A Genetic Algorithm to Infer Contact Characteristics In Multibody Simulations for a Known Target Signal: Application to Pedestrian Head Windscreen Contact

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I. INTRODUCTION

Multibody simulations are often used to simulate collision events when detailed material characteristics are not available. The accuracy of multibody models depends largely on the mass distribution, geometry, joint formulations/constraints and contact characteristics. Experimentally derived contact characteristics are not always practical, leading to uncertainty in resulting injury predictions. These contact characteristics are often difficult to find experimentally, or the available information is highly variable (see Figure 1). This short communication presents a genetic algorithm approach to optimise the contact characteristics when a functional form is known. The method works by minimising the difference between a known experimental signal and the predicted signal of the equivalent contact in the model.

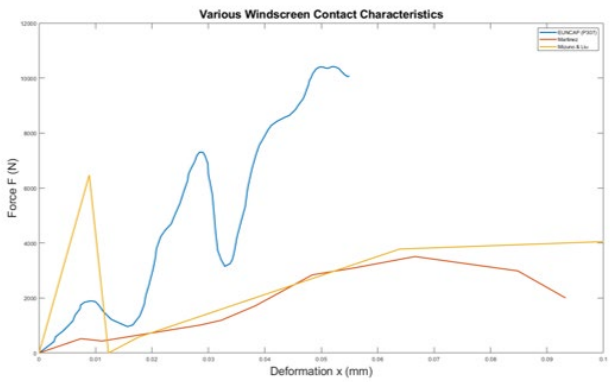

Fig. 1. Various Head Windshield Force Penetration curves [1].

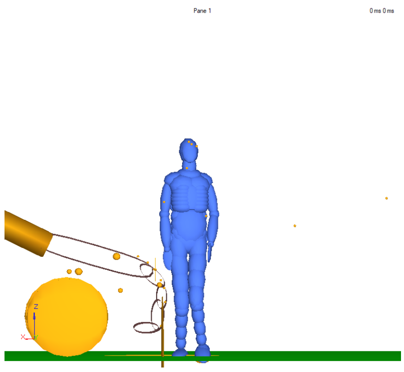

Fig. 2. Example of Multibody Simulation.

II. METHODS

We illustrate the approach by application to vehicle-to-pedestrian collisions as shown in Figure 2. A MADYMO (MAthematical DYnamic Models, TASS International, Netherlands) model of the post-mortem human subject (PMHS) experiments reported in [1] was developed. The first step is parameterising the force-penetration relationship according to the expected functional form. For head windscreen loading, the sharp rise and then fall of force associated with loading and fracture of the glass is followed by a much softer rise in force associated with stretching of the plastic laminate, and this is well established [2]. Thus, we applied an initial high positive stiffness, then negative slope after windscreen fracture and then much lower stiffness, similar to the Mizuno and Liu Curve [2] shown in Figure 1. To achieve this shape we defined bounds for - Initial Slope (M1), - Transition Point from slope 1 to 2 (T1), Secondary Slope (M2), - Transition Point from slope 2 to 3 (T2), - Final Slope (M3) and Hysteresis Slope(HYS).

The genetic algorithm in Matlab (MATrix LABoratory, Mathworks) varies these parameters of the contact characteristic and attempts to find the parameters which minimise difference between a multibody model signal and an experimental one. In this case, the objective function was to minimise the Root Mean Square (RMS) error between the measured and calculated resultant linear head acceleration. An optimisation window was created to ensure that the RMS error was only compared during the head windscreen contact as this was the relevant time segment for the contact characteristic. Figure 3 shows the method used to create this optimisation window for six experimental head acceleration curves. Video footage was used to estimate the head windshield contact time and then an 85% drop in peak acceleration was found either side of this point.

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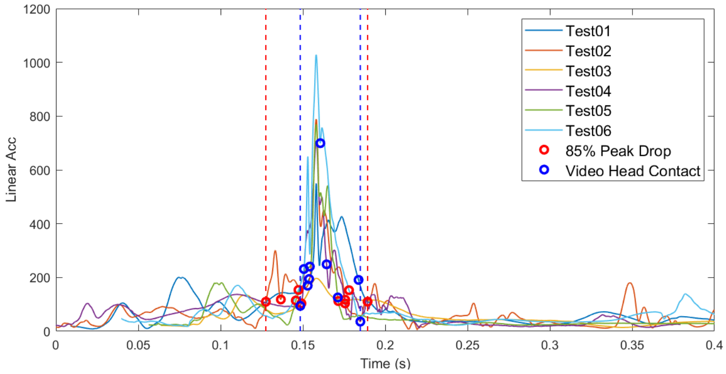

Fig. 3. Optimisation Window Based on 6 PMHS Tests, signals from [3].

III. COMPUTATIONAL MODELLING

The genetic algorithm starts with upper and lower bounds for the contact characteristic variables. Various optimisation parameters are required (population size, number of generations and survivor proportion). Once all generations are completed the output is the optimised force-penetration relationship and hysteresis slope which produces the predicted linear head acceleration which best matches the input head acceleration.

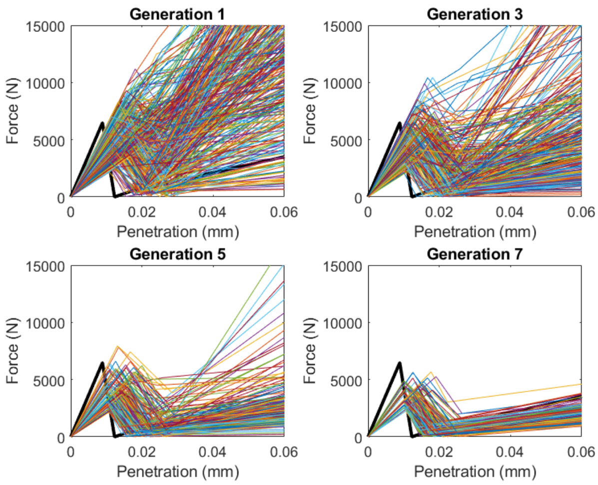

Fig. 4. Calculated Force Penetration Curve Candidates per Generation.

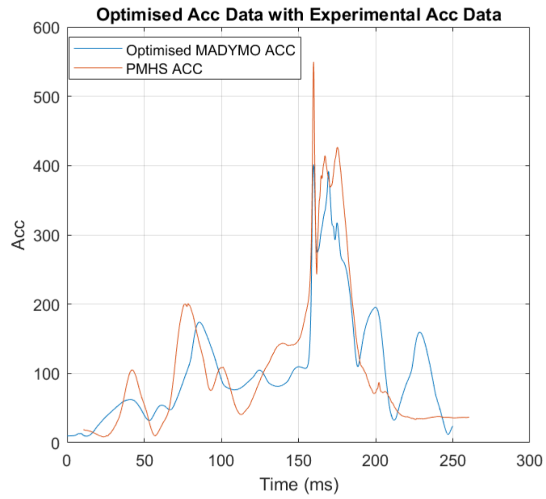

Fig. 5. Target Signal with Best Calculated MADYMO Signal.

IV. DISCUSSION

Figure 4 shows the genetic algorithm creating 400 candidate force penetration curves based on the upper and lower bounds entred. There is great disparity between the curves in generation 1. However, as the generations increase, the curves converge. The black curve shown in Figure 4 is the Mizuno and Liu contact characteristic curve for reference. Figure 5 shows the resulting optimised head linear acceleration compared to the experimental target curve. This genetic algorithm approach is a useful inverse analysis method to infer complex loading characteristics for baseline multibody simulations when a functional form for the contact characteristic and relevant target signal are known. In this case, the head acceleration signal was available, and this is an ideal signal as head acceleration is closely coupled to the head windscreen contact characteristics.

V. REFERENCES

[1] Shang, S et al, 2021, Accident Analysis & Prevention,149, p.105803.
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[3] Shang, S et al, 2020. Safety science, 127, p.104684.