SSRMS

Test Program Description

Spar Aerospace Ltd. is currently designing and building the Space Station Remote Manipulator System (SSRMS) as part of Canada's contribution to the International Space Station (ISS). The SSRMS is comprised of long composite booms made from PEEK/IM7 (PolyEtherEtherKetone / Carbon fibre) composite, which are manufactured by FRE Composites Inc. The SSRMS is shown in the accompanying picture.

The objective of this study was to develop an experimental hypervelocity impact (HVI) database for this advanced thermoplastic composite. The database would permit the development of damage models for the material. Using these models, the vulnerability of the SSRMS to MOD impacts was assessed, and protection systems were added in order to reduce the probability of failure due to MOD.

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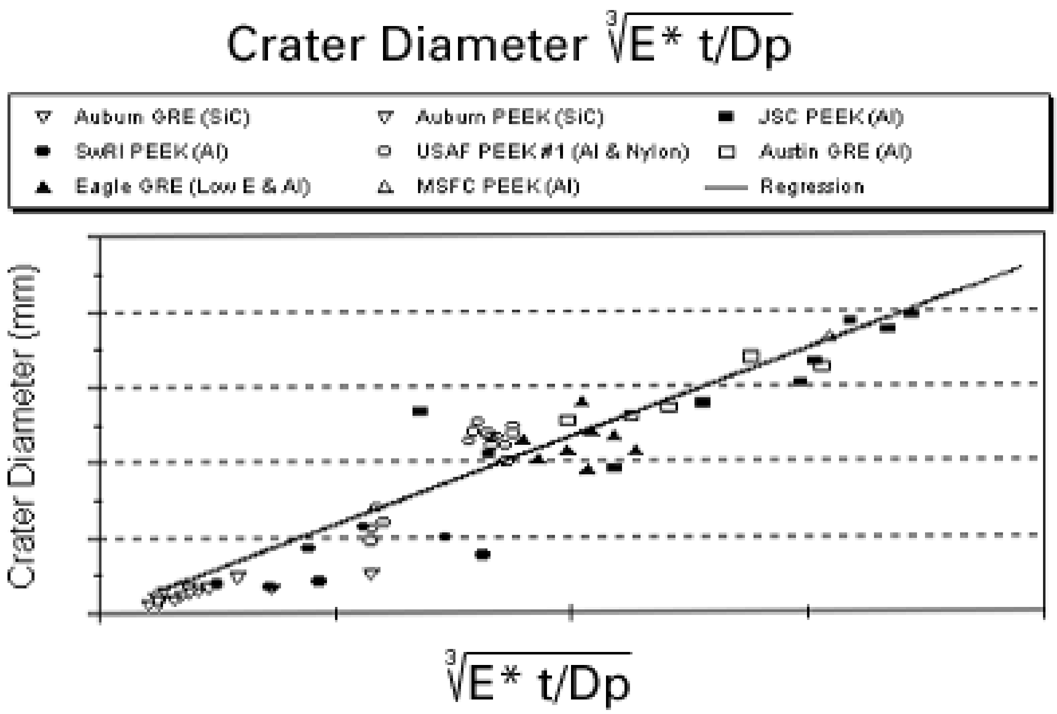
Test Program Results

Initially, 17 hypervelocity experiments into SSRMS PEEK composite plates were performed at the Hypervelocity Impact Technology Facility (HITF) at the NASA Johnson Space Center (Houston, TX), the NASA Marshall Space Flight Center (Tuscaloosa, AL), and the Southwest Research Institute (San Antonio, TX). Each HVI experiment has been fully analysed which allowed for the development of models relating damage to the projectile and target material characteristics (namely projectile diameter, velocity, energy, and target thickness, etc). These results are portrayed in a series of graphs like the one below:



The graph correlates the crater diameter (Dc) produced in an impact involving a particle of a certain energy (E), diameter (Dp), and and SSRMS composite plate of thickness (t). The legend details the source of the data, the target material, and the projectile material respectively. This result is an amalgamation of the data produced in this current research with that found in other published reports. Most projectiles are aluminum, though some shots involve glass and nylon projectiles. The targets are primarily PEEK/carbon fibre composite (used in the SSRMS booms). However, some shots involving GRE targets (with similar material characteristics as PEEK) were found to correlate well and are included in this model as well.

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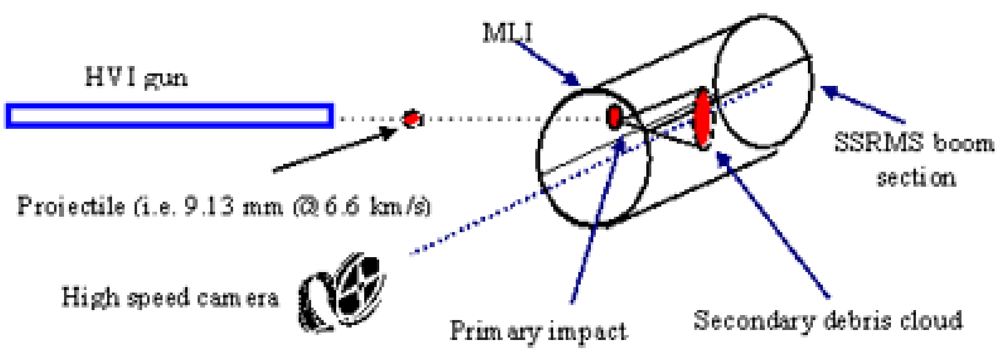
Test Program Results

A subsequent test series, consisting of 6 HVI experiments, was conducted in February, 1996, using actual SSRMS composite boom segments supplied by Spar Aerospace Ltd. The experiments were performed using the .50 Cal two-stage light gas gun, located at the HITF. The general target assembly for these shots consisted of a boom segment, 30 cm long and 33 cm in diameter, complete with a square sheet of MLI (25 cm by 25 cm) mounted on the exterior surface of the front wall. A simulated cable harness unit was mounted on the exterior surface of the rear wall.

Aluminum spherical projectiles, 3.16 mm to 9.3 mm in diameter, traveling at velocities ranging from 6.4 km/s to 6.91 km/s, were used in all of the experiments. Only normal impacts were performed. The basic experimental configuration employed for all 6 shots is sketched below:



As a result of these experiments, the secondary debris ejected out the rear of the crater was found to cause extreme damage to the rear wall of the boom. In essence, the damage created on the interior wall of the SSRMS boom is much larger than that caused by the primary impact.

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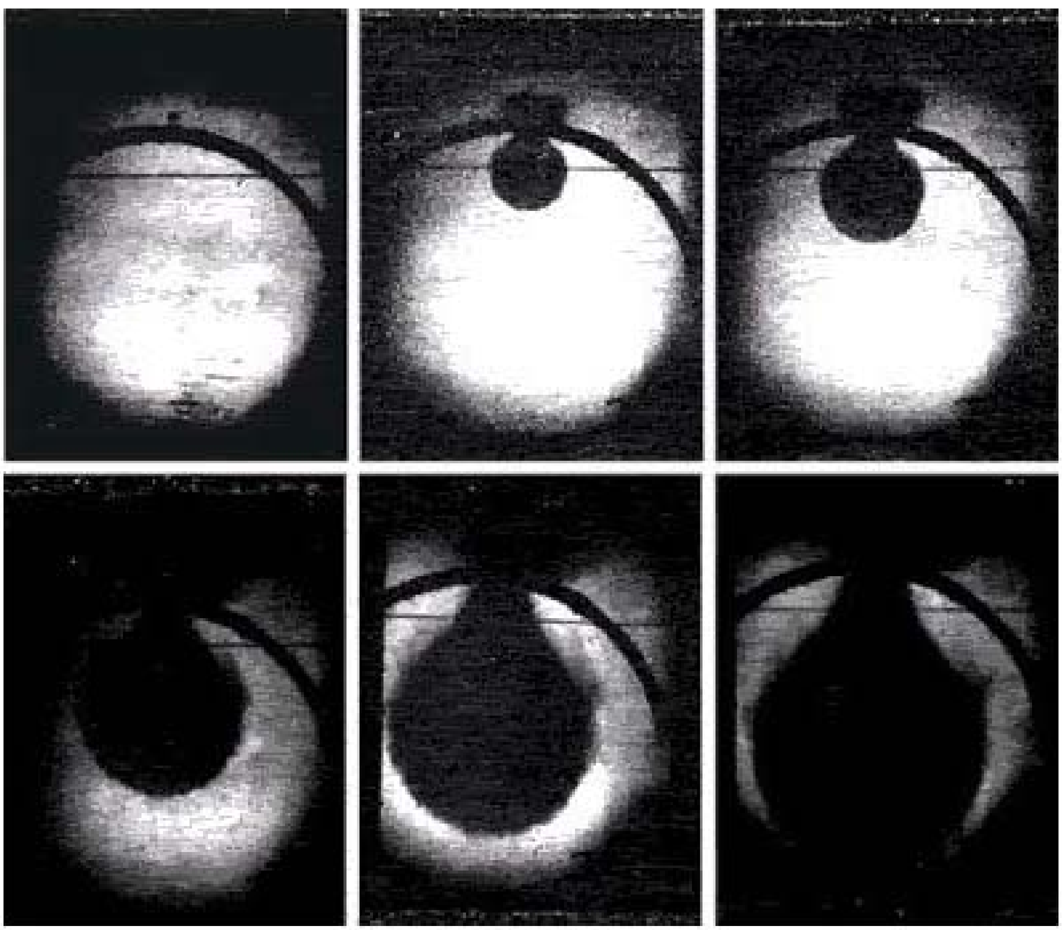
Test Program Results

An excerpt of the high-speed film produced in the SSRMS test #4 is shown here. In the first frame, the incoming projectile can be seen just prior to impacting the surface of the boom. In the subsequent frames, the formation of the secondary debris and ejecta clouds is clearly apparent. Analysis of the debris cloud velocity reveals that the cloud tip travels at approximately the same velocity as the projectile.



This graphic illustrates why the secondary debris cloud is a greater threat to the SSRMS booms than that of the primary impact.

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Test Conclusions

The probability of this type of structural damage, caused by the secondary debris particles, was estimated to be less than 0.2% over the SSRMS' 10 year mission. The probability of failure due to an MOD direct impact with the cable harnesses however was much higher. This high probability ultimately resulted in the decision to wrap protective Nextel AF-10 fabric around the cable bundles to reduce the risk of MOD damage.

A paper, which describes this study in detail and written by G. D. Shortliffe and R. C. Tennyson, can be found on-line at the Canadian Aeronautical and Space Journal (CASJ) site.