A note on Head Acceleration During Low Speed Rear-End Collisions

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ABSTRACT

The purpose of this paper is to find a relationship between vehicle's acceleration and the occupant's head acceleration during low speed rear end collision. It is based on experimental data obtained from tests performed on live human volunteers. It was found that the head acceleration, on the average, is at least two and a half times larger than vehicle's acceleration.

INTRODUCTION

Low speed, 5-10 mph, rear end collisions (LSREC) represent an important percentage of car accidents (7 out 1000 people will involve in such accident). Even though these collisions usually do not cause any visible damage, they might cause neck and upper back injuries. In spite of many years of research and testing, it is still difficult to determine the value of the impact force in these accidents and consequently the related injuries.

A dynamic model for LSREC, which considers the bumper as a spring/damper combination, was proposed in [1]. This assumption is based on the fact that there is very little, if at all, permanent damage to the car and therefore very little energy is absorbed during the collision. Thus the impact can be considered as an elastic one. The model predicts the acceleration of both vehicles (bullet and target) after the collision. In [2] tests were conducted to determine whether the linear model proposed in [1] could be adapted to simulate low-speed impacts for vehicles with various combinations of energy absorbing bumpers (EAB). The types of bumper used in these tests included, in various combinations; foam, piston and honeycomb systems. Impact speeds varied between 4.2 and 14.4 km/h (2.6 and 9.0 mph) and a total of 16 tests in 6 different combinations were conducted. The results of this study reveal that vehicle accelerations vary approximately linearly with impact velocity for a wide variety of bumper systems and that a linear mass-spring-damping model may be used to efficiently model each vehicle/bumper system for low-speed impacts.

However, the cause of injuries is the acceleration of the occupants' heads, in particular those of the occupants in target vehicle. The motion of the head due to the impact is called whiplash and is demonstrated in Figures 1 and 2.

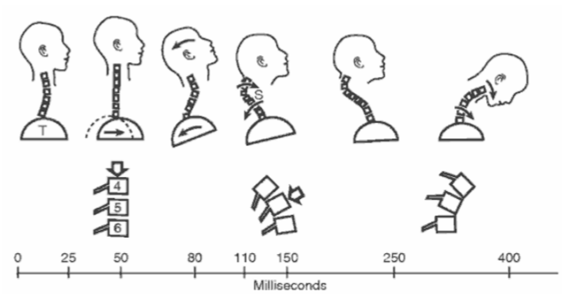

Figure 1: Motion of the target vehicle occupant.

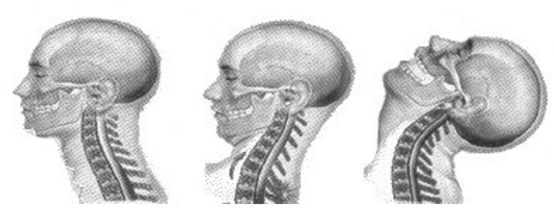

Figure 2 : Head motion in LSREC.

The severity of the injuries in this case depends of the range of motion and the head acceleration. While the above model can predict the target vehicle acceleration, this is not sufficient since there is a large difference between the vehicle's acceleration and the occupant's head acceleration as shown in Figure 3.

Although many LSREC tests were performed using dummies and cadavers, very few were performed on volunteers, and even fewer were fully instrumented. The purpose of this note is to collect data obtained by tests on volunteers and to determine a relationship between the target vehicle's and its occupant head accelerations.

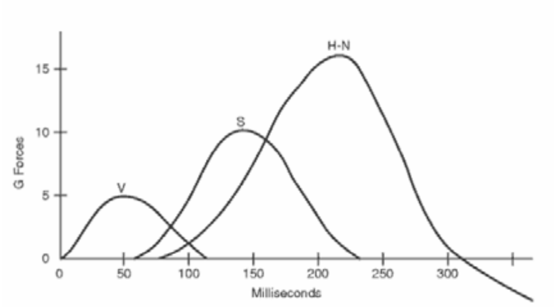

Figure 3: Vehicle, shoulder, neck and head accelerations of a target vehicle's occupant (V-Vehicle, S-Shoulder, H-N-Neck & Head).

SOURCES OF DATA

The first test on human occupant is described in [3]. In this test a 1941 Plymouth was used to rear end a 1947 Plymouth with impact velocities ranging from 7-20 mph. The tests used dummies and volunteers as occupants. It should be noted that these are very old vehicles and their bumpers are by far more rigid than current ones.

In [4], human volunteers were exposed to 10 mph LSREC tests. These tests were conducted with 1981 and 1984 ford escort with both men and women between 27 and 58 years old. It was concluded that: "In spite of the fact that human volunteers in the present study differed in sex, age, height, weight and initial spinal condition, kinematics for all occupants were similar". Also, "head acceleration multiplication factor" was defined as the ratio of the peak head acceleration to the peak vehicle acceleration. This factor was used to evaluate cervical injury and it was determined that in cases where this ratio exceeds the value of 2, it usually indicates cervical injuries.

In [5] tests were conducted with male and female occupants between the age of 22 and 54 years old with impact speeds up to 16 Km/h (10 mph). In this work, in which 2 mid 1970's Volvos were used, two different head restraints were tested. Rear end collisions tests are reported in [6], two 1979 Plymouth where used. In these tests the impact speeds ranging from 1.8Km/h (1.1Mph) to 11.6Km/h (7.2Mph).

The results of rear end collisions with higher impact speeds, 30 mph, are reported in [7]. The test vehicles in this case were two standard Audi 80s. The use of the data obtained from these tests is limited since the speed too high for considering as low speed. However, the data will be presented here for comparison purpose.

EXPERIMENTAL DATA COMPILATION

Figure 4 plots the experimental data collected from all the above tests. To obtain a better insight to the experimental results, the data was regrouped according to the Impact speed and it is shown in Figure 5. It is clear that for high speed impact (>40 [km/h]) the occupant's head acceleration is almost constant and independent of the vehicle acceleration. These cases are not considered to be low speed impact since large plastic deformations are involved. The data for the mid-range speeds (10-20 [km/h]) are not conclusive. However, the data for the low speed (0-10 [km/h]) experiments do show trend which need exploration.

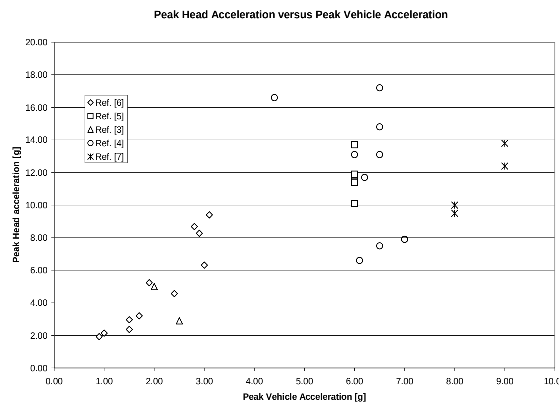

Figure 4: Experimental raw data.

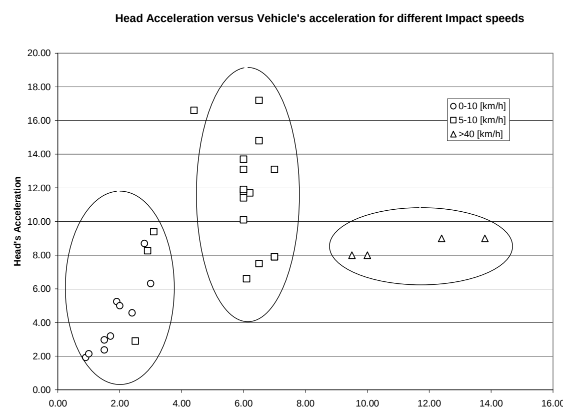

Figure 5: Vehicle and head accelerations for different impact speeds.

The data related to slow speed impact (0-10 [km/h]) are redrawn in Figure 5 and a simple linear regression of the data yielded:

$$A_h = 2.75A_v - 0.89 \qquad (1)$$

where: A_h – Head acceleration
A_v -- Vehicle acceleration

with a correlation index of R^2=0.80.

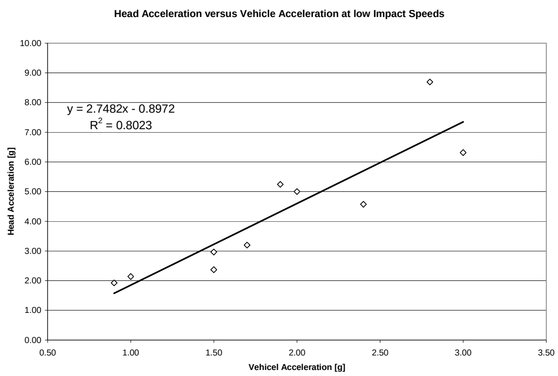

Figure 6: Linear regression for the low speed data.

Having in mind that the repeatability of the above experiments is relative low, due to difficulty in controlling all the experimental parameters, the high value of the correlation index indicates that that this phenomena where the head acceleration is amplified, is real.

CONCLUSIONS

Low speed rear end collision happen very frequently. In most cases there is no damage to the vehicles and as a result, it is assumed that to injury occurred. However, in some cases occupants later complain about neck and back pain which is characterized as “whiplash” injury. The reason for this pain is the exposure of the head to high acceleration.

Experimental results from low speed rear end collisions, which involved live human subjects, have shown that the peak head acceleration is at least two and a half times larger than peak acceleration of the struck vehicle. This assessment is correct for impact speed below 10 [km/h] (6.8 mph).

This fact can explain why injuries are reported although no vehicle damage was observed.

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