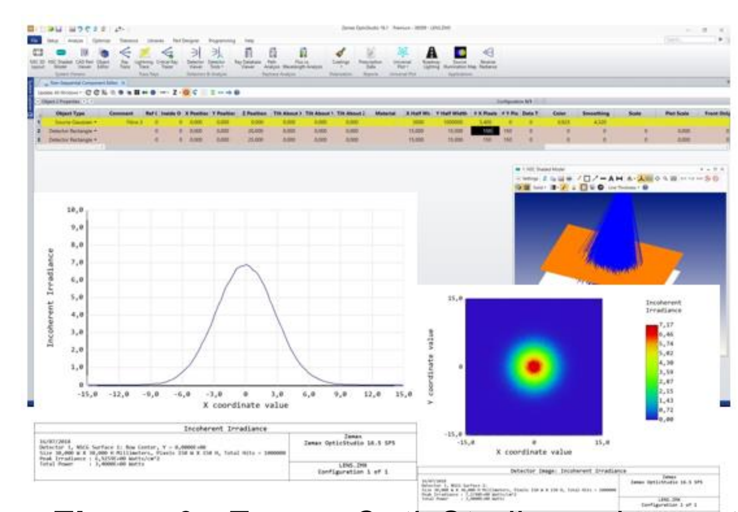

Figure.6 *- Zemax OpticStudio enviroment*

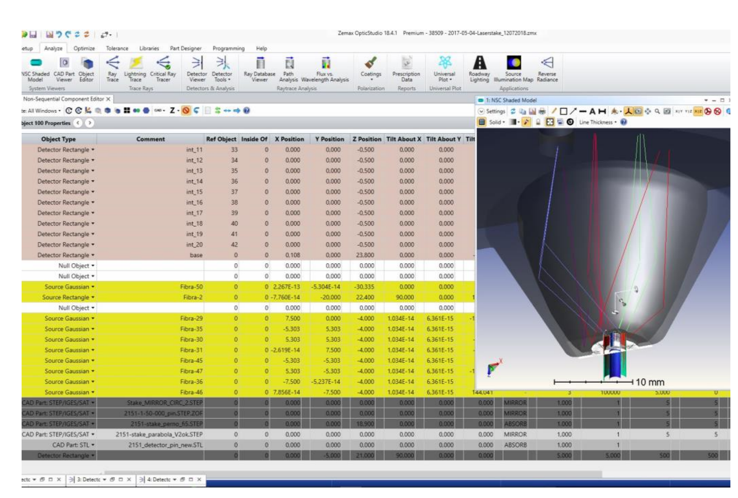

Figure.7 *- Waveguide model*

Laboratory tests were carried out to investigate the materials properties. Different examination was performed to inspect the absorption of the material and the power to reach the softening point.

In order to test this methodology for welding, a prototype was realized (Figure.9.a). The prototype allowed to modify energy density by changing the waveguide and laser support. Two systems were realized. In the first one the laser radiation, driven by metallic waveguides, reaches the component and after the emission a punch hits the pin. In a second configuration the punch loads the rivet during the emission. After this first phase a series machine was designed and assembled (Figure.9.b).

Tensile tests, microscopy, thermal imaging are considered to inspect the results (Figure.8).

To achieve good results with rivets, the plastic must not be heated too much, since a low viscosity fusion has a too high deformation. But materials fill with carbon black are too delicate with power. The plastic has thermal damage due to excessive surface absorption, so it is indispensable reduce the density of power and increase the cycle time.

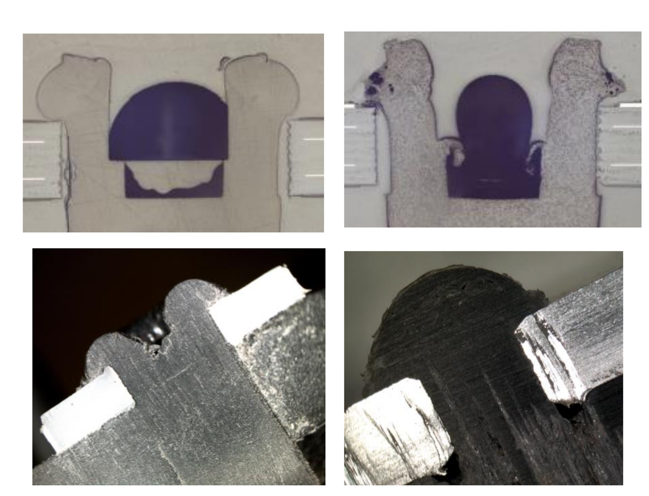

Figure.8 *- Microscopic analysis, photomicrograph of a riveted joint*

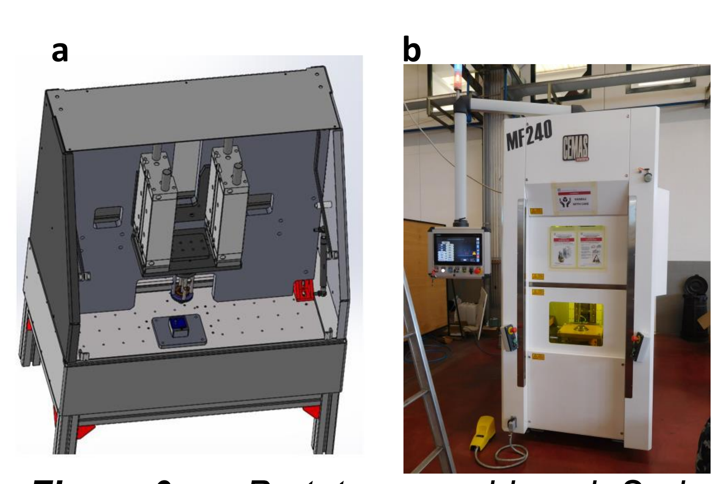

Figure.9 *- a. Prototype machine ; b.Series machine*

Future work

- Enrichment of the catalogue of analyzed material suitable for laser riveting.
- Study waveguides made of different materials, e.g. glass, PMMA.

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