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# STRUCTURAL INTEGRITY MEASUREMENT POSSIBILITIES BY L-FE DIGITAL-HOLOGRAPHIC GAUGE CAMERA

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**SUMMARY:** Holographic interferometry has already more than 50 years of experience in the highly sensitive, full-field and non-contact 3D deformation measurement of various objects – but mostly in laboratory environment. The transition to the industry started only about a decade ago with the maturity of its digital version. This transition is still going on and the Laser-FALCONEYE (L-FE) digital-holographic gauge camera to be introduced here is ready to take its share in this with its own industrial application examples in deformation and stress measurement. The selected applications deal mainly with structural integrity problems – but not exclusively.

## INTRODUCTION

Classical, photo plate based holographic interferometric measuring methods have already more than a half century past. However, their digital versions are not much older than a decade, at least not in real practical applicability. The transition from the closed laboratory rooms toward the real industrial environment started with the advent of small solid state lasers, high resolution digital image sensors and fast desktop computers. The Laser-FALCONEYE (L-FE) digital-holographic gauge camera [1-4] is one of the materialized forerunners in this process – which is undoubtedly far from being over yet. First of all, the usual holographic interferometric methods from the laboratories have to develop further their new features to be really viable in the outside world (at least five plus one: versatile, over-extending, heavy-duty, plus "insistent", "considerate" - and "synergistic"). Second, even more interdisciplinary bridges have to be found and crossed yet: to make the capabilities of holographic interferometry and the actual needs of the technical people of industry meet. L-Fe holocamera would like to push on this process further with its own application results.

## APPLICATION POSSIBILITIES - IN GENERAL

Holographic interferometry "sees" the deformation quite visually (like a sharp-eyed falcon): in the form of contour lines (interferometric fringe systems) overlapping the measured surface. It is a non-contact full-field, and 3D method. It works with high sensitivity of around 0.1 µm but in a relatively limited measuring range with upper limit about 10 µm. However, both limits can be overcome significantly with some extra efforts, as the limits of the field of view and the spatial resolution of the method, as well - which can be put basically around 50-100 mm in diameter and about 0.05 mm. As for the structural integrity inspections, deformation measurements can be useful along two lines: at the examination of the direct effects of actual operating loads - and at monitoring the effects of intentionally applied diagnostic loads.

First, deformation measurement of structures (or structure elements) at actual loads can identify the most deformed and therefore most critical parts (e.g. as seen in Fig. 1.) – and surface strain and stress distribution can be calculated, as well. On the other side, homogeneity of deformations can be controlled (and then properly adjusted if needed) - for example, to get more reliable material property data at their measurements. The precise material data must be vital to increase the accuracy of the lengthy FEA simulations. With real world deformation measurements, the simulation programs get even a direct possibility to validate their calculation results - from deformation side.

Second, deformation measurement at intentionally applied diagnostic loads can reveal many types of structural weakness information. In pressure vessels, the inner pressure increase can cause minor bulgings at local wall weaknesses, for example at corrosion faults. Similarly, welds on pressure vessels can be monitored the same way regarding their mechanical load transfer properties. Their deformation anomalies compared to their surroundings could be the most direct control possibility of their actual mechanical behavior.

A special and extremely useful diagnostic load is the usual blind hole drilling technique at stress measurements –used with strain gauge rosettes since about a century already. The main novelty of the holographic deformation measurement is here (e.g. as seen in Fig. 2.) that it can make the whole stress-relief deformation visible (and measurable) – making the stress evaluation much reliable. It makes it much easier and faster, too, and thus it provides a real practical possibility for detailed scanning of complete (residual or full) stress field distributions. Besides it works even on not easy to access areas (e.g. corners) and on rough surfaces, too. These easily available stress data can be useful not only for direct structural integrity evaluations, but once again, in the case of validation of FEA simulations, as well - in this case on stress level.

## APPLICATION POSSIBILITIES – HIDDEN DETAILS

The above application possibilities, and so the other ones still to come on the lecture, usually require a very high level of action flexibility from the originally only laboratory oriented techniques – and thus from their materialized industry oriented devices, as well. The industrially viable techniques and devices have to possess at least the following features on high level (or more).

First of all, they have to be versatile at clamping the several objects for the different investigations, where objects can have different size, shape, weight – and in addition objects may suffer very different accidental displacements at loadings. Second, they have to be over-extending, that is able to work somehow beyond their usual measurement range, too - because most structural integrity problem come out only at larger deformations. Third, they have to be heavy-duty to withstand well all the non-laboratory disturbances like vibrations, air currents, temperature fluctuations etc. Fourth, they have to be "insistent" to go after the unwanted rigid body motions left behind usually even at proper clamping. Fifth, as opposite to their over-extending feature, they have to be "considerate", too, to react promptly and stop at first sign of deformation - at dangerous hole drilling stress measurements. Finally, they have to be "synergetic" in their relationship with FEA simulations which has to be sustained already all along the measurements: from planning to evaluations.

## PERSPECTIVES

The transition from laboratory to the world of industry is on its way already for holographic interferometry. This is not without difficulties and not without rivals either. Nevertheless, the extreme basic sensitivity of holographic interferometry and its extreme overall quality of its full-field nature will certainly guarantee real successful applications in the high-tech industry of our days.

## REFERENCES


1. F. Gyimesi, Z. Fuzessy, V. Borbely, B. Raczkevi, G. Molnar, A. Czitrovszky, A. T. Nagy, G. Molnarka, A. Lotfi, A. Nagy, I. Harmati and D. Szigethy, "Half-magnitude extensions of resolution and field of view in digital holography by scanning and magnification", Applied Optics 48(31), pp. 6026-6034. (2009)
2. Z.Füzessy, F. Gyímesi and V. Borbély, "Upgrading Holographic Interferometry for Industrial Application by Digital Holography". in *Optical Imaging and Metrology: Advanced Technologies*, edited by. Wolfgang Osten, Nadya Reingand (Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2012), pp. 413-437.
3. J. Dobránszky, Zs. Lőrinc, F. Gyímesi, A. Szigethy and E. Bitay, "Laser welding of lean duplex stainless steels and their dissimilar joints", in *8th European Stainless Steel and Duplex Stainless Steel Conference 2015*, Conference proceedings, edited by Bruno Hribernik (Austrian Society for Metallurgy and Materials, Graz, Austria, 2015) pp. 138-147.
4. www.technoorg.hu, www.dr-gyimesi.hu

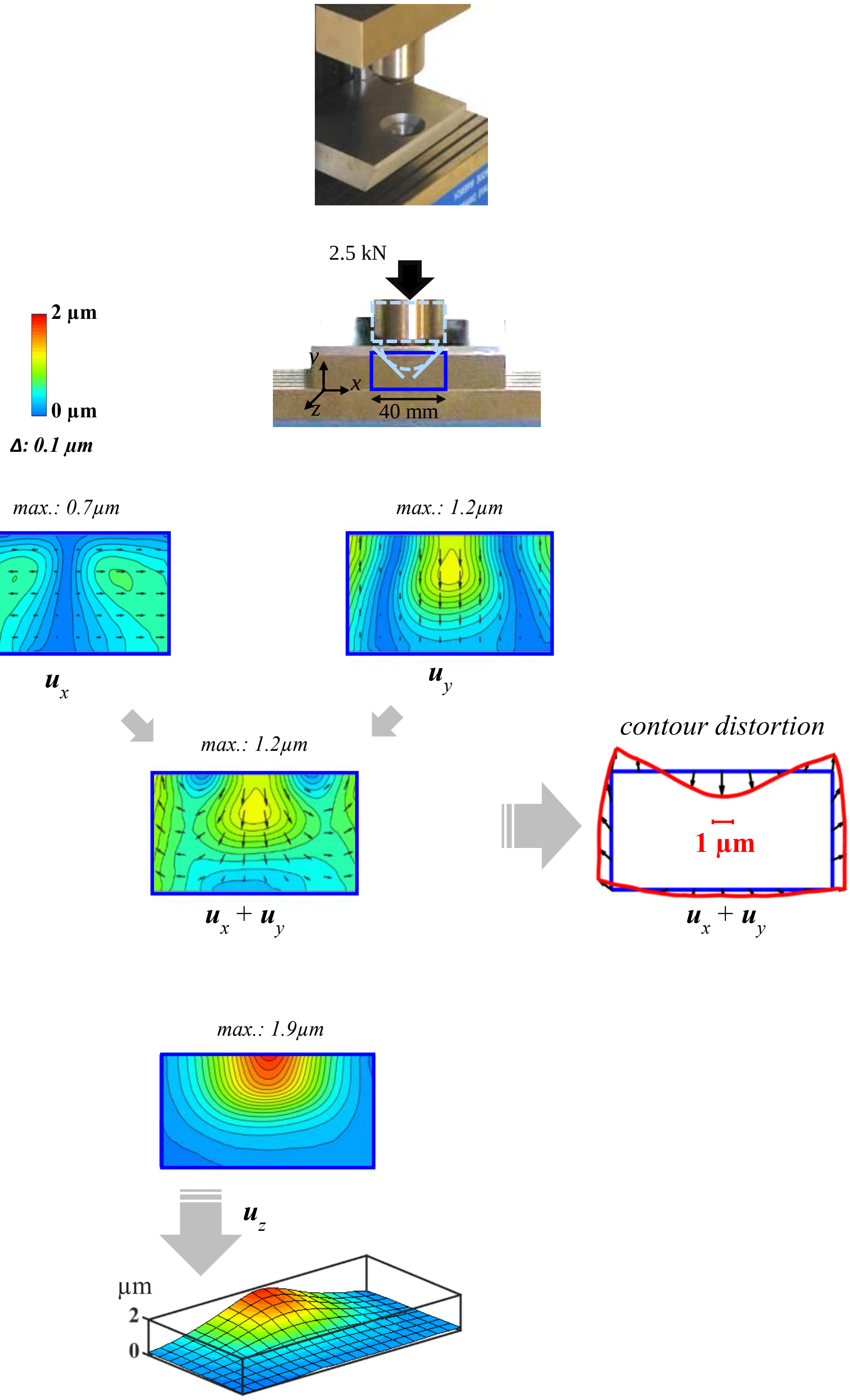


**Figure. 1:**

Deformation distribution at a "self-righting" free contact: "cone outside – sphere inside" surface pair

*(by components on the surface - and at the contour)*

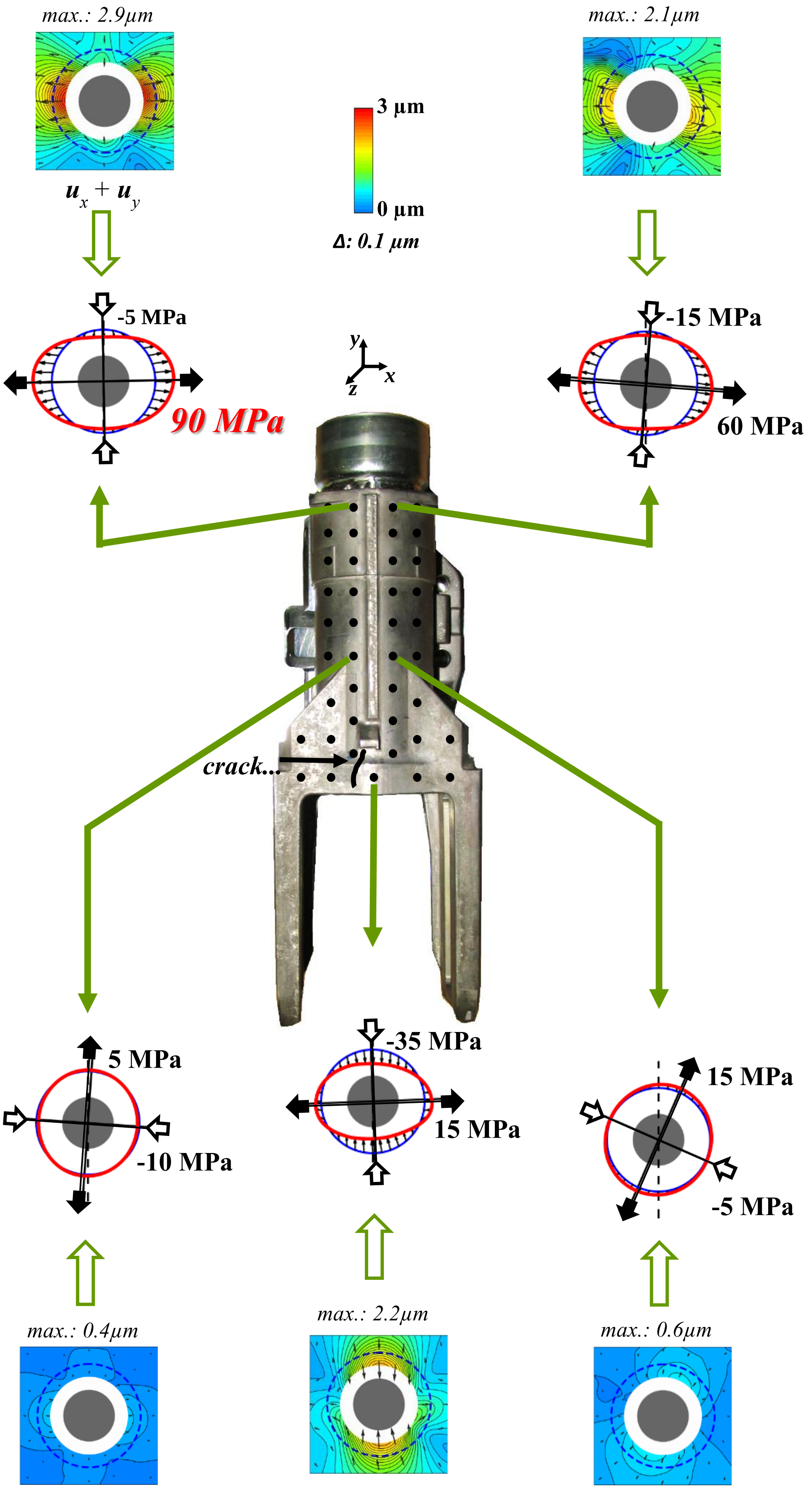


**Figure 2:**
Residual stress distribution at selected points of a stress-scanned aluminum steering bush