Establishment of Relationships to Evaluate Mechanical Properties of Material by Indentation: Numerical Simulation based Approach

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In this study, new relationships are established to predict the mechanical properties of the material such as Young's modulus, yield strength, residual strain, fatigue strength and hardness numbers. The resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching, or wear is measured by hardness or indentation tests. Hardness is a characteristic of a material, not a fundamental physical property. The indentation test can be carried out in macro (10^{-3}), micro (10^{-6}), and nano (10^{-9}) scales according to the specimen sizes. Three-dimensional (3D) and axisymmetric (2D) nonlinear Finite Element (FE) simulations are used to represent the macro and nano-indentation. *ABAQUS* software is selected as the FE simulation platform. This study contains two main parts: (1) numerical simulation of macro-indentation and (2) numerical simulation of nano-indention. In structural health monitoring, detecting the material properties of damaged members of structures is a key item. At present, we need to conduct a series of laboratory tests to detect a set of material properties of a target material sample. It is difficult to find a single test that can be used to detect important material properties. The main focus of the first part of this study is to develop a macro-indentation testing method for evaluation of mechanical properties of metals based on numerical simulation of macro-indentation. When we consider the Nano-indentation, it leads to identifying the hardness properties of micro and nanoscale objects such as thin films, integrated circuits (IC) and, etc. The pile-up or sink-in effects can be observed in both macro and nano-indentation, which depends on the strain hardening coefficient of the target material sample. This pile-up or sink-in effect cannot be neglected in the nano-level as it obtains a considerable change of volume relative to the specimen dimensions. This leads to errors when extracting the hardness number and material properties. There are no direct relationships between the pile-up or sink-in effect and mechanical properties in nano-scale. The main focus of the second part of this study is to understand the behavior of the pile-up effect on nano-indentation by using 2D and 3D numerical simulations.

Key words: Macro-indentation, Mechanical properties of material, Nano-indentation, Nonlinear finite element simulation, Pile-up effect.

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