8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

On structural material diagnosis by instrumented indentation and neural networks

V.Buljak[1], E.J.Chiarullo[2] and *G.Maier[3]

[1] Technical University of Milan (Politecnico) buljak@stru.polimi.it

[2] Technical University of Milan (Politecnico) chiarullo@stru.polimi.it

[3] Technical University of Milan (Politecnico) maier@stru.polimi.it

Key Words: *Indentation test, Inverse analysis, Artificial neural networks.*

ABSTRACT

The computational assessments of safety margins in structural components of plants, infrastructures and buildings exposed to possible deterioration processes primarily requires reliable identification of the parameters to be input into the computing codes. Reference is made here to pipelines extensively employed by oil industries in remote areas. The practical objective pursued by current research is the development of a material characterization procedure endowed with the following features: non destructive, performable in situ, economically repetitive.

The procedure developed by the authors'team can be outlined as follows:
(a) indentation test at the macro-scale (a modern version of classical hardness tests)is carried out on structures no specimen extraction;
(b) "indentation curve" (loading and unloading force versus penetration) is recorded and digitalized by instrument associated to the indenter; (c) the imprint is mapped by means of laser profilometer, Fig.1; (d) the experimental data generated by phases (b) and (c) are computationally elaborated in order to generate their interpolations governed by a reduced number of "coefficients" apt to be input into an artificial neural network (ANN); (e) the ANN has been a priori optimized in its "architecture" on the basis of the planned numbers of experimental coefficients to input in it and of sought parameters as its output; (f) a three-dimensional large-strain finite element (FE) model has been generated for computer simulations of the indentation test using the material model to calibrate; (g) the ANN has been "trained" and "tested", once for all, namely its "weights" and "biases" have been identified and its accuracy checked by means of many (say hundreds) "patterns", each one including a vector of assumed parameters and the corresponding vector of measurable quantities generated by direct analysis through the FE model (f).

The above outlined innovative technique implies the solution of diverse computational problems. Those dealt with in this communication can be specified as follows: (i) sensitivity analysis by means of the FE model, in order to select the experimental data worth being gathered for the identification of the sought constitutive parameters; (ii) optimization of "hidden neurons" number in the ANN to avoid overfitting and to minimize the output perturbation due to input noise; (iii) ANN training by an hybrid procedure consisting of a genetic algorithm first, followed by

backpropagation algorithm with Bayesian regularization; (iv) comparative uses of polynomial approximation and of "proper orthogonal decomposition" (POD) for the transition from the experimental data (gathered by both instrumented indenter and profilometer) to the ANN input; (v) pseudo-experimental comparative assessment of the advantages achievable by possible additional experimental data on residual displacements measured by "digital image correlation" (DIC) on the indented surface.

The computational mechanics results presented herein are emerging from an industrial research project in progress with "Exploration & Production" Division of ENI and with Venezia Tecnologie.

Related results recently achieved by our team on improved indentation methodology at the microscale are available in [1], [2] and [3]. Indentation tests on pipelines are described in e.g. [4]. Inadequacy of indentation curve only was pointed out in [5].

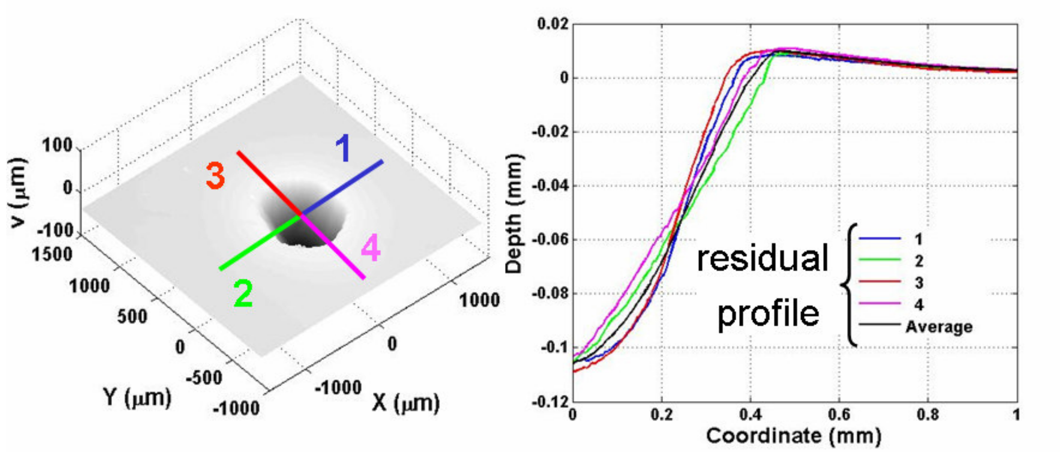

Fig.1- Residual imprint geometry generated by Rockwell B hardness test on steel

REFERENCES

[1] G. Bolzon, G. Maier, M. Panico, *Material model calibration by indentation, imprint mapping and inverse analysis*, Int. J. Solids and Structures, 41, 2004, 2957-2975.

[2] M. Bocciarelli, G. Bolzon, G. Maier, *Parameter identification in anisotropic plasticity by indentation and imprint mapping*, Mech. of Materials, 37, 2005, 855-868.

[3] M. Bocciarelli, G. Maier, *Indentation and imprint mapping method for identification of residual stresses*, Comp. Mat. Science, 39, 2007, 15-34.

[4] J.I. Jang, Y. Choi, J.S. Lee, Y.H. Lee, D. Kwon, M. Gao, R. Kania, *Application of instrumented indentation technique for enhanced fitness-for-service assessment of pipeline crack*, Int. J. of Fracture, 131, 2005,15-34.

[5] X. Chen, N. Ogasawara, M. Zhao, N. Chiba, *On the uniqueness of measuring elastoplastic properties from indentation: the indistinguishable mystical materials*, J. of the Mech. and Phys. of Solids, 55, 2007, 1618-1660.