Effective Stiffness of Vehicle Seats in Rearward Pull to Failure

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I. INTRODUCTION

Seat-back stiffness and strength may affect occupant kinematics and injury risk in rear impacts. Efforts to develop research-focused finite element (FE) models of seats require stiffness properties and failure strength information across a range of seats. This study aimed to investigate the local and effective stiffness response of a variety of front occupant seats through large magnitude moment testing to measure the seats' stiffness and failure point.

II. METHODS

Eight used and anonymised seats were tested, with all exterior fabric, foam and plastic trim removed to allow for optimal observation of the metal frame's deformation. This test was adapted from FMVSS 207 [1], to pull until failure rather than to a specific force. For each seat, the base was attached to a rigid frame and the seat back was pulled with a 2,000 lb. winch attached near the top of the seat-back frame at a 90° angle with respect to its seat back (Fig. 1). The cable from the winch was attached to each seat with a clamp, along the width of the seat, at the highest location possible, and was free to change angle as the seat deformed. The seats were all positioned at mid-height, and mid-track, and the initial seat-back angle (with respect to the vertical) was set to the test position used in the Insurance Institute for Highway Safety's (IIHS) rear-impact sled tests [2]. Three-dimensional motion-tracking markers (Vicon MX™, Oxford, UK) were placed at key locations on the seat-back frame, seat-bottom frame, and winch cable (Fig. 1) to observe the deformation of the seat frame during the tests. Each test lasted 12 s: 4 s of pulling the seat-back frame, a 4 s pause, and 4 s of release.

A load cell was attached to the cable which measured the force on the cable throughout the test (Fig. 1). These data, coupled with the motion-tracking position data, allowed for the post-test calculation of moment about the recliner axis and of seat-back deformation angle throughout the test duration. Cable force, distributed across the seat back, was measured at 10 kHz and three-dimensional positioning at 100 Hz. Cable force was debiased and filtered (CFC10).

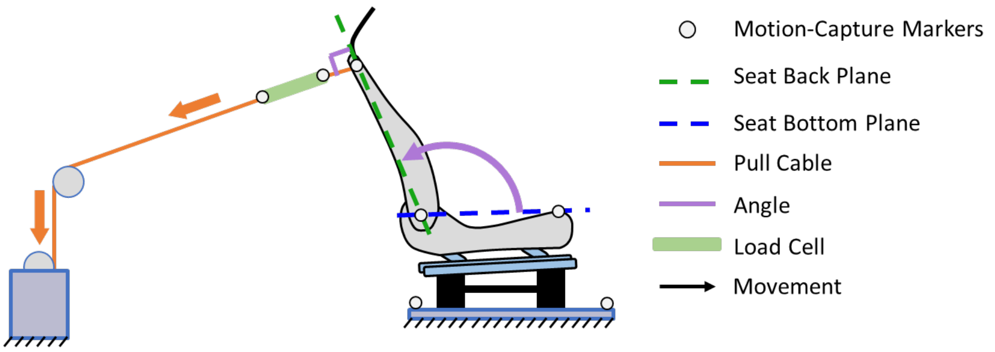

Fig. 1. Pull to failure testing setup. This illustrates the entire seat metal frame, rigid mount and base, as well as the cable and winch.

III. INITIAL FINDINGS

All eight seats failed structurally at some point during the test (permanent deformation of metallic frame) (Fig. 2). In one test, the clamp that attached the cable to the seat shifted significantly during the test and resulted in inaccurate force capture; this seat, F, was then excluded from the data analysis. All seats failed in the structure of the seats, while some also failed at the adjustment mechanisms. There was bilateral failure in most seats, but two seats, R and S, failed on a single side, resulting in a rotation about the sagittal plane and asymmetrical deformation of the seat back (Fig. 2).

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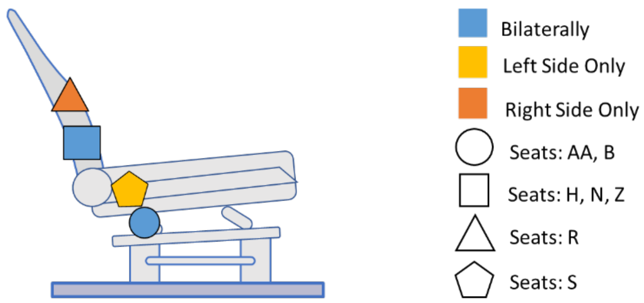

Fig. 2. Failure locations. This illustrates the seat back, seat bottom, mechanical/electrical height adjustor, and the rigid mount.

Progressive failure occurred at multiple points during each test, as seen in their moment-angle (seat-back deformation) responses (Fig. 3). The initial failure, noted by the dots on each line, was defined as the instant when the seat back's stiffness began to decrease significantly, resulting in a dramatic reduction in the force on the winch. While most seats carried on with a secondary stiffness phase after initial failure, seats AA and B experienced failures that prevented further build-up of force within the winch's available pull distance. Seat B's height on the testing rig fell greatly after its initial failure, causing the cable to loosen and the moment to drop to near zero.

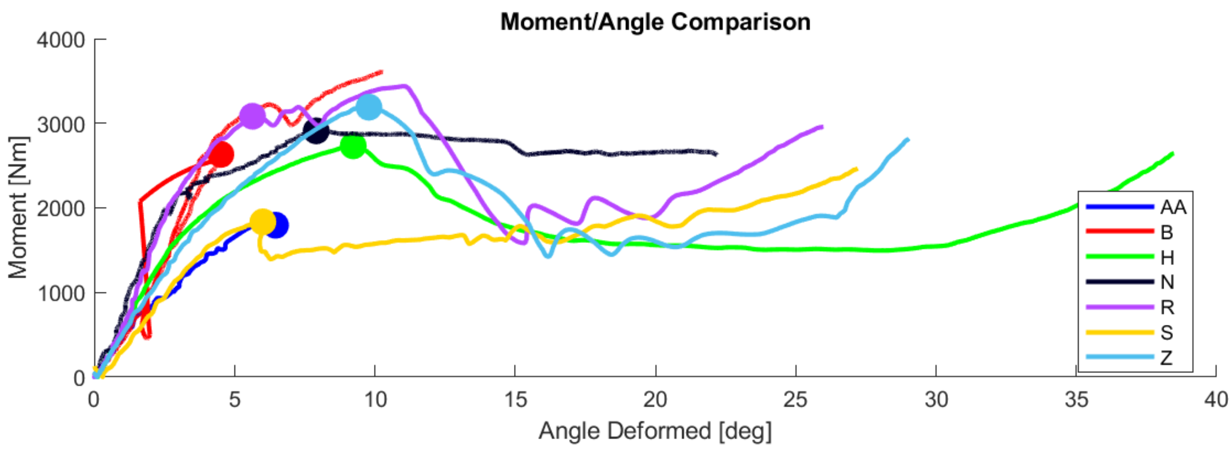

Fig. 3. Seat-back angle deformation due to the moment of the recliner axis.

IV. DISCUSSION

This testing provided useful information on the structural behaviour of different seats that will inform the parameters for research-focused vehicle seat FE models used in studying potential injury risk in rear impacts. The failure patterns varied among the tested seats and are therefore likely representative of the variety of seat failure modes that may be present in the wider vehicle fleet. The moment-angle stiffness of the seat back also varied, though there were some common characteristics. As the seat back was pulled rearwards, the seat frame's structure failed near or at the recliner. In some cases, the failure was symmetric; in others it was not (causing some Z-axis twist of the seat back) [3]. After initial failure, the moment needed to continue to deform the seat tended to decrease. In some cases, the frame stiffened up again after a certain amount of deformation, though this was not universal. Based on the information retrieved, targets have been established for seat-back stiffness and failure location for computer model simulations of parametric seat models to represent the variety of seats present in the fleet.

V. ACKNOWLEDGEMENTS

Technical and financial support received from the Insurance Institute for Highway Safety is gratefully recognised.

VI. REFERENCES

[1] U.S. DOT, NHTSA, FMVSS 207, 1992.
[2] IIHS, Dynamic Test Protocol, 2020.
[3] Edwards, M., et a IRCOBI, 2019.