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Application and Use of Linear Interpolation Models: A Case Study

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ABSTRACT

Computer simulations are often used to analyze vehicle motion and impact forces in accidents. In cases where vehicles have interacted with roadway objects the simulation models may not have the capability of modeling the interaction. Some cases involve an object penetrating the vehicle in such a way that the forces are so minimal that they do not need to be calculated, but that the specific motion of the object and vehicle can be modeled through the use of multiple simulations. This case study is a look at using the SIMON simulation model in conjunction with EDGEN or similar linear interpolation programs to solve specific collision sequences and collision trends.

INTRODUCTION

An accident occurred on a private driveway involving a single vehicle traveling in nighttime conditions with no overhead lighting. The private driveway was a single lane road consisting of well traveled dirt and gravel. The property driveway was secured by a steel gate that rotated about a post on the south side of the driveway and could be locked to a metal post on the north side of the driveway. The gate was maintained by the property owners and they were responsible for the location of the gate prior to the accident. The gate would not rotate freely and required a reasonable application of force to rotate about the southern post.

On the date of the accident a guest of the property owner had joined them for dinner and was leaving the property on the private driveway. The property owner was traveling in front of the guest and had stopped at the gate to ensure that the gate was off of the driveway and then continued down the road. The guest was following the taillights of the owner's vehicle at a distance of 5 to 6 car lengths and had a dog in the right front passenger's seat of the vehicle. The guest looked over to check on the dog near the location of the gate and then the accident happened. The vehicle the guest was driving impacted the end of the steel gate pole. The steel gate pole entered the vehicle through the windshield near the driver's side A-pillar, impacting the head of the driver, driver's headrest and then exiting through the small rearmost passenger's side window of the vehicle. The documented path of the gate pole through the vehicle was very specific with the pole rotating slightly as it traveled through the interior of the vehicle.

Figure 1: Impact and penetration location of pole through windshield at the driver's side A-pillar.

Figure 2: Pole exit location through small rearmost passenger's side window.

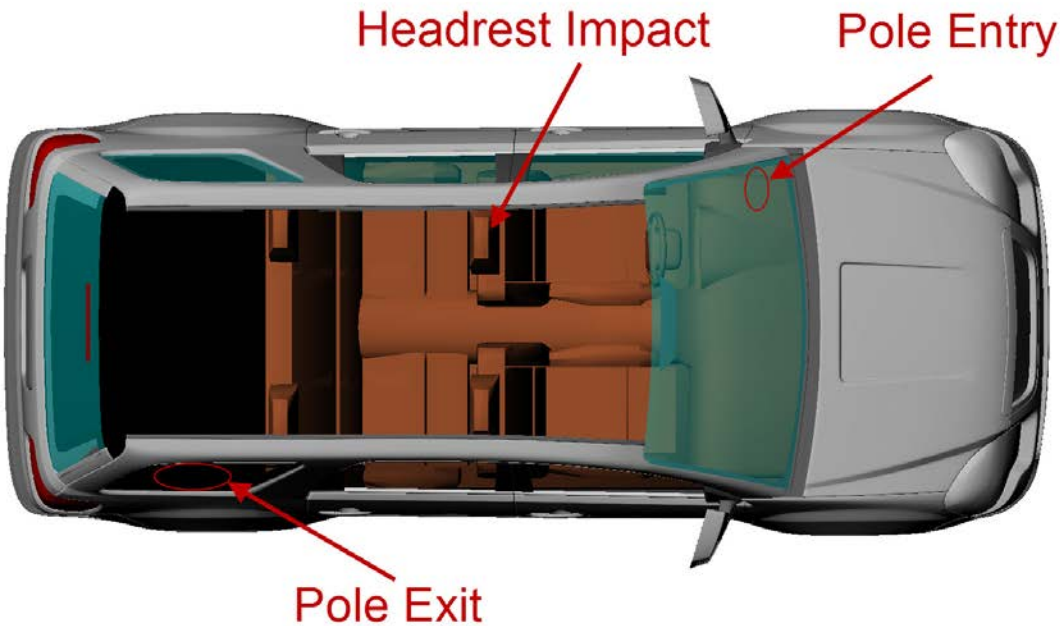

Figure 3: Damage to the vehicle from the pole.

The property owner was certain that the end of the steel gate was located off of the traveled portion of the driveway at the time of the accident and the guest argued that the gate was in the center of the driveway. Investigative Training Service was hired to look at the available evidence to determine the most likely location of the steel gate at the time of the accident.

TECHNIQUE

The private driveway consisting of dirt and gravel was uneven leading up to the area of the accident. The driveway also curved at the location of the steel gate. A Total Station was used to map the driveway, shoulder and details of the gate. The scene was then imported into the HVE simulation software for use with SIMON as well as EDGEN for further analysis of the collision sequence.

The steel gate was a 4.5 inch diameter capped cylinder that extended horizontally approximately 24 feet to the southern metal post. The author was informed that prior to the accident the gate was straight with no noticeable damage. At the time of the inspection the end of the gate had been bent 12 inches from the collision with the guest's vehicle. There was a clear "bend point" approximately 12 feet from the end of the gate.

The vehicle that was being driven by the guest was an all wheel drive 2007 GMC Acadia. The damage to the vehicle was to the driver's side of the windshield, driver's headrest and the rearmost passenger's side window. The damage to the windshield consisted of a hole at the base of the driver's side A-pillar. The driver's side headrest was impacted by the end of the steel gate and was knocked off of the seat. The rearmost passenger's side window was shattered with evidence of contact to the rear of the passenger's c-pillar.


Figure 4: Photograph of the roadway showing the pole involved in the accident.

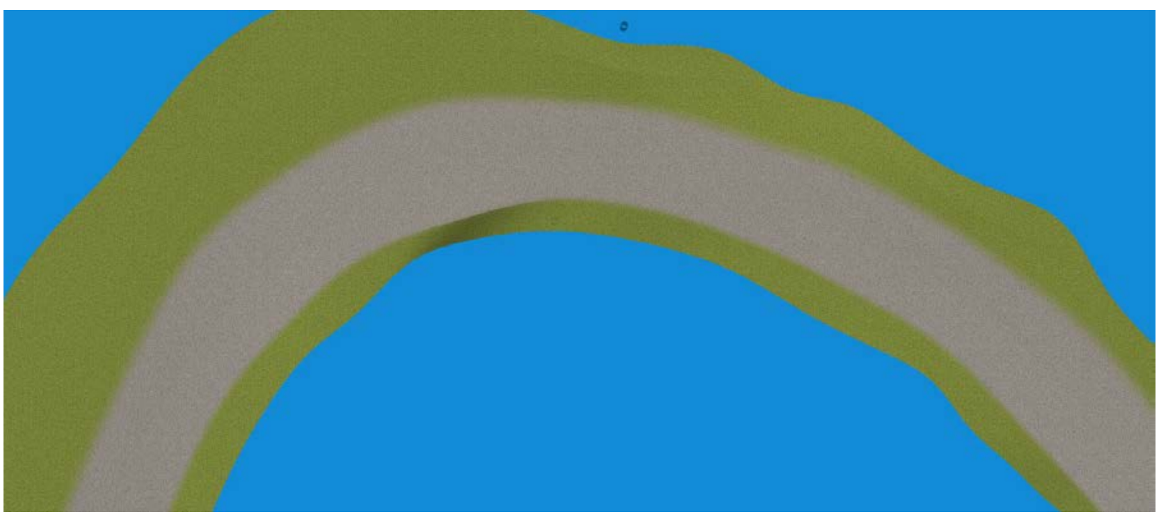
Figure 5: Scene drawing from total station measurements.

ANALYSIS

The 3-Dimensional scene was drawn in Rhinoceros 3D from the total station data and imported into the HVE software. The 2007 GMC Acadia from the EDC database was used for the guest vehicle. The steel gate was drawn as a separate object and placed as the geometry of a fixed barrier. At this time the HVE simulation software cannot accurately calculate and predict the forces between the steel gate penetrating the windshield of the vehicle and interacting with the driver's side A-pillar, driver's headrest and passenger's side c-pillar. Although HVE cannot "simulate" the interaction, we can use SIMON in conjunction with EDGEN or a similar linear interpolation program to predict the trend of the path of the steel gate through the interior of the GMC Acadia.

The GMC Acadia was simulated driving along the path of the gravel driveway using the SIMON physics model at a constant speed. With the location of the gate near the apex of the right hand curve in the driveway, the path follower option was used so that the vehicle would be turning with the contour of the driveway, matching the description of the witnesses. A second simulation was then run using the EDGEN analysis tool for the movement of the steel gate.

The SIMON physics package was used to accurately simulate the GMC Acadia traveling over the uneven and contoured surface of the gravel driveway. Due to the large weight discrepancy and impact configuration between the steel gate and the Acadia, the steered path of the vehicle as it traveled along the driveway would not have been altered as the end of the gate penetrated the windshield and traveled through the interior of the vehicle. Thus, the SIMON simulation was continuously run for some distance past the gate intrusion to be used in conjunction with the EDGEN simulation.

EDGEN was used for analysis of the motion of the steel gate as it traveled through and interacted with the GMC Acadia. The geometry of the steel gate was applied to a fixed barrier for use in EDGEN.[1] Knowing the exact location of the southern metal post, the steel gate was placed within the environment such that the base of the gate would pivot around the southern post. The six degrees of freedom available to us in EDGEN (X, Y, Z linear motion, and roll, pitch and yaw angular motion) were utilized to predict the rotation of the steel gate during the accident.

The process of this analysis was through trial and error by utilizing the Playback Editor in HVE. A Trajectory Simulation (Traj Sim) of the SIMON run with the vehicle driving along the path of the driveway at a constant speed was added in the Playback Editor along with a preliminary Trajectory Simulation of the movement of the steel gate in EDGEN. With both Traj Sim's active and viewable in the Playback Editor, modifications could be made to the EDGEN run to match the physical evidence. The two scenarios were then simulated to determine the initial location of the end of the gate as the vehicle traveled down the driveway.

The first scenario was as described by the guest with the end of the gate in the middle of the driveway. The EDGEN run was continuously modified through the EDGEN event so that the end of the gate penetrated the windshield at the base of the driver's side A-pillar and traveled through the interior of the vehicle to match the contact points within the vehicle as best as possible. With the understanding that the gate would make contact with the forward/interior portion of the driver's side A-pillar without deforming it, the gate was iteratively rotated about the southern pivot post so that the side of the gate never "penetrated" the A-pillar. Due to the specific damage and path of the gate through the GMC Acadia, the A-pillar was a constraint for the nature of the gate rotation. With the vehicle driving at a constant speed near the center of the roadway and following the contour of the single lane, the end of the gate could penetrate the windshield at the proper location but would have been "pushed" forward by the driver's side A-pillar such that the gate rotated to exit the vehicle through the right rear passenger's window. Under this scenario the gate would not have contacted the driver's headrest and would also exit the wrong passenger's side window (see figure 8 through 11).

[1] The Gate was drawn completely straight to match the condition before the accident.

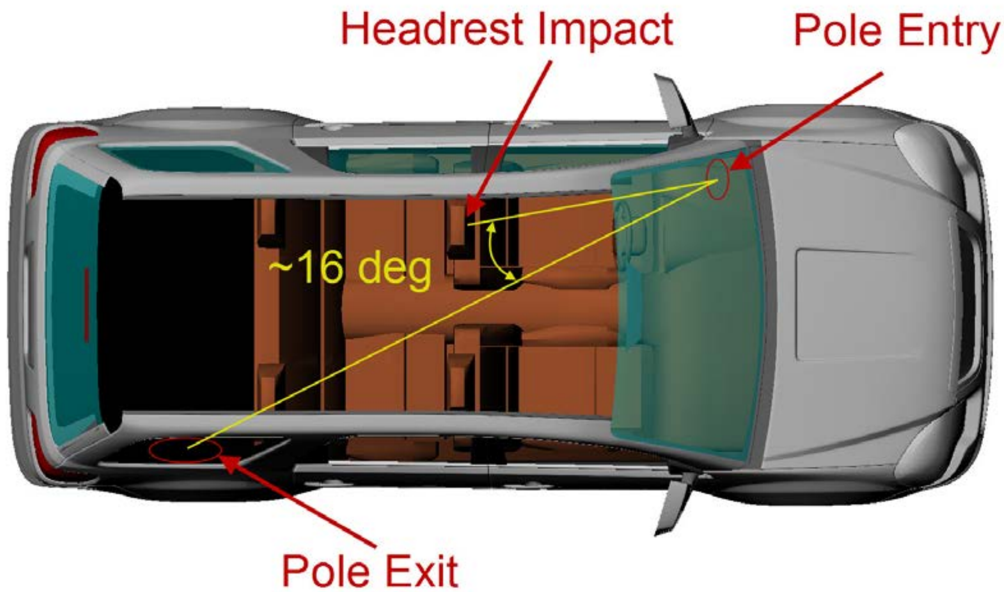

Figure 6: Path of travel of pole through the vehicle.

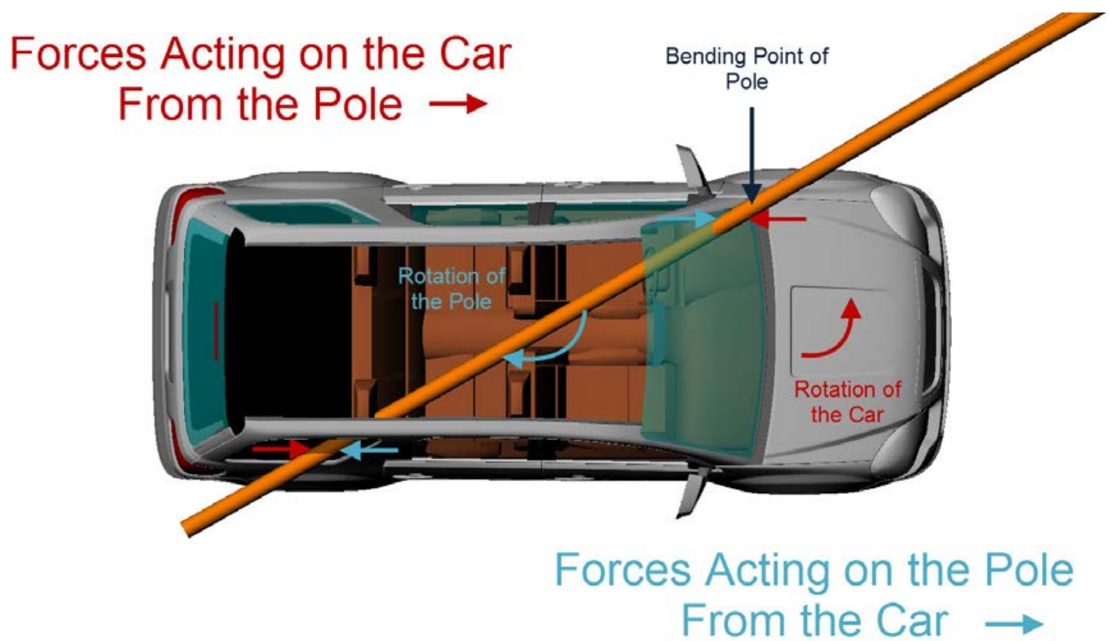

Figure 7: Diagram of forces from pole-vehicle interaction.

Figure 8: Vehicle traveling in the center of the road with the pole located near the center of the road.

Figure 9: Pole penetrating the windshield.

Figure 10: Pole rotating due to contact with driver's side A-pillar.

Figure 11: Pole continuing to rotate due to contact with the driver's side A-pillar and exiting the incorrect rear passenger's side window.

The second scenario was as described by the property owner with the end of the steel gate off of the traveled portion of the roadway and on the grass shoulder. The EDGEN run was continuously modified through the EDGEN event so that the end of the gate penetrated the windshield at the base of the driver's side A-pillar and traveled through the interior of the vehicle to match the contact points within the vehicle as best as possible. The gate was iteratively rotated about the southern pivot post so that the side of the gate never "penetrated" the A-pillar. With the vehicle driving at a constant speed at the edge of the roadway and following the contour of the single lane, the end of the gate could penetrate the windshield at the proper location, impact the driver's headrest and rotate to exit the rearmost passenger's side window. After penetrating the rearmost passenger's side window the forward motion of the Acadia created a lever situation for the gate with the southern post acting as the fulcrum. The gate remained secured at its base with the southern post as force was applied in a forward direction by the driver's side A-pillar and a rearward force applied by the passenger's side c-pillar. The result caused the steel gate to bend at a location approximately 12 feet from the end. The second scenario matched the damage to the interior of the GMC Acadia and was a good match for the location of the bend in the steel gate (see figure 12 through 14).

Figure 12: Vehicle traveling at the edge of the roadway with the end of the pole located off of the traveled portion of the road showing the pole penetrating the windshield.

Figure 13: Pole traveling through the vehicle to impact the driver's side headrest.

Figure 14: Pole rotates due to contact with the driver's side A-pillar to exit the rearmost passenger's side window.

CONCLUSIONS

While this simulation is not calculating the forces exchanged between the steel gate and the GMC Acadia, it does provide a scientific, geometrical basis for the collision event. The use of the SIMON run in conjunction with the EDGEN liner interpolation model was able to show that the end of the steel gate was located off of the traveled portion of the driveway at the time of the accident as described by the property owner. This scenario certainly is not a common occurrence, but the purpose of this paper is to give an example of how to think “outside of the box” and use the tools available in the HVE software to analyze and solve collision trends.

REFERENCES

1. Day, T.D., Roberts, S.G. and York, A.R., “SIMON: A New Vehicle Simulation Model for Vehicle Design and Safety Research,” SAE Paper No. 2001-01-0503, 2003.
2. Fay, R.J. and Siddall, D., “Using Imported Objects and Images in HVE,” SAE 980019, 1998.
3. EDGEN-Engineering Dynamics Corporation General Analysis Tool, users manual, Third Edition (January 2006).