

Effectiveness of Photogrammetry-Based Three-Dimensional Modeling for Post-Crash Test Vehicle Inspection

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Post-crash vehicle inspection is essential for understanding deformation of the body structure, failures of joints and welds, and positional changes of fuel- and electrical-system components, and for correlating these findings with simulation results. Conventional photographs preserve color and local damage states, but they only record preselected viewpoints. Three-dimensional point measurement can obtain accurate coordinates at predefined locations, but it cannot continuously capture surface geometry. In addition, post-crash vehicles are subsequently measured, disassembled, and discarded, which creates strong time and space constraints for re-inspection. Therefore, this study investigated the effectiveness of photogrammetry as a complementary method for post-crash inspection by generating textured three-dimensional models of crash-tested vehicles.

Images were acquired using a Sony $\alpha 7S$ III with an FE 16–35 mm F2.8 GM II lens at a shooting distance of 0.8–1.0 m, focal length 20 mm, aperture F14, and ISO 400–640. A ring flash and cross-polarization filters were used to suppress cast shadows and specular reflection. The target vehicle was photographed from multiple directions and heights so that both overview images and close-up detail images overlapped continuously. After RAW development, camera alignment, scale setting, and textured mesh generation were performed in RealityScan. For a frontal crash vehicle, the front structure, lower instrument-panel area, and underbody were recorded within one hour, which corresponds to a practical operation time for post-test work.

Shape reproducibility was verified by comparing a photogrammetry model with a high-accuracy laser-scanned reference model of an aluminum die-cast component approximately 1 m in size. After best-fit alignment, 200 points were randomly sampled from the general exterior surface and another 200 from rib and edge regions. The deviation color map is shown in Fig. 1. The standard deviation of surface deviation was 0.072 mm on the general exterior surface and 0.167 mm in ribs and edges, indicating high geometric reproducibility on ordinary exterior surfaces while showing the expected increase in error at sharp, recessed, and optically difficult regions. In application to post-crash vehicles, the three-dimensional model enabled inspection of frame buckling, weld failure, sheet failure, and component shift while preserving the positional relationship with surrounding structures. Representative inspection examples are shown in Fig. 2. The model also remained available after the real vehicle had been disassembled or scrapped, which improved information sharing with remote stakeholders and post-test comparison with simulation and design data.

To clarify the influence of shooting conditions, an L9 orthogonal array was used for four factors: shooting distance, number of images including horizontal interval and number of vertical levels, aperture, and ISO sensitivity. Polygon count and mean feature-point error were used as response variables. The contribution ratios of the four factors are summarized in Table 1. The contribution ratio for polygon count was 39.94% for shooting distance and 40.68% for the number of images, while the contribution of the number of images to mean feature-point error reached 78.07%. These results indicate that image continuity and overlap have a greater influence on model quality than exposure parameters, although aperture and ISO sensitivity remain important for suppressing blur, noise, and local reconstruction errors caused by reflection. Photogrammetry is not intended to completely replace conventional photography or point measurement, but rather to complement them by continuously recording geometry and texture around important damage locations. Based on these results, the photogrammetry-based three-dimensional modeling method was demonstrated to be effective in mitigating temporal and spatial constraints in post-crash vehicle inspection and in facilitating information sharing among relevant personnel.

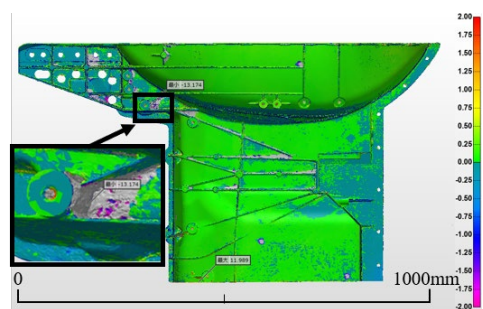


Fig. 1 Deviation color map relative to the laser-scanned reference model.



Fig. 2 Examples of post-crash inspection using the three-dimensional model.

Table 1 Contribution ratios of shooting-condition factors.

Factor	Contribution ratio for polygon count [%]	Contribution ratio for mean feature-point error [%]
Shooting distance	39.94	5.14
Number of images	40.68	78.07
Aperture (F-value)	9.38	11.10
ISO sensitivity	9.99	5.70