THE HEAD-REST - A NECESSARY SAFETY-FEATURE FOR MODERN PASSENGER CARS

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INTRODUCTION

Technical measures taken to increase passenger protection in vehicles refer to head-on-, side-, rear-end-collisions and rollovers. This paper deals with a very small section of this broad spectrum of safety measures - namely the head-rest.

The head-rest has become an integral part of the seat. Seats do not only have the function of providing comfort for passengers during their stay in the car, but they can also make a positive contribution to passenger protection in the event of a collision when provided with the correct technical design.

The kinematics of passengers during a rear-end impact show that the head-rest - particularly during this type of collision - can prevent unendurable movements of the head relative to the upper body.

Fully aware of the fact that the benefit/cost ratio of head-rests is low the intention of the paper is to underline once again the positive effect of head-rests to reduce head-neck injuries especially in the event of rear-end collisions (1). Basic tests were performed which show the difference of head-neck movement during rear-end collisions with and without head-rests. Furthermore an indication is given of the difference of dummy behaviour using a Hybrid II and a Hybrid III dummy.

PHYSICAL DATA IN REAR-END IMPACTS

The most important details are shown in a very simple velocity-time history of a car-to-car rear-end collision (Figure 1): Vehicle 1 hits stationary vehicle 2 from behind with velocity v_o. This consists of a straight, central, full plastic impact. Provided that vehicle 1 is not deformed, that vehicle 2 is subject to constant acceleration versus time and that the masses of the colliding vehicles versus time are constant, this provides the velocity-time sequence for a car-to-car rear-end collision as represented in Figure 1.

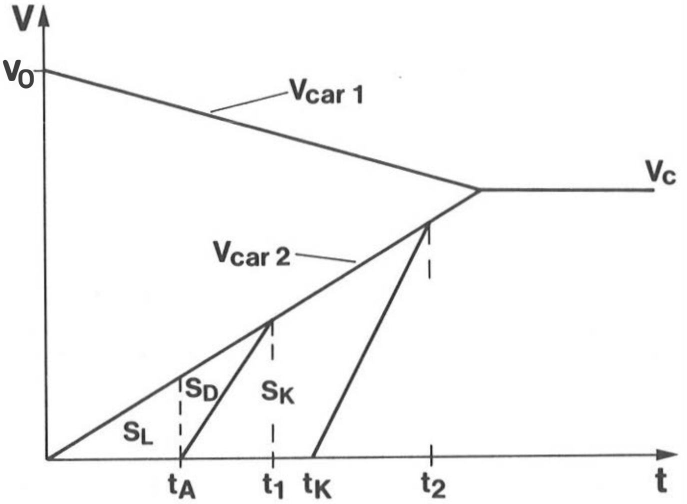

Fig.1 Velocity-Time-History of a Rear-End-Collision

Observations of the passenger seated in vehicle 2 (impacted vehicle) show the following findings: After overcoming the distance body-seatback - represented in the diagram as s_L - the passenger is accelerated from moment in time t_A in accordance with the force characteristic of the seatback upholstery along distance s_D. From moment in time t_1, the body then participates in the acceleration of the vehicle. The head moves relative to the body and passes through distance s_K. From moment in time t_2, the head also participates in vehicle acceleration. From moment in time t_A to moment t_K, the head prescribes a combination of longitudinal and rotational movements relative to the torso. The injury mechanism to the cervical spine caused in such sequences of movement is described in detail in (2).

Further biomechanical research combined with the analysis of real accidents is needed in order to establish a reliable correlation between dummy-behaviour and the severity of injuries of real victims. Even without knowledge of the forthcoming results the task of the vehicle engineer has to be to limit or to prevent the movement of the head relative to the torso. The objective is thus to prevent unendurable hyperflexion and intolerably high accelerations of the head.

SAFETY-RELATED DESIGN OF HEAD-RESTS

The head-rest is an integral part of the seat, i.e. of the seatback. The seat must fulfill both comfort and safety oriented requirements. These requirements are in part contrary the one to the other. The most important bases for design of seats including head-rests are described below.

Strength:

Figure 2 shows which forces and moments a seat must withstand.

Seat structures today are designed to provide high levels of passive safety in a wide range of rear-end collision exposures. The design of a rigid, non-yielding free standing seat structure is not practicably feasible and would represent a reduction in overall levels of passive safety for vehicle occupants. Seatbacks are thus designed to resist rearward forces and to yield in a controlled manner to reduce force levels and generally mitigate the overall exposure for the seated occupant. Seatback collapse without corresponding energy absorbtion reduces and can eliminate altogether the benefits of existing head restraints.

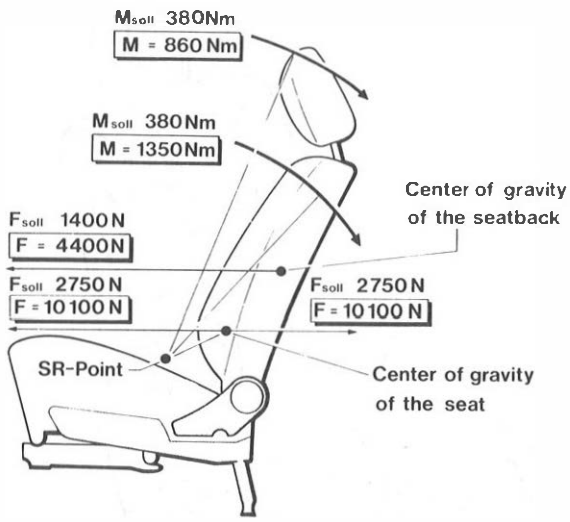

Figure 2: Seat Strength Requirements

Comfort:

Figure 3 shows the basic structure of a modern vehicle seat. The upholstery of the seatback is responsible for a high degree of comfort in normal driving conditions and determines passenger acceleration from t_A to t_1 in accordance with Figure 1 in the event of rear-end collision.

The head-rest must be located so that the distance in horizontal direction to the head is small and its top edge extends approximately 70 mm in vertical direction above passenger eye level or is adjusted to at least eye level. The head-rests for rear seats can restrict the view out of the rear of the vehicle. This conflict of objectives between comfort and safety can be solved. It is possible to produce open head-rests or at least those which can be lowered when the rear seats are not occupied.

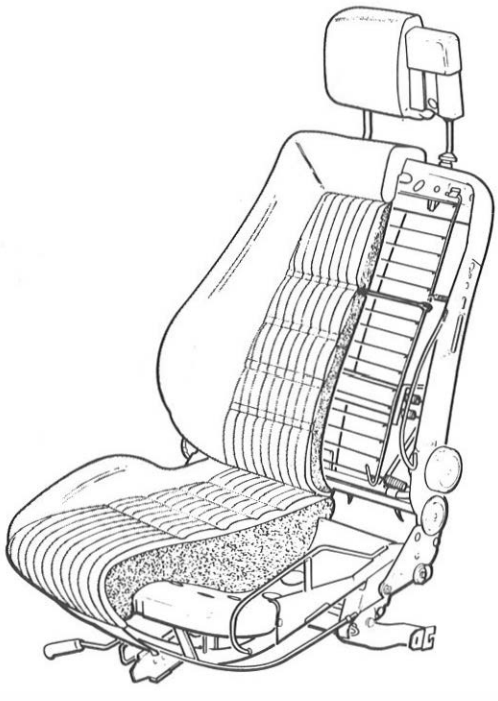

Figure 3: Basic Structure of a Modern Vehicle Seat

EXPERIMENTAL VERIFICATION OF THE ADVANTAGE OF HEAD-RESTS

Rear-end-impact testing plays an important part of safety related test programs. For the purpose of this paper rear-end collisions were simulated in basic experiments on a horizontal sled system. The front seatback was tested with and without head-rest. 50 percentile male dummies of the types Hybrid II and Hybrid III were used.

The kinematics of the dummies were filmed with a high-speed camera. The photo sequences shown in Figures 4 and 5 are taken from these films. The differences in head movement can be clearly seen in a comparison of the results of the experiments:

Seatback without head-rest:

The movement of the head relative to the torso reference line is extremely large. The head of the Hybrid II dummy is tilted 64° to the rear (Figure 4) and the head of the Hybrid III dummy is tilted even 120° to the rear (Figure 5).

Seatback with head-rest:

The movement of the head relative to the top of the body is limited as diagram 1 shows in principle.

A comparison of the head movements of the two dummies clearly indicates a significant difference in neck bending characteristics (Figures 4 and 5). Further testing will be done to underline and to extend these first findings regarding dummy behaviour.

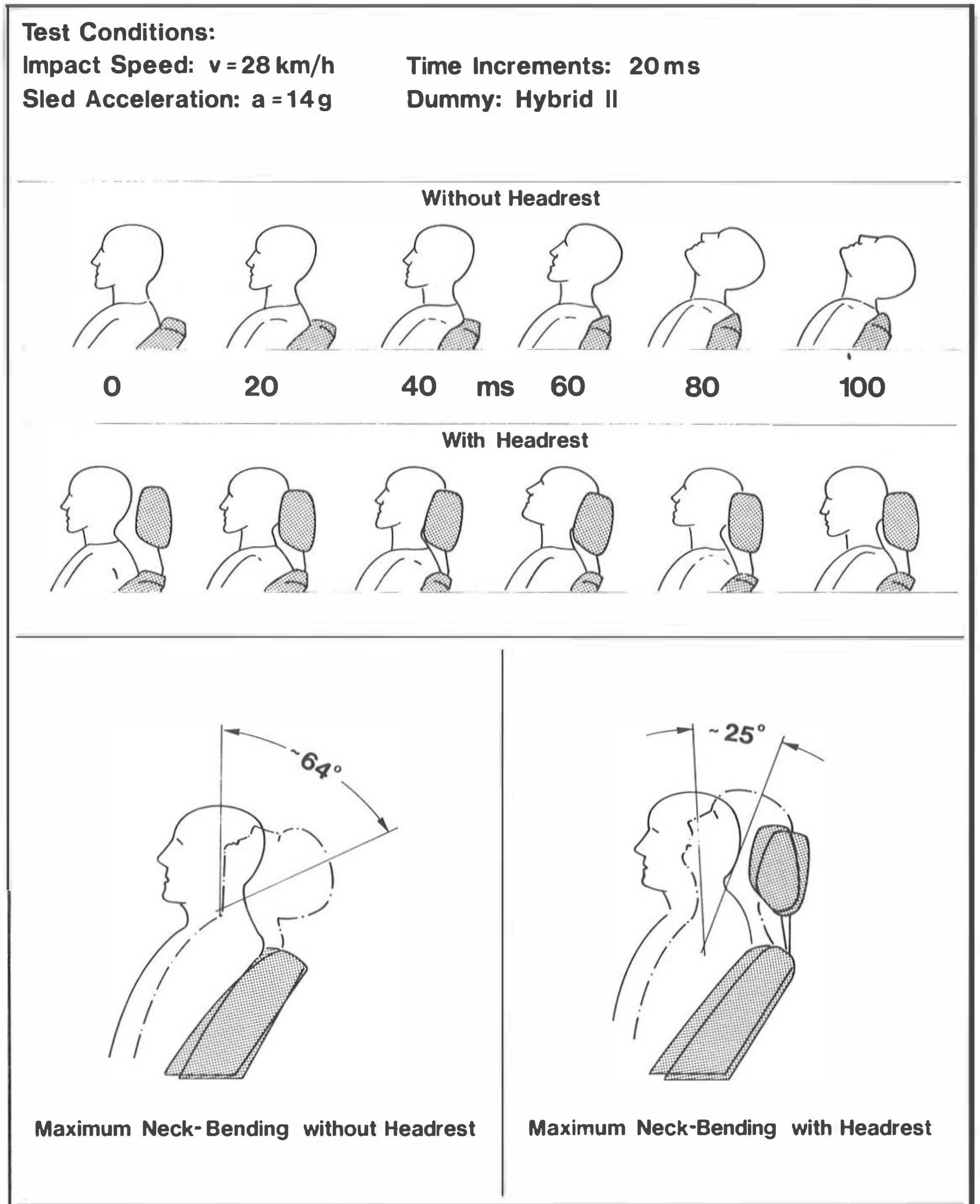

Figure 4: Head Movement during Rear-End-Impact Tests

Test Conditions:

Impact Speed: v = 28 km/h
Sled Acceleration: a = 14 g

Time Increments: 20 ms
Dummy: Hybrid III

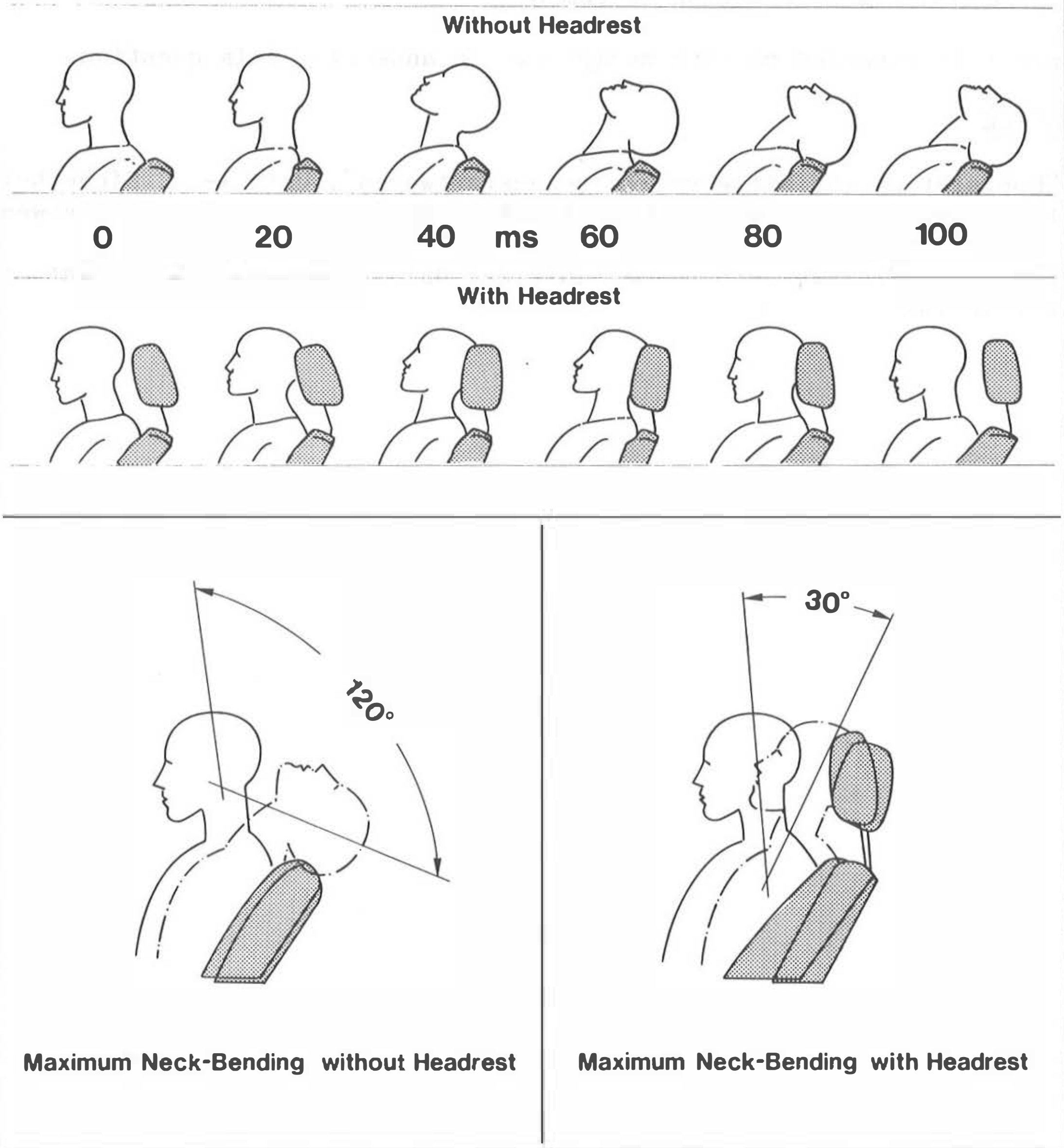

Figure 5: Head Movement during Rear-End-Impact Tests

CONCLUSION

The properly positioned head-rest is essential in the context of the high levels of passive safety in a passenger vehicle. It can have important benefits in the event of a rear-end collision. In any discussion on the advantages of head-rests, the question should not be "Head-rests - yes or no", but the question should rather be: "How must a head-rest - understood as integrated part of the seat - be designed so that it fulfills the necessary requirements for maximum safety and minimum restriction of comfort?"

This paper is intended to give assistance in answering this question.

LITERATURE

(1) "Kopfstützen für Sitze von Personenkraftwagen", Unfall- u. Sicherheitsforschung Straßenverkehr, Heft 6, 1976, Bundesanstalt für Straßenwesen

(2) Burow, K. "Zur Verletzungsmechanik der Halswirbelsäule" Dissertation TU-Berlin 1974