NEW INSTRUMENTATION AND ANALYSIS METHODOLOGY FOR NANO-IMPACT TESTING

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Nanoindentation testing has become increasingly popular for mechanical characterization of materials. This is motivated by the high versatility of the technique that allows testing of small volumes that could not be tested otherwise by macroscopic techniques, with minimal test preparation. The interest on nano-/microscale characterization of materials has been also extended to the study of high strain rate mechanical behaviour. One of the available techniques is nano-impact testing. It is carried out on a pendulum-based force-actuated, displacement-sensing device with the ability of performing energy-controlled impacts. The combination of conventional nanoindentation, for which a range of strain rates from 10^{-3} to 10^{-1} s^{-1} can be tested, with nano-impact provides a tool for materials characterization at the nano/microscale from 10^{-3} to 10^{3} s^{-1}.

Regarding the analysis of nano-impact test results, there has been no consensus in literature over what material metrics to extract from the test. Several authors base the analysis of nano-impact test on the calculation of a dynamic hardness defined as change in kinetic energy throughout the impact divided by the residual volume of indentation [1-4]. However, there are two issues with the assumptions in which this equation is based. First, it only considers the change in kinetic energy and it neglects other important contributions like the work of impulse force. Then, it assumes that hardness is constant throughout the entire impact period. While for self-similar indenters this is true in the loading part, Cheng's dimensional analysis shows that this is not the case in the unloading [5]. Therefore, the hardness calculated from this definition is not necessarily equal to the hardness under load commonly used in the instrumented indentation literature. To this end, an alternative analysis methodology is proposed. The analysis is based on the same definition of hardness under load commonly used in the instrumented indentation literature, computed as force divided by contact area. This way, the nano-impact hardness is directly comparable with results of conventional nanoindentation that use this definition. The instrumentation of the nanoindentation device with force-sensing capability was found crucial for the implementation of the analysis methodology. In addition, and in line with the nano-impact hardness definition in literature, an energy-based hardness is presented.

The technique is assessed using finite element simulations and by testing six materials covering a wide range of mechanical behaviours. The FE simulations are used to assess the two energy-based definitions of hardness, the one in literature and the one proposed in this work. It was found that the literature definition leads to values that differ significantly from the ones obtained as force divided by contact area. On the other hand, the proposed energy-based definition provides values that match the ones obtained by force-approach. The experimental results are also in line with this conclusions. The literature energy-based hardness presents significant differences compared to the force-based hardness, which are higher for the more elastic materials. Furthermore, the force-based hardness computed from nano-impact results was compared with the hardness from conventional nanoindentation. A close match is found between both set of results.

References

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