ADVANCES IN NDE IMPACT DAMAGE CHARACTERIZATION: WHAT DO WE FIND AND WHAT DOES IT MEAN?

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SUMMARY

The application of NDE high resolution damage diagnostics is a significant engineering challenge in many technology areas. Impact damage in terminal ballistics is one area of significant concern that has received considerable renewed attention over the past decade with the evolution and application of x-ray computed tomography, XCT, voxel diagnostic and 3D visualization techniques. The non-invasive spatial damage diagnostic approach with XCT presently appears to provide the only effective nondestructive modality for high resolution ballistic impact damage interrogation, spatial characterization, quantification, visualization, and 3D analysis. This XCT impact damage diagnostic approach has been successfully demonstrated by the author and his collaborators on armor ceramics (1-5), Ti-6Al-4V metallic armor materials (6) and, most recently, on a ballistic gelatin target (7). It has also been proposed for inclusion into predictive ballistic impact damage modeling (8).

The occurrence of sub-surface impact damage precedes the occurrence of penetration, and consequently, the ballistic performance of the armor material on both first and subsequent strikes may well depend upon the types, extent and morphology of such impact-induced damage. The armor materials research and development paradigm thus needs to be augmented from predominantly penetration testing to include significantly increased and aggressive impact damage characterization and analysis. To logically create armor ceramic materials with significantly improved penetration resistance, one first needs to improve their intrinsic damage tolerance and/or damage resistance. An essential step in that improvement process is the diagnosis and understanding of the physical nature of ballistic impact damage. A significantly improved characterization of the types, morphologies and extent of the impact-induced damage manifestations involved in a particular ballistic test, could enable us to begin to decipher the active material damage mechanisms and their respective contribution to the loss of the localized target structural integrity leading to penetration.

Examples of some of the dramatic results and visualizations of impact damage details previously unobserved and/or uncharacterized before the introduction of evolving XCT damage diagnostic techniques, shown in Figure 1, will be presented and briefly discussed. Included are observations of segmented (virtually isolated) penetrator fragments, novel cracking morphologies including 3D superimposed hour-glass shaped ring cracks and spiral cracking, 3D quantification and spatial mapping of damage fraction levels, impact-induced porosity, impact surface topological radial cracking, and surface debris. The full capabilities of the XCT diagnostic approach have not yet been reached. The beneficial utilization of this new impact damage knowledge has yet to be applied and exploited in many areas in addition to terminal ballistics.

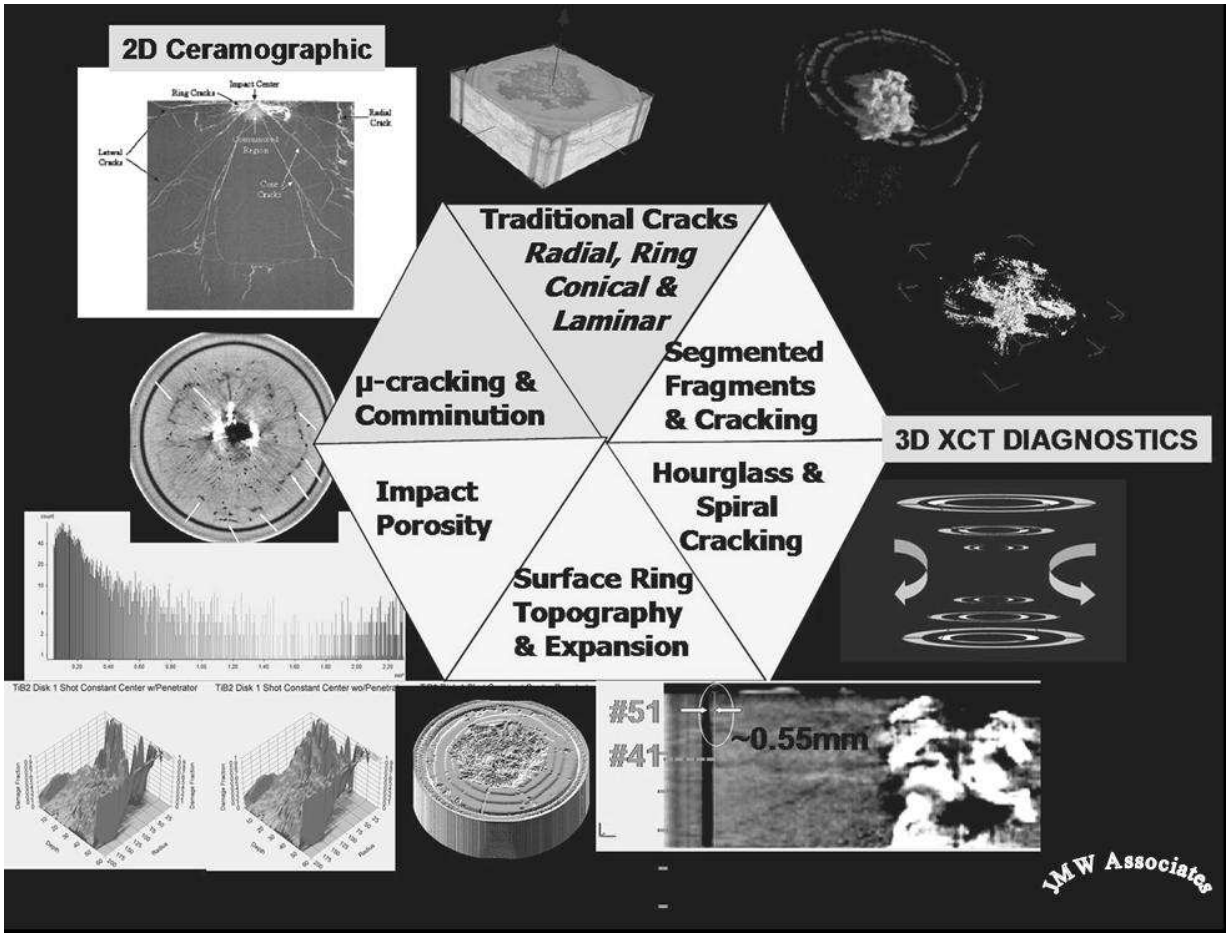

Figure 1. Representative examples of terminal ballistic impact damage details including those observed with both traditional destructive sectioning and those more fully characterized with non-invasive XCT damage diagnostic techniques.

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