BROAD APPLICATION WHIPPLE EQUATION

Kevin Deighton[1], Kirk Heuiser[1]

[1] Amentum Services, Inc, NASA Johnson Space Center, Astromaterials Research and Exploration Science, 2101 NASA Parkway Houston, TX 77058, United States

The Bumper 3 Micrometeoroid and Orbital Debris (MMOD) analysis tool is NASA's standard software for assessing the risk of MMOD penetrating a spacecraft's shielding. Bumper 3 employs Ballistic Limit Equations (BLEs) to determine the size of particle that causes a shield to fail, and this particle size is central to subsequent risk calculations. Many different BLEs are coded in Bumper 3, each with unique use cases generally based on the details of the shield configuration being assessed. It is the task of the Bumper 3 user to select the correct BLE for each region of the spacecraft being analyzed.

One of the most common shields used to defend spacecraft from MMOD is the Whipple shield, in which a sacrificial outer wall causes the incoming particle to break up, melt, or vaporize, forming a cloud of debris that is less damaging to the critical rear wall than a strike by a unitary particle. In a Bumper 3 analysis, the New Non-Optimum (NNO) equation is currently the preferred BLE for assessing generic Whipple shields. However, the equation assumes that the thickness of the outer wall meets a minimum design threshold to fully shock the projectile. If it does not, an alternate BLE, known as Reimerdes, must be used instead to derate the shield's capability accordingly. Previously, it was the responsibility of the analyst to determine which of these two equations to use. A novice user may incorrectly assume an excessively thin wall to be adequate and use the NNO equation when Reimerdes should have been employed. Doing this will overestimate a shield's performance and underestimate risk. When the proper outer wall threshold check is performed, doing so places the burden of manual labor on the analyst.

The Broad Application Whipple BLE was written to automate the task of performing this outer wall threshold check. The Bumper 3 user enters the relevant shield information, such as wall thicknesses, then the code performs the threshold check internally and selects the appropriate Whipple shield BLE. This removes the possibility of the analyst inadvertently selecting the wrong equation and unknowingly producing erroneous results. It also reduces the analyst's workload by moving this previously manual task into the software.

The Broad Application Whipple BLE also incorporates other features that have previously been the responsibility of the user. An outer wall specified only with an areal density, as is common with blankets, can be directly entered and will be converted into an equivalent wall of aluminum within the BLE. The NNO BLE is only designed to consider failure as perforation of the rear wall. If an analyst wishes to consider a crater depth short of perforation as the failure, an adjustment to the wall thickness previously needed to be made outside of Bumper. The Broad Application Whipple BLE brings this adjustment internal to the code with a user-friendly interface. Kevlar™ blankets are a popular tool to increase MMOD protection. For a configuration at the design stage, not yet tested to derive a custom BLE, Kevlar™ blankets need to be converted into an amount of aluminum with an equivalent performance, which has been established through laboratory testing. The Broad Application Whipple BLE incorporates such an equation for easy application of Kevlar™ protection.