"Engineering-Medical Analysis of Fatal and Non-Fatal Head Injuries of Helmeted Motorcycle Victims"

Introduction

Many investigators have reported on the tolerance levels of the human head to static and impact loading* Their data are based upon investigations of loading on unembalmed and embalmed cadavers, primates and various headforms. Protective helmets are being designed, based on such data.

This paper presents one of the studies in our program of investigating fatal and non-fatal motorcycle accidents from which head injury data might be derived, and a severity index could be established and collated with the studies of other investigators. We also solicit from medical examiners, neurologists, neurosurgeons, and other personnel involved in accident work to send us medical and engineering reports and helmets of well documented helmeted motorcyclist accidents. Our procedure is to conduct a program of impact loadings on helmeted instrumented headforms in an attempt to simulate the injury producing phenomena thus obtaining a measure of the forces and energies transmitted into the head.

Accident Description

A brief description of the accident data will illustrate the factual basis for the engineering calculations. This case is interesting from many aspects in that parameters of vehicle, environment and rider combined to produce this accident. This incident involves a single vehicle, a motorcycle with sidecar (passenger was riding pillion, not in sidecar). The sidecar had recently been attached to the motorcycle. Experienced riders report that the handling characteristics of a motorcycle changes considerably with such an addition. In an emergency situation, an inexperienced rider can come to grief. The rider and his passenger were both part-time barmen at a local pub and had left work just after 11 p.m. It was raining. Another barman, in his car with two passengers, had left the pub parking area just ahead of the motorcycle. On the roadway, both vehicles passed a slower moving car and then the motorcycle rider passed his colleague's car on the short straight-a-way and remained on the offside as he went into the left-hand bend at a speed of between 50-60 m.p.h. This speed was agreed upon by the colleague and the driver of the other slower moving car, which had been overtaken. The motorcycle did not appear to go into the bend, but continued on a straight path, striking the kerb and mounting the verge. It continued on a straight path on the verge until it came into contact with a chain

(*References 1. - 12.)

link fence which began to redirect it counter-clockwise. Sparks were seen in the darkness. The motorcycle collided with, knocked down and over-rode a concrete fence post and continued to penetrate the fence and field for another twelve feet, coming to rest about one foot short of the next concrete post.

The helmeted rider of the motorcycle had been projected through the air and his head struck a concrete fence post, immediately adjacent to the next-in-line post. The force of the impact rotated this post in the direction of motion of the rider, about 45° and his body landed about five feet further. The pillion passenger, who was not wearing a helmet, was also projected through the air and landed about twelve feet further in the same direction of motion. The helmeted rider was dead of severe cranial injuries and the unhelmeted pillion passenger survived with only a fractured right femur.

Energy Calculations

Figure 1 shows the severity of the damage to the helmet.

The witnesses' statements suggest an upper speed limit of 50-60 m.p.h. when the vehicle left the roadway. Upon contact with the verge and fence this speed would be reduced so that the velocity of the two bodies would be less upon leaving the motorcycle. First the pillion passenger was probably slowed down when his right femur was fractured. It is likely that this occurred during his initial flight, upon contact with the chain link fence. He would leave the motorcycle from a greater elevation than the rider, as the rear of the vehicle bucked-up. His flight path is assumed to have reached a greater elevation; he cleared the concrete fence post (assumed 5 feet elevation). His total flight path was approximately 29 feet, beginning at the first severe deceleration of the motorcycle when it struck the concrete fence post. Assuming no air friction and a parabolic flight path, the speed (after fracturing femur) is calculated to have been approximately 28 l/s.

Similarly, if we assume that the rider's body had started his flight path at the same angle as the pillion passenger and struck the fence post at an elevation of about four feet and the beginning elevation from motorcycle seat of about 2 1/2 feet, with a body weight of approximately 182 pounds, the velocity at impact is estimated at 23 l/s. Thus the flight path of the pillion passenger and that of the rider result in closely agreeing velocity conditions.

Coroner's Report

The body was that of large, well developed young man showing multiple lacerations on the face and lower lips with bruising and abrasions around the left eye. There was a laceration on the outer side of the left knee and a small abrasion on the right knee.

Head. The skull showed a long vertical fracture running from the left forehead down into the base of the skull on the right side and a series of basal fractures.

The brain showed superficial haemorrhage and contusion.

Test Program

Eight helmets of the same manufacture were purchased for this program. These were mounted on rigidly supported beechwood headforms and subjected to increasing increments of impact energy. A swingaway helmet testing apparatus (13) was utilized in this program. In order to provide a greater number of test blows, each helmet was impacted at the same angle, once with a frontal and once with a rear attack. These helmet locations are sufficiently separated so that the resulting deceleration curves are not significantly location sensitive. Figure 2 shows the damages produced by one of these tests. A deceleration-time record was provided by an accelermeter mounted on the drop hammer and ancillary amplifiers, oscilloscope and polaroid camera.

Experimental Results

Table 1 lists the series of tests conducted, the drop heights and forces transmitted. Figure 3 is an example of the deceleration-time curves recorded by the polaroid camera attachment to the oscilloscope.

It was found that the helmet shell "bottomed-out" on the rigid beechwood headform preventing the development of the severe fracture pattern displayed by the accident helmet. Therefore, the beechwood headform was cut back and relieved by a 2 1/2 inch depression. The test results indicated a more severe fracture pattern at the impact capacity of the apparatus, but again the shell had "bottomed-out". The depression was completely cut away, permitting a maximum shell movement of about 1 inch (from the normal contour of the headform). The results of these impacts indicate the beginning of a fracture pattern, similar to the accident helmet. However, the maximum impact energy of the apparatus was not sufficient to induce further similitude of fracture pattern.

The testing program was started with the energy load specified by the minimum specifications BS2001 and increased until reaching the capacity of the apparatus.

Discussion

The experimental difficulties involved the bottoming-out of the helmet shell on the beechwood headform. Flexible plastic headforms are now being developed in an attempt to more nearly simulate the deformations and mechanical properties of the human skull.

Theoretical engineering dynamic calculations require the assignment of an appropriate mass to the kinetic energy equation. The simplest consideration would be to assume that the mass of the head was attached to a flexible neck and only this mass plus that of the helmet was involved in the energy calculations. This resulted in much too low an energy value. If one reads the coroner's report, it will be seen that there were "a series of basal fractures". This would indicate that some of the mass of the torso was also involved in the energy transfer.

Thus it is necessary to have both the engineering and medical data, which then must be verified by the experimental program.

TABLE 1

Helmet no.	Size	Head-form size	Striker config-uration	Mass lbs.	Drop height (ft.)	Impact Energy ft.lbs.	Postion of blow	Peak recorded 'g'	Peak trans-mitted force (lbs.f)
1	3	7 3/8	Flat	11.0	14.0	154	Front	900	9,900
2	3	7 3/8	Flat	11.0	18.0	198	Rear	838	9,220
3	3	7 3/8	Flat	22.0	14.0	308	Front	710	15,620
4	2	7	Flat	22.0	22.0	484	Front	1010	22,220
4	2	7	Flat	22.0	22.0	484	Rear	1010	22,220
1	3	6 1/4	Flat	22.0	22.0	484	Rear	680	14,960
5	2	6 1/4	Flat	22.0	23.0	506	Front	886	19,490
6	2	6 1/4	Flat	22.0	23.0	506	Front	948	20,860
6	2	6 1/4	Flat	22.0	23.0	506	Rear	996	21,910
5	2	7	Flat	22.0	7	154	Rear	214	4,710
3	3	7	Flat	22.0	14	308	Rear	510	11,220
7	2	7	Flat	22.0	23	506	Front	1040	22,880
7	2	7	Flat	22.0	23	506	Rear	985	21,670

FIGURE 1 - ACCIDENT HELMET

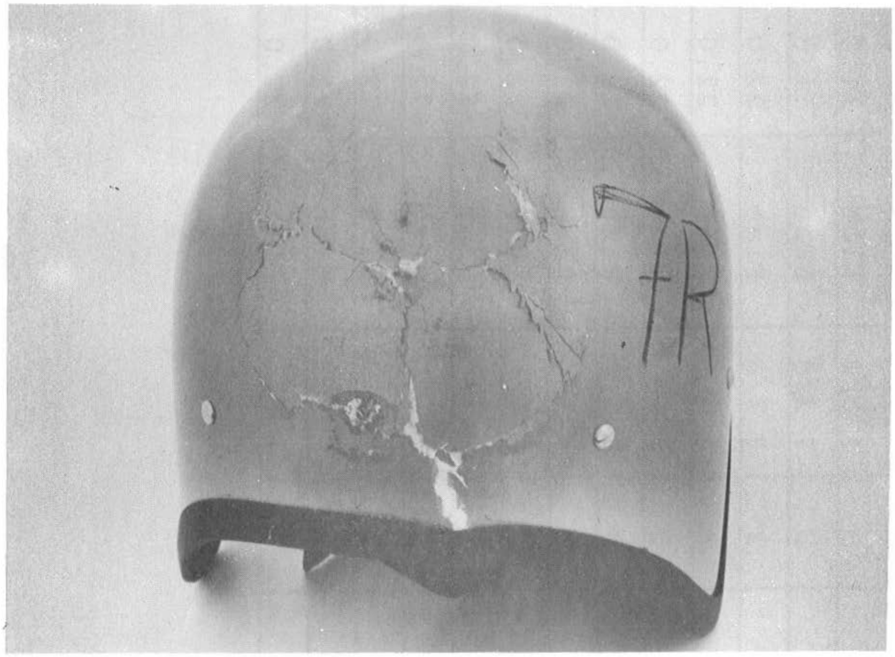

FIGURE 2 - EXPERIMENTALLY IMPACTED HELMET

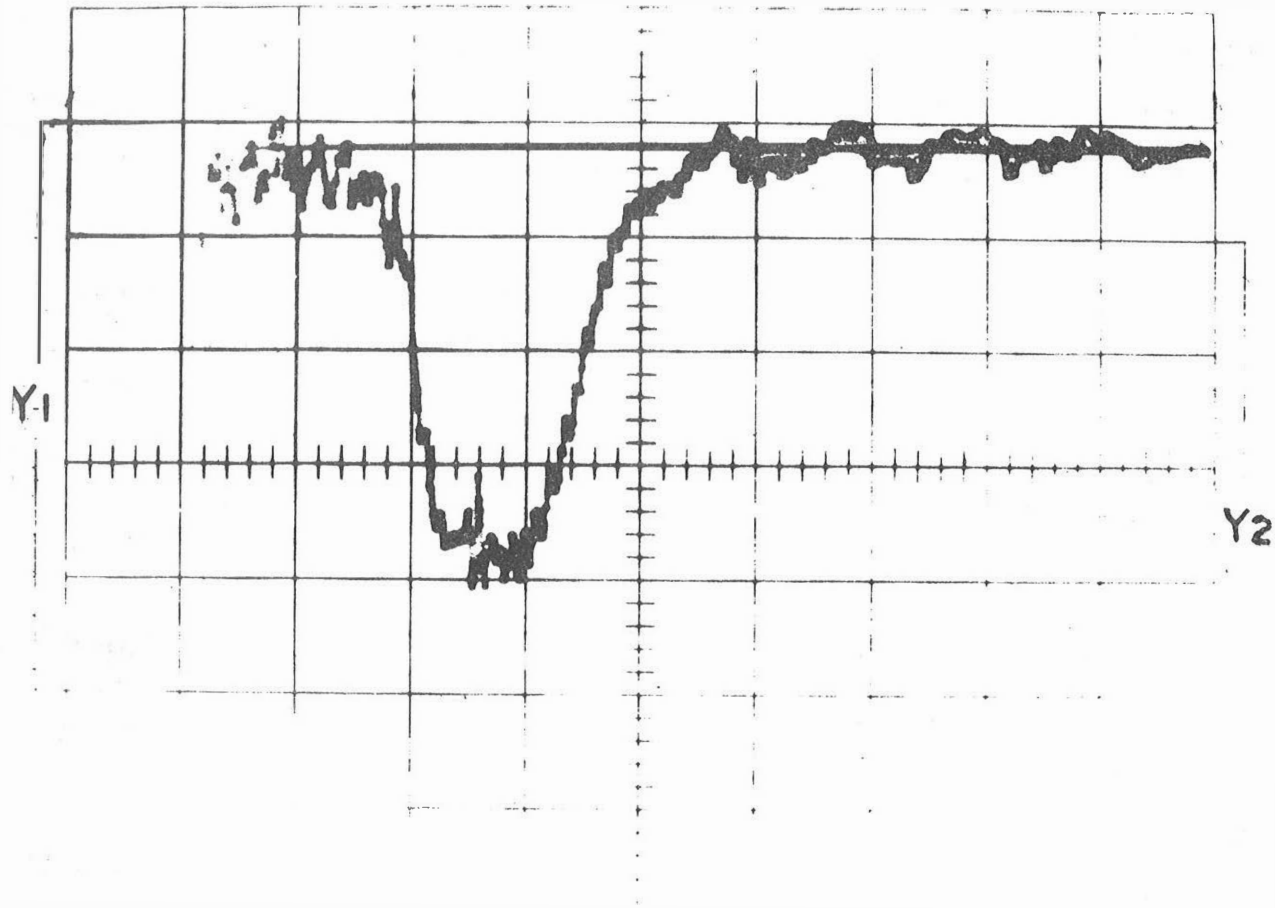

FIGURE 3 - DECELERATION - TIME CURVE FOR
EXPERIMENTALLY IMPACTED HELMET

Scales: Horizontal - 10 units/ms
Vertical - 10 units/500g

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