Potential Effects of Friction on Injury Measures Computed in Aircraft Seat HIC Analysis Testing

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Abstract

Aircraft seating systems are evaluated utilizing a variety of impact conditions and select injury measures. Injury measures like the Head Injury Criterion (HIC) are evaluated under standardized conditions using anthropomorphic test devices such as those outlined in 14 CFR part 25. An example test involves decelerating one or more rows of seats and allowing a lap-belted ATD to engage components in front of it, which typically include the seatback and its integrated features. Examples of head contact surfaces include video monitors, various plastic and composite fascia, and a wide range of seat back materials. The HIC, and other injury measures such as Nij, can be calculated during such impacts. It has been shown in other safety applications that the friction between a headform and contact surface can affect the test results. A series of finite element simulations of a frontal deceleration pulse with a generalized aircraft seat was performed to determine the variation in HIC and Nij observed based on various friction characteristics between the ATD and select seat components. The results indicate that the level of friction on the test device headform can influence the ability to pass the HIC analysis test. Of particular interest is the change in response due to the use of friction characteristics representative of human skin compared with ATD skin.

Introduction

The coefficients of friction associated with contacts during testing can affect the kinematic response and injury measures output by anthropomorphic test devices (ATDs). Some of the variations associated with friction, such as the surface finish of a component, are controllable through the design process. Friction can also be affected by the testing methods utilized particularly with regard to the surface characteristics of the ATD. Previous studies have shown that typical ATD head skin friction can be quite different from human skin for the same contact surfaces. Such differences have been shown to potentially affect the results of safety testing in ground vehicles [1].

Aircraft seating systems are evaluated utilizing a variety of impact conditions and select injury measures. Injury measures like the Head Injury Criterion (HIC) [2] are evaluated under standardized conditions using ATDs such as those outlined in 14 CFR part 25. Typical frontal impact tests involve an ATD seated in an upright position restrained by a two-point belt. Such a test setup provides multiple contacts between the ATD and seat for which friction characteristics likely have an impact on the test outcome. These include contact between the ATD and its clothes, its clothes and the seat cushion, and the target seat with various ATD body parts including the head.

To the extent that the kinematics of the ATD are affected by the friction in these contacts, it may affect the resulting measured HIC. Other injury measures, such as Nij [2], are also of interest and have the potential to be affected. In this study, Finite Element (FE) simulations of a frontal deceleration pulse with a generalized aircraft seat were performed to investigate the effects of select friction coefficients on HIC and Nij values. Friction variations between the ATD head and the target seat contact surfaces are considered. Separately, friction between ATD and the seat cushion are also considered.

Method

The finite element simulations were setup in LS-DYNA [3] to replicate a Zone C HIC evaluation test in which a 16 g deceleration pulse decelerates two rows of seats such that the ATD head impacts the upper center region of the target seatback [4]. A generic deceleration pulse shape, which meets the Zone C impact test requirements shown in Figure 1, was used to prescribe the motion of the simulated sled. A view of the virtual test setup, with generalized aircraft seat (913 mm pitch), is provided in Figure 2. A 50^{th} percentile Hybrid III ATD [5] was settled in the launch seat with the lap belt tightened across the hips.

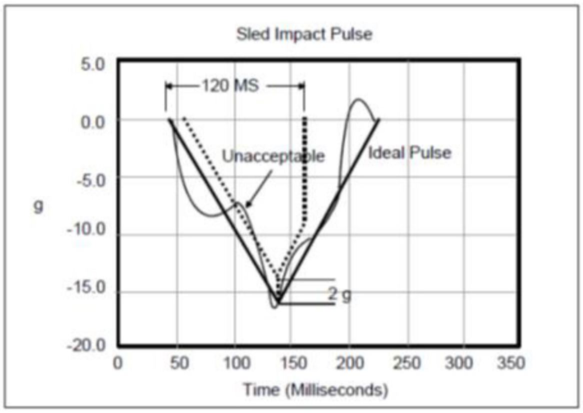

Figure 1. Frontal sled impact pulse requirement from 14 CFR 25.

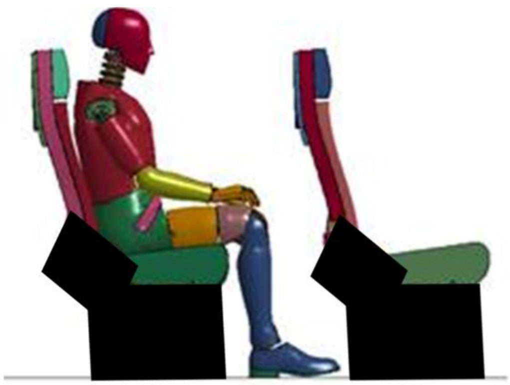

Figure 2. Example of initial virtual test setup

Four series of four virtual tests were run for a total of 16 virtual tests. Three target seats configurations were utilized: one with a monitor and plastic bezel (MPB), one with a plastic egg crate type seatback (PEC1), and one with covered foam seatback (CF). The head-to-target seatback friction coefficient (dynamic and static were defined as equal) was varied for each of the three seat configuration test series. In the fourth test series, conducted with the egg crate type seatback and designated PEC2, the ATD-to-launch seat friction was varied while ATD head-to-target seatback friction was kept constant. Table 1 summarizes the test matrix.

Table 1. Test matrix

Seat configuration	ATD head to seatback friction coefficient	ATD-to-launch seat friction coefficient
MPB	0.2, 0.4, 0.6, 0.8	0.2
PEC1	0.3, 0.6, 0.9, 1.2	0.2
CF	0.3, 0.6, 0.9, 1.2	0.2
PEC2	0.2	0.2, 0.4, 0.6, 0.8

Filter classes consistent with SAE J211 [6] were used for post processing. The HIC was calculated for the first head to seatback impact using a time interval of 36 ms [7]. A neck injury criteria, referred to as Nij, was also calculated for each impact according to the equations and thresholds outlined by Eppinger et al. [2]. All results were normalized to those calculated from the lowest friction case in each series.

Results

The results for each series are summarized below.

MPB - Seat Back with Monitor

These results represent the effect of variation in the head-to-target seat friction coefficient for the monitor seatback.

The results with the monitor type seatback showed fluctuations in injury measures with variations in friction (Figure 2). Beyond the lowest friction level, the peak head acceleration generally trended upward with increased friction. On the other hand, HIC and Nij values did not appear to be directly associated with the prescribed friction.

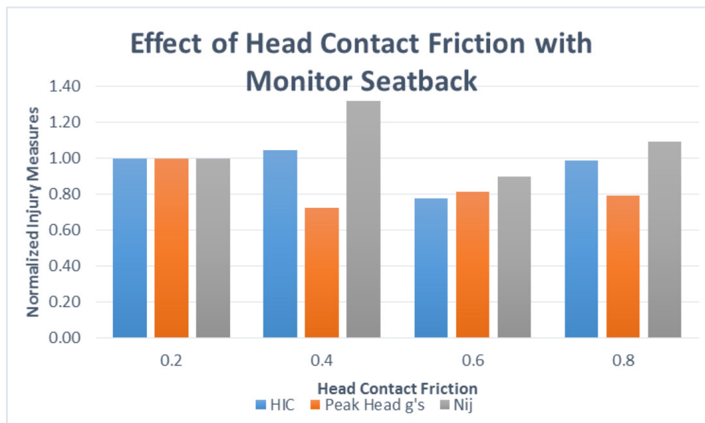

Figure 2. Effect of head contact friction with monitor seatback

PEC1 Plastic Covered Seatback

These results represent the effect of variation in the head-to-target seat friction coefficient for the plastic egg crate seatback.

The peak head acceleration remained fairly constant across all friction values while the HIC and Nij were elevated relative to the lowest friction case as shown in Figure 3. This may suggest that for this configuration the peak acceleration was limited but the friction increased the duration of contact with stiffer areas. The trend of the Nij values indicates that there are optimum levels of friction that may increase or decrease neck injury risk.

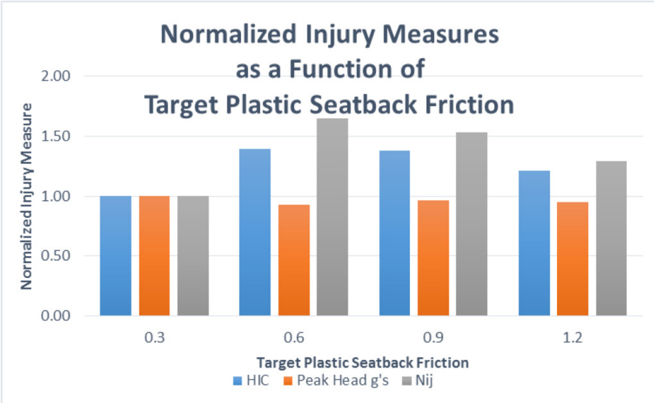

Figure 3. Results from PEC1 test series varying target seat to ATD friction levels

CF Target Seat with Covered Foam

These results represent the effect of variation in the head-to-target seat coefficient of friction for the covered foam seatback.

The CF series showed generally decreasing head injury measures as the friction coefficient was increased beyond 0.6 as shown in Figure 4. The Nij values generally followed the same trend as the head injury measures, with the exception of the highest friction case. Overall, the minimum results typically occurred at the lowest friction.

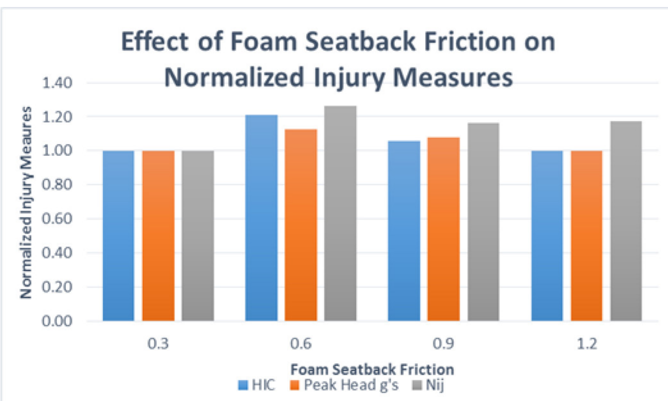

Figure 4. Injury measures obtained with increasing target seat frictions

PEC2 Launch Seat Friction Variations

These results represent the effect of variation in the ATD-to-launch seat friction coefficient for the plastic egg crate seatback.

Increasing the ATD-to-launch seat friction resulted in reductions in the HIC. The Nij and peak head acceleration values remained approximately constant across all tests. A summary of the normalized injury measures is presented in Figure 5.

Examination of the tests indicated that with lower launch seat friction the ATD pelvis tended to rotate slightly more under the belt which resulted in earlier contact between the extremities and the target seat. With the higher launch seat friction, the pelvis and upper torso remained more erect enabling the head to contact the target seatback about 5 ms sooner than the lower friction case and in a higher location on the target seatback that was less rigid. The seatbelt loads were also observed to be increased with the lower ATD-seat cushion friction.

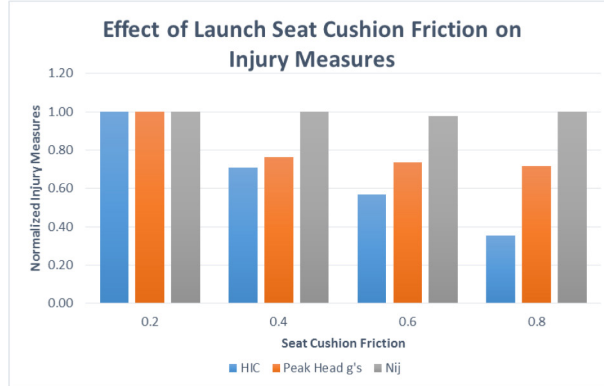

Figure 5. Effects of launch seat friction on injury measures

Discussion

Variations in the friction coefficients between the ATD, launch seat, and target seat were shown to have substantial effect on the ATD head and neck injury measures. This is important with regard to both seat design and evaluation of test methods. These results indicate that the surface properties of the seat and seatback can be optimized to improve performance and occupant safety in emergency landing situations. Additionally, the results of evaluation tests are likely to be significantly affected by variations in test device friction that are not currently well defined or documented.

The magnitude of the friction between the ATD and the seat cushion affects the kinematics observed prior to head impact. The friction associated with those contacts also affects the observed injury measures. Interaction between the ATD hands and target seat prior to head impact complicates the resulting response of the ATD head and this timing may be affected by the seat contact friction.

The ATD head friction can vary due to many factors. For example, a newer ATD could have a higher coefficient of friction relative to a given material than an older ATD where the surfaces may be more worn or have other characteristics that alter its surface finish. The friction observed with a given head may be reduced by its preparation prior to a test. For example, cleaning or applying chalk on the ATD head skin likely has an effect on ATD friction.

It has been shown that the coefficient of friction between human skin and various materials have dramatically different friction characteristics than the ATD skin against those same materials. In addition, variations in head friction have been shown to result in variations in test results between laboratories. [8, 9, 10, 11]

Comparison of test results from one laboratory to another may be affected by the friction characteristics presented by the ATD. For example, besides the conditioning of the head the nature of the clothes could introduce variations as well. Standardization of these procedures and ATD preparation would likely reduce the variability observed between laboratories when testing the same model seat. One approach attempting to control such variability has been incorporated in SAE J3095 [12] and SAE J2937 [13] where, while not reducing the ATD head friction to human levels, the friction of the head being used in the test is documented to enable an understanding of variations in test results between labs.

Conclusion

The results show that variations in contact friction of the ATD head and body with the aircraft launch and target seat surfaces can affect the resulting injury measures observed. There are a wide range of contact frictions between surfaces that can be created. The effects of these variations should be understood when considering the design implications from test results.

Since the potential exists for large differences in the observed HIC from a compliance viewpoint the effects of a friction incorporated into the system design should be considered. Probabilistic methods or design of experiment approaches would likely enable identification of optimum friction characteristics that result in the best HIC results for a given seat design.

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