QUANTIFICATION OF OCCUPANT DYNAMICS, DELTA V & ACCELERATION ASSOCIATED WITH VEHICLE COMPONENT DAMAGE IN SIDESWIPE IMPACT

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INTRODUCTION

In minor sideswipe impacts, displacement of the vehicle side rearview mirror often occurs along with aesthetic damage to the body panels. In these impacts, can the dynamics exceed tolerance levels for human biological tissues? Drop testing was conducted to quantify the Energy required to dislodge side rearview mirror housings. The test procedure and mathematical models followed a peer-reviewed protocol approved by a panel of qualified experts with experience in Dynamics and BioMedical Engineering. The drop tests were conducted from various heights corresponding to related quantifiable impact velocities. The drop test results allowed for quantification of the Energy associated with displacing the side mirror. Peer-reviewed conservation of Energy and Momentum analyses were performed in order to compare the Energy required to displace the side mirror with the relative occupant pre-and post-impact Kinetic Energies.

BACKGROUND

Previous research has shown that the Peak Gs experienced by vehicle occupants in minor sideswipes are relatively small. Tanner, et al, reported vehicle Delta Vs of 0.7 to 0.85 m/s with associated driver Peak Gs of 0.8 to 1.2 g when a stationary car was hit by a 2.2 m/s bullet vehicle [1]. Bailey, et al, found that the occupant acceleration for sideswipe impact was within the driving maneuver envelope [2].

THEORETICAL CONSIDERATIONS

Peer-reviewed conservation of Energy analyses were performed in order to estimate the Delta V associated with sideswipe impact. Assuming the vehicle had pre-impact Kinetic Energy KE_i, post-impact Kinetic Energy KE_f, dissipated Energy associated with deformation of the vehicle structure $E_{deformation}$, and dissipated Energy associated fracture and rotation of the mirror $E_{fracture}$ and $E_{rotation}$ yields:

$$KE_i = KE_f - E_{deformation} - E_{fracture} + E_{rotation} \tag{1}$$

The pre/post-impact Kinetic Energies are related to the vehicle mass with and without the mirror component m_v and $m_{v\text{-}m}$ and pre/post-impact speeds v_i and v_f.

$$\frac{1}{2}m_v v_i^2 = \frac{1}{2}m_{v-m}v_f^2 - E_{deformation} - E_{fracture} + E_{rotation} \tag{2}$$

The Energy dissipated via the vehicle structural deformation is related to the applied Force F and the crush distance d.

$$E_{deformation} = Fd \tag{3}$$

The Energy required to fracture the mirror housing was equated to the Potential Energy required for a drop mass m_{drop} to fracture the side mirror in a drop test from a specified drop height h_{drop} under normal gravitational forces.

$$E_{fracture} = m_{drop} g h_{drop} \tag{4}$$

Energy required to rotate the mirror housing was equated to the Moment of Inertia I and the rotational velocity ω_f.

$$E_{rotation} = \frac{1}{2}I\omega_f^2 \tag{5}$$

Substituting each term into Energy Equation (1) yields:

$$\frac{1}{2}m_v v_i^2 = \frac{1}{2}m_{v-m}v_f^2 - Fd - m_{drop}gh_{drop} + \frac{1}{2}I\omega_f^2 \tag{6}$$

There was minimal vehicle structural deformation, and thus $E_{deformation}$ approaches zero. Input at the mirror center of gravity reduced rotational effects, $E_{rotation,}$ to negligible levels (consistent with scratch evidence on the vehicle door). Rearranging terms yields the final theoretical equation from which the impact Delta V v_i-v_f can be estimated.

$$\frac{1}{2}m_v v_i^2 = \frac{1}{2}m_{v-m}v_f^2 - m_{drop}gh \tag{7}$$

EXPERIMENTAL METHOD & RESULTS

The drop test method consisted of 7 trials on a passenger side mirror housing at the center of gravity. During the drop testing, the side mirror was observed to fracture in multiple samples from a drop height of less than or equal to 0.4 m. Energy required to fracture the mirror was calculated to be on the order of 42 N-m. The vehicle initial Kinetic Energy was calculated to be on the order of 18,000 N-m, which is over 400 times greater than the Energy required to fracture the mirror. Thus, the Delta V associated with the sideswipe impact was estimated as less than 0.4 m/s and the related CG acceleration was significantly less than 1.0 g.

CONCLUSIONS

The peer reviewed methodology was proven effective and recommended for future use. Energy Conservation of analysis indicated that the Energy required to displace the side mirror is comparatively low. A sensitivity analysis indicated that applying a sensitivity factor to the quantified Energy required to displace the side mirror did not significantly affect the calculated Delta V or acceleration. It was therefore determined that in minor sideswipe impacts where the vehicle damage is limited to side rearview mirror displacement and aesthetic body panel deformation, the occupant dynamics are such that secondary impact within the vehicle interior would not likely occur.

REFERENCES

1. Tanner, et al., "Vehicle & Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts," SAE Paper No. 2001-01-0900, March 5-8, 2001.
2. Bailey, et al., "Data and Methods for Estimating the Severity of Minor Impacts," SAE Paper No. 950352.
3. Meriam & Kraige, Engineering Mechanics, John Wiley & Sons, 1992.