Dynamic Cushioning Performance Criteria for Snowmobile Seats—SAE J89a

SAE Recommended Practice
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LAND SEA AIR SPACE

PREPRINT

DYNAMIC CUSHIONING PERFORMANCE CRITERIA FOR SNOWMOBILE SEATS—SAE J89a

SAE Recommended Practice

Report of Snowmobile and All-Terrain Vehicle Committee approved July 1973 and last revised April 1976.

1. Introduction

1.1 Purpose—The purpose of this SAE Recommended Practice is to facilitate the development of seats used on snowmobiles to minimize occupant spinal injury during impacts of:

(a) The rider on the snowmobile seat.

(b) The snowmobile and seat on the rider.

Operators and passengers of snowmobiles can be subjected to high levels of impact with the snowmobile seat under riding conditions. This recommended practice was developed to identify the cushioning properties of snowmobile seats.

1.2 Scope—This recommended practice encompasses the significant factors which determine the effectiveness of a seat system in limiting spinal injury during vertical impacts between the rider and the snowmobile seat system. The recommended practice is intended to provide a tool for the development of safer snowmobile seats. It is recognized that the seat is only a portion of the entire vehicle protective suspension system. It is, however, usually required that the seat serve as added protection to the suspension system, since the latter may "bottom out" during a severe impact.

The term "seat" refers to the occupant-supporting system not normally considered part of the vehicle suspension or frame system. In some cases, it may include more than the foam cushion.

This recommended practice provides the minimum requirements for performance of a general seat system, and a description of specific means of evaluating the shock absorbing characteristics of foam seat cushions using a specific testing procedure and a companion safety evaluation chart. The recommended practice relates measurable mechanical data attainable in controlled laboratory testing to known biomechanical data on living subjects.

The test input and means of interpreting the results are unique to the seats of typical recreational snowmobiles as illustrated in SAE J33.

Therefore, this SAE Recommended Practice should not be applied to evaluate seats of snow vehicles of significantly different design, dimensions, construction, or intended usage from the typical recreational snowmobile illustrated in SAE J33.

The test input and means of interpreting the results are unique to snowmobiles and snowmobile seats. Therefore, this SAE recommended seat is to be used for snowmobile seats only, and is not to be used to evaluate seats on any other type of vehicle.

1.3 Contents

2. Performance Requirements—The shock-absorbing performance of a seat is the degree to which it protects the vehicle occupant from spinal injury. Snowmobile seats will be measured using the injury model developed by the U. S. Air Force which correlates with probability of injury. Although that particular model relates to the average Air Force man, it can still be used for comparative evaluation of snowmobile seats. The reason is that the natural frequency and dampening ratio of a man's back are not strongly dependent upon age or weight, but are rather uniformly constant for all persons without previous back injury.

An acceptable snowmobile seat is one having cushioning properties such that the Air Force injury model[1] illustrated in Fig. 1, when impacting the cushion with a velocity of 175.7 in/s (4.46 m/s) (equivalent to 40 in [1.02 m] free-fall), will not exceed 2.48 in (63.0 mm) of compressive deflection. This performance requirement correlates with a 5% incidence of injury for the average seated man described by Brinkley[1] when subject to such an impact.

In adapting the Air Force model to snowmobile seats, some interface seat impact form representative of static pressures of human buttocks,[2] such as the one shown in Fig. 2, must be used as a base plate indentor for the injury model, when used as described above. The base plate must have the smallest mass possible, if a mechanical injury model base plate is assumed massless.

Note also that if the test and evaluation procedures of paragraphs 4 and 5 are used, the seat impact form must be used with a total mass of 200 lb (90.7 kg).

3. Dynamic Cushioning Testing Method

3.1 Scope—This procedure provides a uniform method for measuring, with a high degree of reproducibility, dynamic cushioning properties such as the deceleration-time history profile of a standard buttocks form ("missile") equipped with an accelerometer and weighted to provide typical human buttocks bearing pressures, and impacting seat test specimens. The results from this testing method can be related to the performance requirements listed above for cushioning the average seated man.

3.2 Definitions

3.2.1 SNOWMOBILE SEAT—The seat includes the cover, energy-absorbing materials, and substrates (if any).

3.2.2 BASELINE—The baseline is the starting reference plane of the seat from which total penetration is determined. It is taken as the top plane of the seat at the fore-aft position used by an average snowmobile rider.

3.2.3 G—Symbol for the dimensionless ratio of any acceleration to acceleration of gravity.

3.2.4 t_p—Time duration from impact to peak deceleration, in milliseconds.

3.2.5 t_h—Time duration from impact to ½ value of peak deceleration, in milliseconds.

3.3 Apparatus

3.3.1 TESTING MACHINE—Any design of stationary dynamic testing apparatus will suffice when the following criteria are met.[3] (See Fig. 3).

3.3.1.1 The weighted missile can be held in readiness for impact, released upon command, and guided to the point of impact.

3.3.1.2 The test specimen should be supported on a foundation which under impact will not deflect more than 1% of the thickness of the specimen.

3.3.1.3 The deceleration-time profile can be read out and recorded on an instrument, such as an oscilloscope, starting at the time of initial contact of the missile on the seat.

3.3.2 SENSING DEVICES

3.3.2.1 The accelerometer system should be capable of measuring single impacts of short duration (less than 0.050 s) in the 5–100 *g* range within ±2% throughout the duration of the pulse.

3.3.2.2 A penetration measuring device or some other means is required to determine the exact starting time of the penetration. A velocity measuring device may be used for measuring the impacting velocity of the missile if the missile is not totally free to fall under the influence of gravity.

A velocity transducer is useful for setting the drop height for the desired impact velocity.

3.3.3 MISSILE—The missile shall be a rigid segment of a hemisphere, the segment having a radius of 7 in (178 mm) and the hemisphere having a radius of 9.665 in (245.5 mm). (See Fig. 2) The top surface of the missile must be designated to accommodate weights to provide total missile mass capability of 200 lb (90.7 kg).

3.3.4 RECORDING EQUIPMENT—The acceleration-time recording equipment should be capable of recording impacts compatible with the accuracy of the accelerometer. Some type of triggering device will be necessary for the recording device.

3.3.5 TEST SPECIMEN—May be any seating system or component for which dynamic cushioning data are desired.

The number of specimens tested as a sample can vary widely depending upon the intended use of the data. It is recommended that at least three specimens be tested for each set of conditions. The specimens shall be preconditioned at 70 ± 10°F (21 ± 6°C) for a minimum of 8 h.

3.3.6 PROCEDURE—Prewarm the recording equipment as recommended by the manufacturer. Place the test specimen in position under the missile such that the minimum thickness of the region of the seat normally used by the operator coincides with the center of the missile. Mass of the missile shall total 200 lb (90.7 kg).

Determine the baseline by contacting the specimen with the missile and adjust the recording apparatus to read zero penetration.

Set the missile propelling mechanism at a position to obtain the desired impact velocity of 124 in/s (3.1 m/s) (equivalent to 20 in [508 mm] free fall) at the impact surface of the specimen. Calibrate the G-time recorder according to the recommended procedure of the manufacturer. Release the missile and record results by recommended procedures of the equipment manufacturer. Five consecutive strikes shall be made at 2 min intervals on the same impact

[1] J. W. Brinkley, "Application of a Biodynamic Model to Predict Spinal Injuries From Use of Aircraft Ejection Seats." Presented at AFSC Science and Engineering Symposium, October 1971. (Available Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio.)

[2] J. J. Swearingen, C. D. Wheelwright, and J. D. Garner, "An Analysis of Sitting Areas and Pressures of Man." Civil Aero Medical Research Institute Paper 62-1, FAA, Aeronautical Center, Oklahoma City, Oklahoma, January 1962.

[3] L. R. Schanbals, Private Communication to SAE Occupant Protection Subcommittee of the Snowmobile and All-Terrain Vehicle Committee, 1971. Dow Chemical Co., Midland, Michigan 48640.

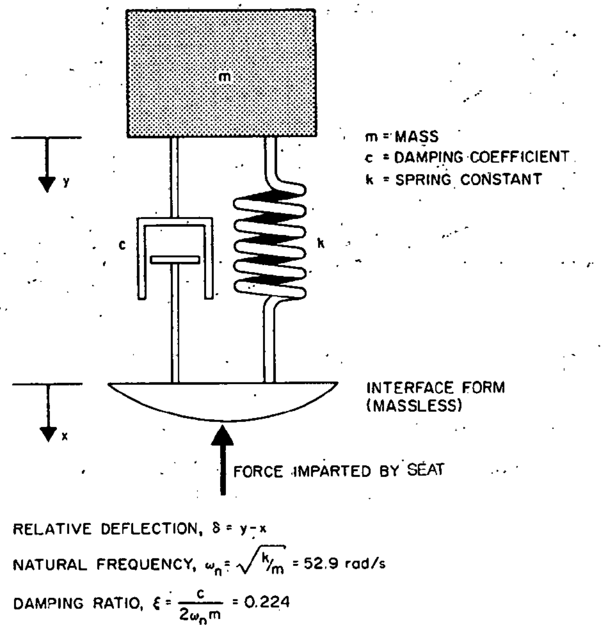

FIG. 1–SPINAL INJURY MODEL

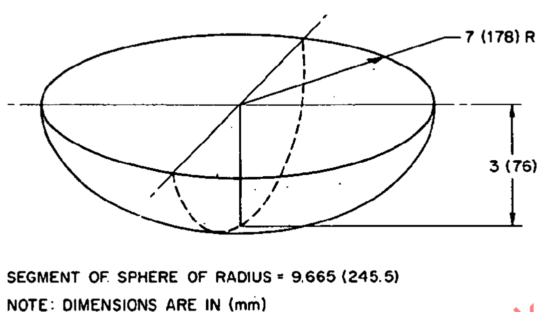

FIG. 2–SEAT IMPACT FORM

area. The data from the fifth drop of each of the three specimens shall be averaged and retained for use in the evaluation procedure of paragraph 4.

4. Evaluation

4.1 Data—From the deceleration-time trace, as illustrated in Fig. 4, record peak deceleration (point C), time from impact to peak deceleration (point t_p), and time from impact to ½ peak deceleration (point t_h). Calculate and record percent distortion using the following calculation:

$$\% \text{ distortion} = \frac{2t_h - t_p}{t_p} \times 100\%$$

4.2 Chart Usage—On the 5% injury probability chart (Fig. 5) for the *average man* impacting the seat at 175 in/s (4.46 m/s) (40 in [1.02 m] free fall), which is equivalent to the 200 lb (90.7 kg) rigid missile described above impacting the seat at 124 in/s (4.4 m/s) (20 in [508 mm] free fall), plot the point corresponding to peak deceleration and time from impact to peak deceleration. If this point lies above the 90% distortion line, the seat fails to meet the criteria of less than 5% probability of injury. If the point lies below the 30% distortion line, the seat meets the criteria of less than 5% probability of injury. If the data point lies within the region of 30-90% distortion, then the point must be evaluated with respect to its calculated percent distortion. If the data point lies above its distortion value, the seat fails to meet the criteria of less than 5% probability of injury. If the data point lies below its distortion value, the seat meets the criteria of less than 5% probability of injury.

Suppose:

$$t_p = 40 \text{ ms}$$
$$t_h = 30 \text{ ms}$$
$$G_{max} = 35\,g$$

Then:

$$\% \text{ distortion} = \frac{2(30) - 40}{40} \times 100\% = 50\%$$

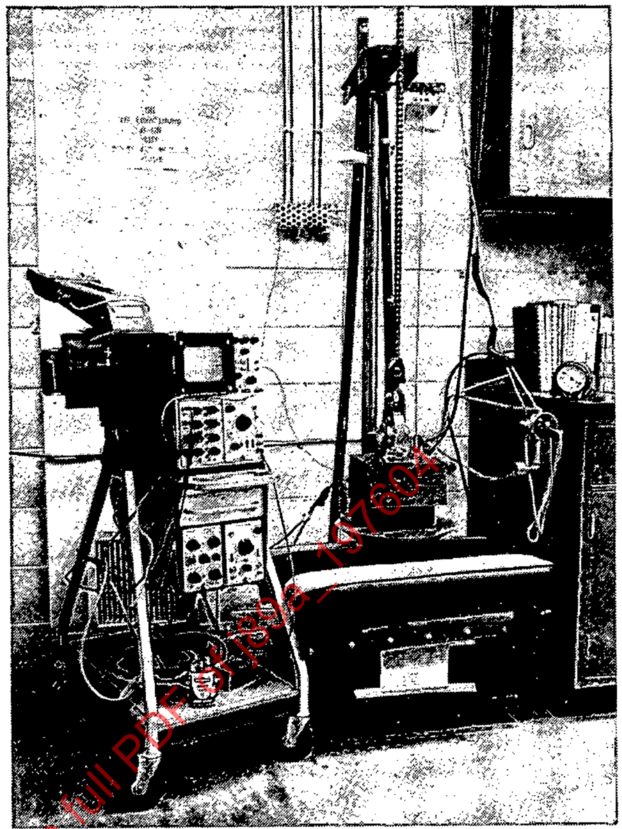

FIG. 3–DYNAMIC TESTING APPARATUS

Plotting 35 g at 40 ms on Fig. 5 indicates the data point falls above its distortion curve. Therefore, the seat fails to meet the performance criteria. If G_{max} had been below 35 g, the seat would have met the criteria.

The evaluation chart was constructed by the following procedure:

4.2.1 A mathematical curve was fitted to the three data points of each possible deceleration pulse in the range of the chart. A distorted haversine function was used since its inherent properties closely match the typical deceleration pulse.

4.2.2 A force model of the seat was found using the following equation, and a curve-fitting scheme applied to the first and second integrals of the distorted haversine curve:

$$F = k_1 x + k_2 x^p + c\dot{x}$$

where:
- F = force
- x = compression displacement of the seat
- $\dot{x}$ = compression velocity of the seat
- k_1, k_2, p, and c = fitting parameters

4.2.3 The injury model of Fig. 1 was dropped onto the seat by simulation, that is, using the injury model equations and the seat force model equation. The height of simulated drop was 40 in (1.02 m) yielding the impact velocity of 175.7 in/s (4.46 m/s). The parameters of the distorted haversine curve (representing the deceleration data pulse) were varied until the injury model reached 2.48 in (63.0 mm) at maximum deflection (correlating with 5% injury). Then a point was plotted on the chart in Fig. 5. The whole process was iterated to find other points on the chart. The iteration procedure was done holding each of several distortion values constant to yield the chart in its final form.

NOTE: The particular procedure described above using the test procedure and evaluation chart is not applicable to seats giving rise to deceleration pulses of shapes radically different from that shown in Fig. 4. However, the performance requirements given in paragraph 2 are still desirable, but other means of evaluation will be required. The specific method of seat evaluation described in this section is generally applicable to foam seat cushions. The details of this evaluation procedure were developed by Pershing.[4]

[4] R. L. Pershing, Private Communication to SAE Occupant Protection Subcommittee of the Snowmobile and All-Terrain Vehicle Committee, 1971. Technical Center, Deere & Co., Moline, Illinois 61265.