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Photometric Data Acquisition Procedures for Impact Test

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) defines the test set-up requirements, general analysis procedures, and test report documentation for impact tests where photometric analysis of the high speed film or digital video will be required to obtain target paths (typically the Anthropomorphic Test Dummy (ATD) head path and knee path). Such tests support the requirements of AS8049 - Performance Standard for Seats in Civil Rotorcraft, Transport Aircraft and General Aviation Aircraft.

These setup and analysis procedures are applicable to conventional, geometry based, two-dimensional analysis. If a more sophisticated technique that allows cameras to be installed at oblique angles for two or three-dimensional analysis is used, then the specific procedures required by that technique supersede any conflicting procedures contained herein. Some of the requirements that could be superseded include camera placement, optical data channel evaluation, camera to subject measurements, and scaling procedures.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J211-2 Instrumentation for Impact Tests - Part 2: Photographic Instrumentation

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2.2 Definitions:

AIRCRAFT SEAT COORDINATE SYSTEM: An orthogonal XYZ axis system fixed to a known point on the seat. The axis orientation is X parallel to the local seat forward-aft direction, Y parallel to the local seat lateral (left-right) direction and Z parallel to the local seat vertical (up-down) direction.

ANALYSIS SYSTEM: A system for measuring and collecting the coordinates of image points as a function of time and converting them into full scale coordinates in object space.

DATA COLLECTION: The process of measuring and recording the digital XZ location of target centers when viewing or processing the images on an analysis system.

FIELD OF VIEW (FOV): The area of the test set-up that is recorded by film or video.

FOCAL LENGTH: The distance measured along the lens axis from the rear nodal point to the plane of best definition of an object located a long (infinite) distance from the lens. It also indicates the angular coverage of the lens. For a given picture size, wide-angle lenses have short focal lengths, and narrow angle lenses (e.g., telephoto lenses) have longer focal lengths.

FRAMES OF INTEREST: The film or digital video frames beginning at the initial impact event and continuing as long as required to adequately assess the interaction between the occupants and the airplane interior representation.

IMAGE PLANE COORDINATES: For analysis of film, the coordinate system of the digitizer tablet or digitizing scanner. For analysis of digital video, the pixel coordinates of the video screen containing the image being analyzed. Image Plane Coordinates are mathematically interpreted to yield full scale coordinates.

LENS CORRECTION: The process of mathematically displacing the measured position of targets from their original location in the image plane to the location where they would have been if there was no lens distortion present in the system.

MOTION PLANE: A plane parallel to the Sled XZ plane.

OPTICAL AXIS: A straight line that passes through the centers of curvature of the camera lens surfaces. (In a perfectly aligned camera system, this line would intersect the image at the center of the image.)

OPTICAL DATA CHANNEL: A system composed of an image taking device (for example, camera and lens), a recording medium for those images (film, disc, magnetic tape), an optical path (for example, fiber optic cable), and a system for analyzing the images including any analysis procedure.

PARALLAX: The apparent displacement of objects located in different motion planes (related to the angular displacement of the objects from the optical axis) caused exclusively by the separation of the motion planes.

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2.2 (Continued):

PERSPECTIVE: The apparent difference in the size of the image of an object as it is positioned closer to or further from a camera. [For the same initial image size, a lens having a short focal length (wide-angle lens) produces a greater perspective effect than a lens having a long focal length (telephoto lens)].

SCALE FACTOR: The actual distance between two targets in a motion plane divided by the distance between the two targets measured in Image Plane Coordinates.

SCALING TARGETS: Targets within the FOV that are attached to a rigid fixture either on or off the sled. Used to determine the scale factor for converting the collected data into full scale coordinates.

SLED: The vehicle holding the seat, restraint, anthropomorphic test dummy, aircraft interior features, targets, and any other items necessary for the impact test.

SLED COORDINATE SYSTEM: An orthogonal XYZ axis system that moves with the sled. For horizontal sled systems, the axis orientation is X horizontal and parallel to sled motion, Y horizontal and perpendicular to the sled motion, and Z vertical.

SLED REFERENCE TARGETS: Targets within the FOV that are attached to a rigid fixture on the sled. Used to normalize the collected data to the Aircraft Seat or Sled Coordinate System.

VALIDATION TARGET PAIR: A pair of targets placed in the field of view such that the distance separating them remains constant, and such that they are both visible throughout the impact test. Used to assess overall analysis accuracy.

3. TEST EQUIPMENT AND SETUP:

3.1 Cameras:

3.1.1 Camera Placement and Coverage: To simplify analysis, the camera should be placed such that its optical axis is parallel to the Sled Y axis. If the camera is not oriented in this manner, the analysis procedure must compensate for that angularity. Note that this alignment's effect on overall accuracy increases when a wide-angle lens is used.

The recorded image of the sled, seat, and ATD should fill the FOV as fully as possible consistent with coverage of the impact event.

3.1.2 Optical Data Channel Evaluation: The performance of the optical data channel shall be evaluated per SAE J211-2, and after application of any lens corrections, the Overall Error calculated shall not exceed 1%. If a zoom lens is used, the evaluation shall be performed with the same focal length setting as used in the tests requiring photometric analysis. Alternatively, if a zoom lens can be shown to meet this requirement (without lens correction) at any two focal length settings, then the lens can be considered to meet the requirement without further evaluation at any focal length setting within that range.

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3.1.3 Camera Frame Timing: A time origin identifier shall be visible on the film/digital video in order to correlate optical data with electronic data. The time origin identification shall be at or prior to the impact event. The accuracy of the method shall meet the requirements of SAE J211-2.

A time base of the accuracy specified in SAE J211-2 is required. For film cameras, an on-film numeric time indication or timing mark of a known frequency shall be used to document the camera frame rate. On-film timing mark frequencies equal to or greater than 100 Hz are recommended. Each frame of digital imagery shall have a related numeric time indication.

3.1.4 Camera Frame Rate Requirements: The nominal frame rate shall be 500 frames/second (or greater).

Film cameras shall start in advance of the impact test as required to stabilize film speed.

3.2 Photometric Targets:

3.2.1 General Requirements: The centers of the targets shall be easily discernible during data collection. The targets are typically 5 cm (2 inches) in diameter and cover at least 1/100 of the FOV width covered by the camera. The targets shall be of contrasting colors or shall contrast with their background.

3.2.2 ATD Target Placement: As a minimum requirement, targets shall be placed on the ATD head center of gravity (CG) (as defined in the applicable ATD drawings) and the center of the knee pivot. The head target can be located at the head center of gravity by inserting a pin through the center of the target and through the head flesh into a guide hole in the skull that is at the exact location. The knee target shall be fixed to the ATD and not the ATD clothing.

If rotation of the ATD head is of interest, or if the ATD head target might be obscured by ATD motion during the test, a pair of targets may be placed n the side of the head or rigidly mounted not more than 15 cm (6 inches) from the head. The relationship between these additional targets and the CG of the ATD head must be measured and documented. The target mounts should be light in weight to limit the affect on the ATD's initial position and dynamic performance.

The ATD shirt shall be form fitting so that it does not billow out and obscure targets during testing. Shirt sleeves may be taped to the ATD's arms if the movement of the arms is not affected.

3.2.3 Reference Target Placement: Two Sled Reference Targets shall be mounted rigidly on the sled. These targets are used as a sled location and orientation reference in the photometric analysis. These targets shall be separated by at least one third of the FOV width, and remain visible in all frames of interest. They shall lie in a plane that is parallel to the Sled XZ plane and on a line that is at a known angle to the Sled XY plane.

Additional Sled Reference Targets may be mounted to ensure that a pair of reference targets are visible in each frame utilized in the photometric analysis. Each pair of targets utilized as Sled Reference Targets shall meet the target pair relationship requirements stated above (separation, planar, known angle).

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3.2.3 (Continued):

Two Scaling Targets shall be mounted rigidly on or off the sled to allow image scaling. These targets shall be separated by at least one third of the FOV width, and lie in a plane that is parallel to the Sled XZ plane. The distance between these targets is referred to as the Scaling Length. If desired, the Sled Reference Targets may also be used for this purpose.

To simplify analysis, both the Sled Reference and Scaling Targets should be in the same plane as the motion plane of the primary target of interest, typically the ATD head target. If this is not practical, they should be mounted as close to that plane as possible. The goal in placing these targets should be to achieve the maximum separation between each target pair, while keeping them visible in all frames of interest. Increasing this separation distance reduces the global scaling and/or normalization errors induced by those target's Data Collection Error.

Two additional sled mounted targets, referred to as the Validation Target pair, shall be mounted as specified in SAE J211-2. If all targets are not in the same motion plane, then the target pair should be placed in a motion plane other than the one containing the scaling targets to allow assessment of the parallax and perspective correction methods employed. The actual distance between these targets is measured pre-test and then compared to the analysis results to assess overall analysis accuracy as described in 4.8.

The mounting surface for all of these reference targets shall be rigid enough so that the distance between the targets does not change during the sled impact.

3.3 Measurements:

The following measurements shall be made after final placement of the camera(s), placement of the ATDs, and adjustment of the restraint system. Any target locations that are affected by floor deformation must be measured after deformation is imposed. The measurements shall have an accuracy of ±3.0 mm (0.1 inch) except as noted.

3.3.1 Photometric Target Measurements: The XYZ locations of all targets shall be measured in the Sled Coordinate System with respect to a common origin. However, the X and Z measurements of the ATD targets (usually the head center of gravity and knee targets) are optional.

The angle between the line on which the Sled Reference Targets lie and the Sled XY plane shall be measured or calculated. If measured this measurement shall have an accuracy of ±0.5 degrees. Additional points measured in order to calculate this angle do not need to be targeted.

3.3.2 Seat and Seat Track Location Measurements: The purpose of measuring the location of a point on the seat is to provide the location of a rigid, known point, relative to the Sled Reference Targets, to which the derived target paths can be referenced.

For conventional track mounted seats, the XYZ location of the intersection of the centerline of the front stud and the plane of the top of the seat track is the preferred reference point.

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3.3.2 (Continued):

The point selected shall be defined on seat envelope drawings and easily accessible in the test set up for measuring. This point shall be identified in the dynamic test plan and its XYZ location measured in the Sled Coordinate System with respect to the same common origin used in 3.3.1. This location does not need to be targeted.

The angle between the Aircraft Seat Coordinate System X axis and the Sled X axis shall be measured or calculated. If measured, this measurement shall have an accuracy of ±0.5 degree. Additional points measured in order to calculate this angle do not need to be targeted.

3.3.3 Camera to Reference Target Measurement: The Y distance from the camera image plane to the Sled Reference Target plane shall be measured as an accuracy of ±0.5%.

4. PHOTOMETRIC ANALYSIS:

4.1 General Analysis Procedures:

For manual data collection, the projected image on the digitizing tablet or video screen shall be sufficiently large to clearly identify the centers of the targets. One person shall perform all of the optical data collection for each test.

The minimum nominal sampling rate for analysis shall be 500 Hz (e.g., every frame for frame rates of 500 frames/second, every other frame for frame rates of 1000 frames/second, etc.).

Data shall be collected sufficiently before and after the frames of interest so as to enable stabilization of data filtering for smoothing techniques used in the analysis.

4.2 ATD Target Data Collection:

Typically, the ATD head center of gravity and knee pivot target image plane coordinates shall be collected for all frames of interest. If tight framing causes the head CG target to be out of frame during the early part of the sled impact, the loss of the early portion of the head path is acceptable provided the estimated missing portion of the head center of gravity target path would clear the airplane interior surfaces.

The image plane coordinates of targets that are temporarily obscured may be interpolated from measurements of nearby features in the same frame. For example, an ATD head center of gravity target obscured by the ATD arms can be found from the ATD's nose and back of head or from the supplemental head targets. Determining obscured target locations by using curve-fitting methods is not acceptable.

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4.3 Reference Target Data Collection:

The image plane coordinates of the Scaling Targets shall be collected for at least one frame.

The image plane coordinates of the Validation Target Pair shall be collected per SAE J211-2 for all frames of interest.

The image plane coordinates of the Sled Reference Targets shall be collected for all frames of interest.

4.4 Lens Correction:

The locations of the collected targets shall be adjusted to compensate for any significant image distortion present as indicated by the results of the optical channel evaluation called for in 3.1.2. The mathematics used to make these corrections is based on the results of a camera calibration that compares the derived versus actual location of a known pattern of targets.

4.5 Scale Factor Calculation:

The scale factor for images in a given motion plane can be obtained by dividing the actual distance between two targets by the distance between those two targets in image plane coordinates. The scaling factor for images in any other motion plane can be obtained directly, as above, or can be derived from a known scaling factor by multiplying that factor by the ratio of the camera image plane to the motion plane distances.

4.6 Perspective and Parallax Correction:

All error due to Perspective and Parallax must be corrected. The mathematics used to make these corrections is based on the measured camera and reference target locations.

4.7 Data Normalization:

The target coordinates from each collected frame shall be normalized by removing any relative translation or rotation between the camera and the sled, as indicated by the observed motion of the Sled Reference Targets.

The normalized target coordinates should then be transformed into the Aircraft Seat Coordinate System or the Sled Coordinate System by using the reference point and angles measured in 3.3.2.

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