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ORIGINAL ARTICLE

Mechanical properties evaluation for engineering materials utilizing instrumented indentation: Finite element modelling approach

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ABSTRACT – Instrumented indentation technique gives the possibility to determine the mechanical properties for small specimens and material in service. Several researchers have attempted to evaluate this approach experimentally and investigated the factors that affect it by using different indenter's geometries for different engineering materials. In this work, the instrumented indentation technique was used to evaluate the mechanical properties experimentally and numerically using finite element simulation to understand the contact mechanics between the indenter surface and the substrate for two types of steel alloys namely ASTM516-G70 and AISI1010 steel. Two shapes of indenters, blunt (spherical) and sharp (Vickers) were used. The results were then compared with the experimental results extracted from the instrumented indentation test. The results have demonstrated a good agreement between the experimental and the finite element simulation results with error bound a ±5% for young's modulus and ±7.7% for yield strength. Whereas excellent agreement is observed in the elastic region and the beginning of the plastic region for the true stress-strain curve. Finally, it is to be emphasized that the obtained results are more applicable for the tested materials and further research is recommended to accommodate other materials as well and to confirm the generality of this method.

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INTRODUCTION

An instrumented indentation test or sometimes called depth-sensing indentation instrument used to obtain mechanical properties such as hardness, Young's modulus, and yield strength by analyzing the load-displacement curve. The instrumented indentation test can be performed on a macro or nano-scale using a variety of indenters geometries and the load-displacement curve will represent the shape of the indenter. In microscale, indentation the hardness test was widely used to determine the effect of surface processing such as hardening or coating for different materials, due to the difficulty of performing another mechanical testing [1]. Instrumented indentation test is relatively new and still under development to be more flexible and trust-worthy in use in the field applications. The elastic-plastic response of materials during the indentation has been extensively investigated in the literature experimentally and theoretically [2-6,20]. Determination of the exact shape of the indenter at the tip is important to measure the mechanical properties such as the hardness and the elastic modulus for indentation depths less than a micro-scale [7].

The finite element method has been used to simulate the conical indentation hardness test of elastoplastic micropolar material by S. Hassan Sakchi *et al.* [8] Indentation load-depth curves were obtained, and the elastic modulus was calculated. Results justified and showed that the shapes of the plastic zones depend strongly on both the indenter angle and the ratio of young's modulus to yield strength. Where the yield zone of Aluminium (E/σ_y =157.1) is bigger than the yield zone of silicon (E/σ_y =28.8) [8].

Because of the non-linear nature of the indentation hardness test (elasto-plastic behaviour), it is quite hard to obtain the mechanical properties directly from the experimental load-displacement curve. J. A. Knapp *et al.* [9] attempted to characterize layers and thin films using finite element modelling. The yield strength, Young's modulus, and hardness of the layer material extracted, with an absolute accuracy of at least 20% [9]. Improving the test equipment for instrumented indentation method and consideration to the error sources such as the error due to pile-up or sinking in it is a way to make it more accurate. Test procedures and concepts are still demanding to improve the method that was introduced 10 years ago [10]. Recently, a good agreement between experimental Nanoindentation hardness test for bulk material and finite element simulation in a two-dimensional (2-D) axisymmetric model, and a three dimensional (3-D) model have been obtained by using finite element analysis [11]. Numerical simulations of pure copper, pure titanium, pure iron, and copper films were obtained using FE simulation. It is found that the result depended greatly on mesh size, indenter radius, and the hardening model used to simulate the indentation test [12]. Also, a finite element model for spherical indentation test for metallic substrates have been developed and the results were found to be relatively in close agreement to experimental data with a very minor effect of Poisson's ratio on the load-displacement curve; however, the polymeric materials was less successful because of the effects of anisotropy strain rate dependence e.g., a viscosity [13]. Continuous instrumented indentation test with the Oliver–Pharr method using Vickers's indenter under load values from (10 to 100 N) was

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Properties, Evaluation, and Control of Engineering Materials William A. Cordon,1979 Sustainability and Innovation Salah M. El-Haggar,2016-05-04 One of the most urgent problems facing the world today is environmental sustainability Current practices of pollution control waste treatment and environmental protection are not only hugely expensive and a burden on development but also unsustainable in the long run for their steady depletion of the world s natural resources Any solutions must have proven economic benefits be technologically viable and meet prevailing environmental and social perspectives The main objective of this new set of studies is to describe methods that help to protect the environment and conserve natural resources This can be achieved by applying the cradle to cradle concept which aims to use materials in closed cyclic loops without generating any type of waste or pollution The authors provide the reader with an introduction to basic concepts of sustainable development describe the mechanisms and benefits of related technologies and suggest potential uses on a practical level by examining innovations developed in the mechanical engineering laboratories of the American University in Cairo Particular focus is placed on innovation as a vital means of attaining sustainability A timely contribution to the debate on environmentally sustainable practices this book will be indispensable to environmentalists scientists economists engineers development specialists and policy makers as well as being of interest to the lay reader

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