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CHEST/PELVIS INTERACTION DURING AIR BAG DEPLOYMENT

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ABSTRACT

During a vehicle crash test the Hybrid III dummy interacts with the restraint system. In addition, different parts of the dummy can also interact with each other, such as , the pelvis and the chest. This paper is a technical note that documents one of the interaction of the chest with the pelvis when an airbag restraint system is used. This interaction is characterized by: reduced chest deflection, acceleration spikes in the A-P and I-S of both the chest and the pelvis, and angular acceleration spikes around the R-L axis in both the chest and the pelvis. This interaction appears to be an artifact of the dummy and can significantly affect the response of the chest during passenger airbag deployment--contributions to the chest resultant as high as 20 g's have been observed.

INTRODUCTION

One method of passive restraint is to use a knee blocker to control the lower half and an airbag to control the upper halve of the body. However, in vehicle development tests using a Hybrid III dummy an interaction between the upper and lower dummy segments is possible: Allowing either the upper half of the dummy to manage some of the energy of the lower half or the lower half of the dummy to manage some of the energy of the upper half. This interaction is generally seen in airbag restrained and not in belt restrained dummies (1). Although this interaction is almost always seen in an airbag restrain, it is not always significant enough to be detected. Two factors have been found to contribute to the interaction: differential motion of the chest with respect to the pelvis and pelvis rotation. This type of response is more common in a passenger airbag system than in a driver system. Therefore the results to be presented are for a passenger airbag system and represent a very significant interaction between the pelvis and chest.

METHODS

A series of 30 mph frontal sled tests were conducted to document the effect of pelvis-chest interaction. The sled was fitted with a specially designed knee bolster that could be positioned at different distances from the Hybrid III knees. It was designed so the impact response, femur loads, would comply with FVMSS 208. A passenger airbag support structure and reaction surface were also part of the test set up; it allowed for different deployment angles. The windshield simulation allowed for different angles with respect to the horizontal. Each dummy was equipped with multiple acceleration arrays that allowed for documentation of rigid body motion (2-4). The results are presented in terms of angular and linear accelerations, velocities, and displacement of the chest, femur, and pelvis. In addition femur forces are also presented.

RESULTS

The following represents the typical response signature of the pelvis-chest interaction: Figure 1 presents the chest deflection and its relation to the peak spinal acceleration. This acceleration occurs when the chest is unloading; indicating that not all the load is coming directly through the chest. Figure 2 presents the I-S acceleration for the pelvis and the chest. Near the time of peak chest acceleration resultant, acceleration spikes opposite in direction can be seen in the pelvis and chest, indicating that they are being driven towards each other and that the interaction is not coming from outside of the dummy system. The pelvis is not being driven up forcing the chest up nor is the chest being driven down forcing the pelvis down. In addition, there is an angular acceleration spike(Figure 3) in both the pelvis and the chest in the same time frame when there is an acceleration spike in the A-P/I-S acceleration. Finally, if the force measured by the load cell in the femur is compared to the force obtained by multiplying the effective mass of the femur and it's acceleration, there is a spike-like divergence of the two at about the same time when the chest and pelvis angular and linear acceleration spikes occur (Figure 4). This indicates there is a force coming from the pelvis to the femur--beyond inertial loading.

The above represents a description of the forces and accelerations that can occur during the pelvis-chest interactions. In addition the displacement signature, both angular and linear, can be documented. Figure 5 represents a motion reconstruction of the dummy during a test. The reconstruction is accomplished through the use of the output from the multiple acceleration arrays. The image represents the chest, pelvis, and left side femur. In this reconstruction it can be seen there is very little rotation of the chest up to peak acceleration. The top of the pelvis rotates forward, up to this point in time (Figure 6), then stops abruptly and reverses direction. In addition, there is significant linear differential motion of the pelvis with respect to the chest; the chest leads the pelvis by about 100mm.

In this test series it was found that pelvis-chest interaction occurs for a wide range of: knee offsets, airbag deployment angles, and windshield angles. The indication is that this interaction will occur in many airbag tests. However, in some of these tests it will be small enough to go unnoticed. In addition, there are combinations of knee offset and airbag deployment angles where the pelvis-chest interaction is unpredictable. Identical test setups can produce different results by as much as 20 g's. The dummy can be sensitive to initial set up; small changes in the initial pelvis angle and chest position can lead to big differences in chest g's.

DISCUSSION

The above results indicate the following: Up to a point in time the pelvis and the chest move somewhat independently. At about 75ms an interaction develops generating a torque in the pelvis and chest as well as an upward force on the pelvis and a downward force on the chest. In addition an interactive force generated between the chest and the pelvis is transferred to the knees. The chest is driven away from the airbag system and the pelvis/femur is driven toward the kneeblocker, increasing the femur contact load by a small amount.

Since the connection between the chest and the pelvis is the lumber structure, it is reasonable to assume that its response profile is important. Although the chest and pelvis are constrained by the lumbar geometry some differential motion can occur. During the initial dummy motion little or no forces are passed between the chest and the pelvis. If significant differential velocity in the A-P direction is allowed, then, when the pelvis-chest differential displacement reaches the allowable limit significant tension develops rapidly in the lumbar segment thus, resulting in the acceleration profile observed. Although the differential motion of the chest to the pelvis is important, it is not the only necessary factor to generate the above interaction; the pelvis rotation also plays a part. If the chest moves forward with respect to the pelvis then when tension develops in the lumbar spine the top of the pelvis will be forced forward. However, the resistance of the pelvis, for this type of rotation, is much smaller than is necessary to generate the forces observed. In addition, the angular acceleration during the spike event is in the opposite direction of the pelvis rotation; the torque is slowing the pelvis forward rotation. Instead, the pelvis rotates forward early in the impact event and tension develops in the lumbar stopping the rotation. Since the angular velocity is significant when tension develops, considerable forces are needed to manage this energy in a short time frame. Therefore, two factors are needed for the pelvis-chest interaction: differential motion between the chest and the pelvis and the forward rotation of the pelvis.

CONCLUSION

During a crash the Hybrid III dummy interacts with the restraint system. In addition, different parts of the dummy can also interact with each other, such as, the pelvis with the chest. This interaction appears to be an artifact of the Hybrid III dummy, can induce up to 20 g's in the lower spine, and generates chest acceleration that do not represent chest loads.

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REFERENCES

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Fig. 1

PASSENGER CHEST A–P ACCELERATION AND DEFLECTION

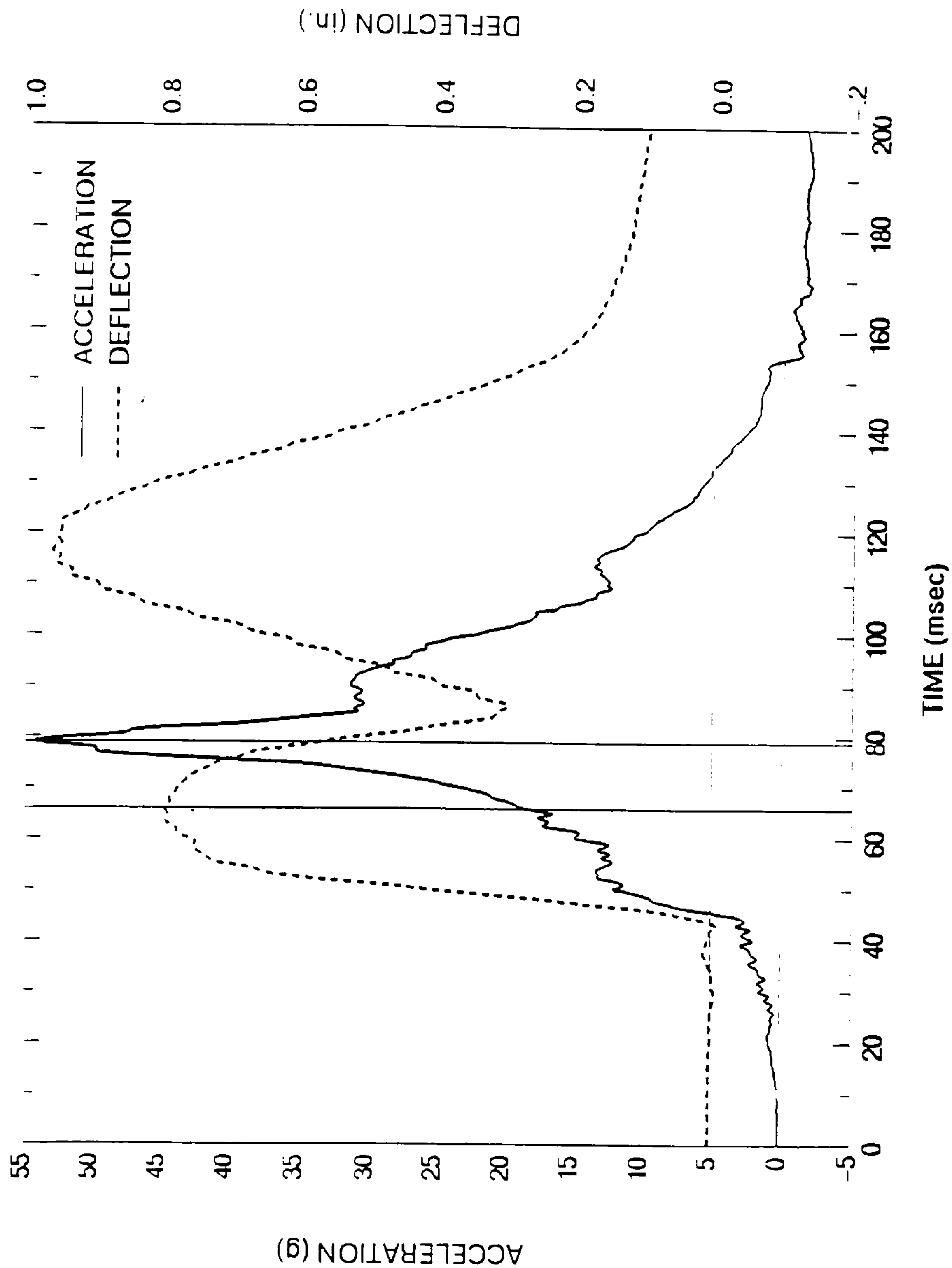


Fig. 2

PASSENGER CHEST AND PELVIS I−S ACCELERATION

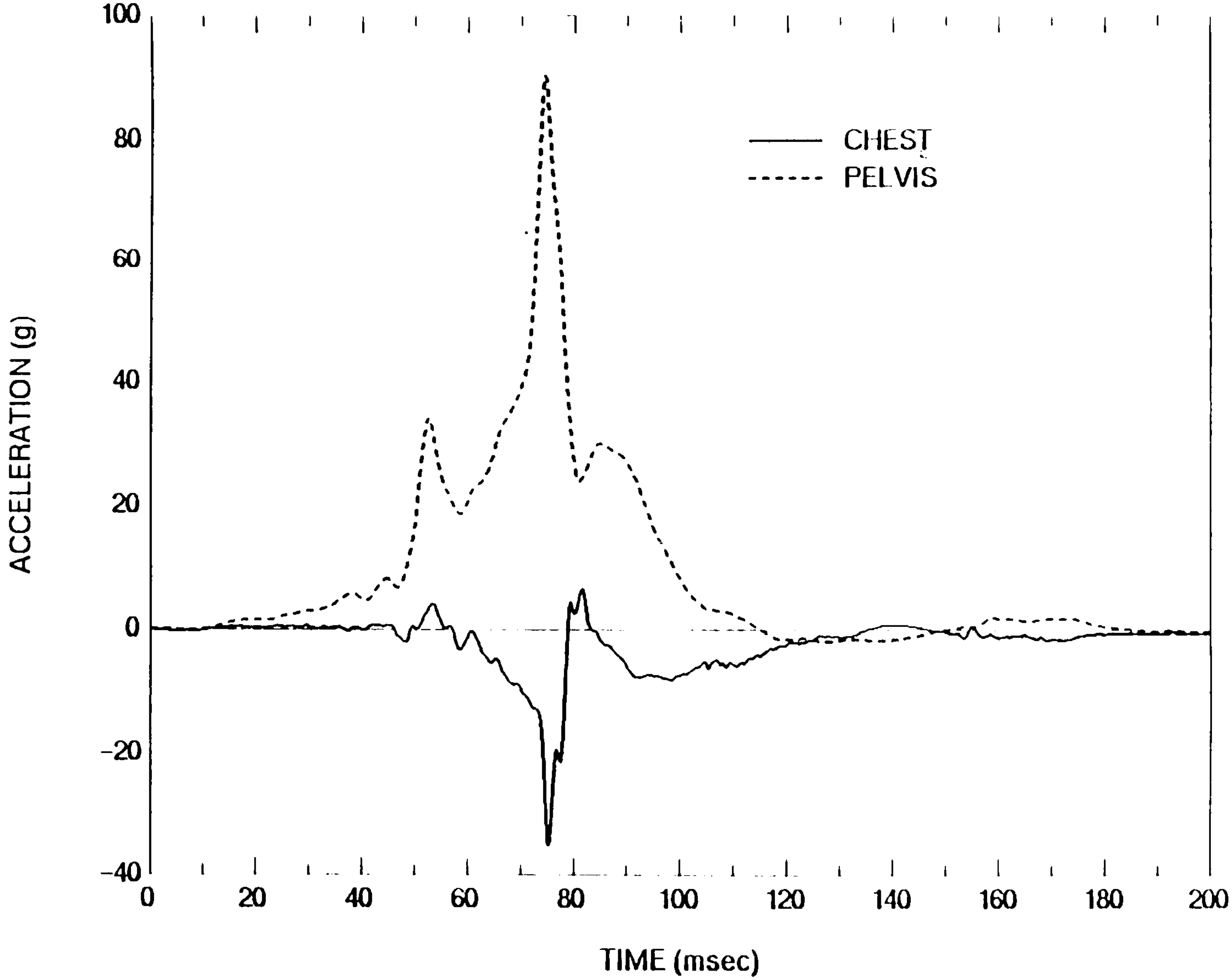


Fig. 3

PASSENGER CHEST AND PELVIS ANGULAR ACCELERATION

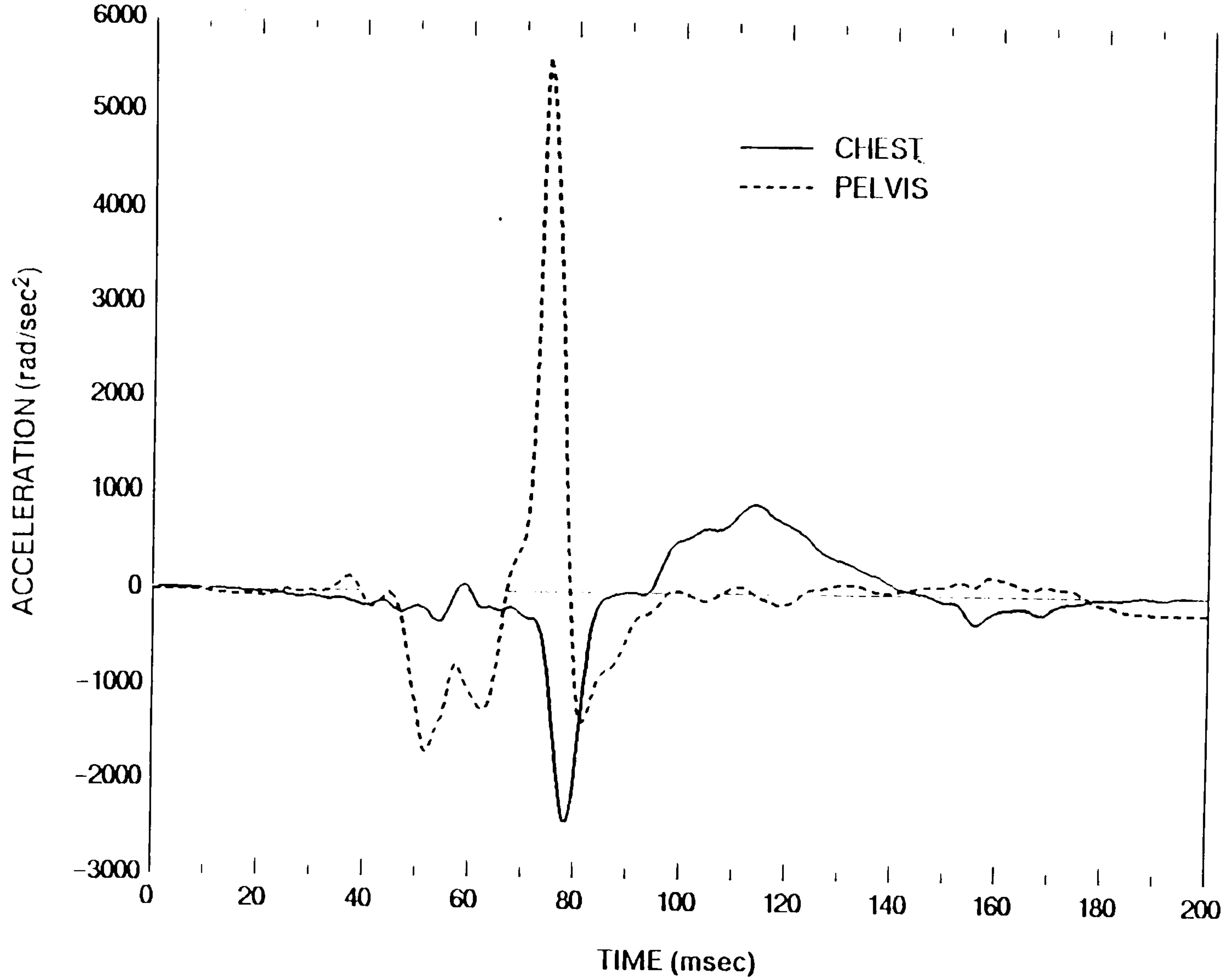
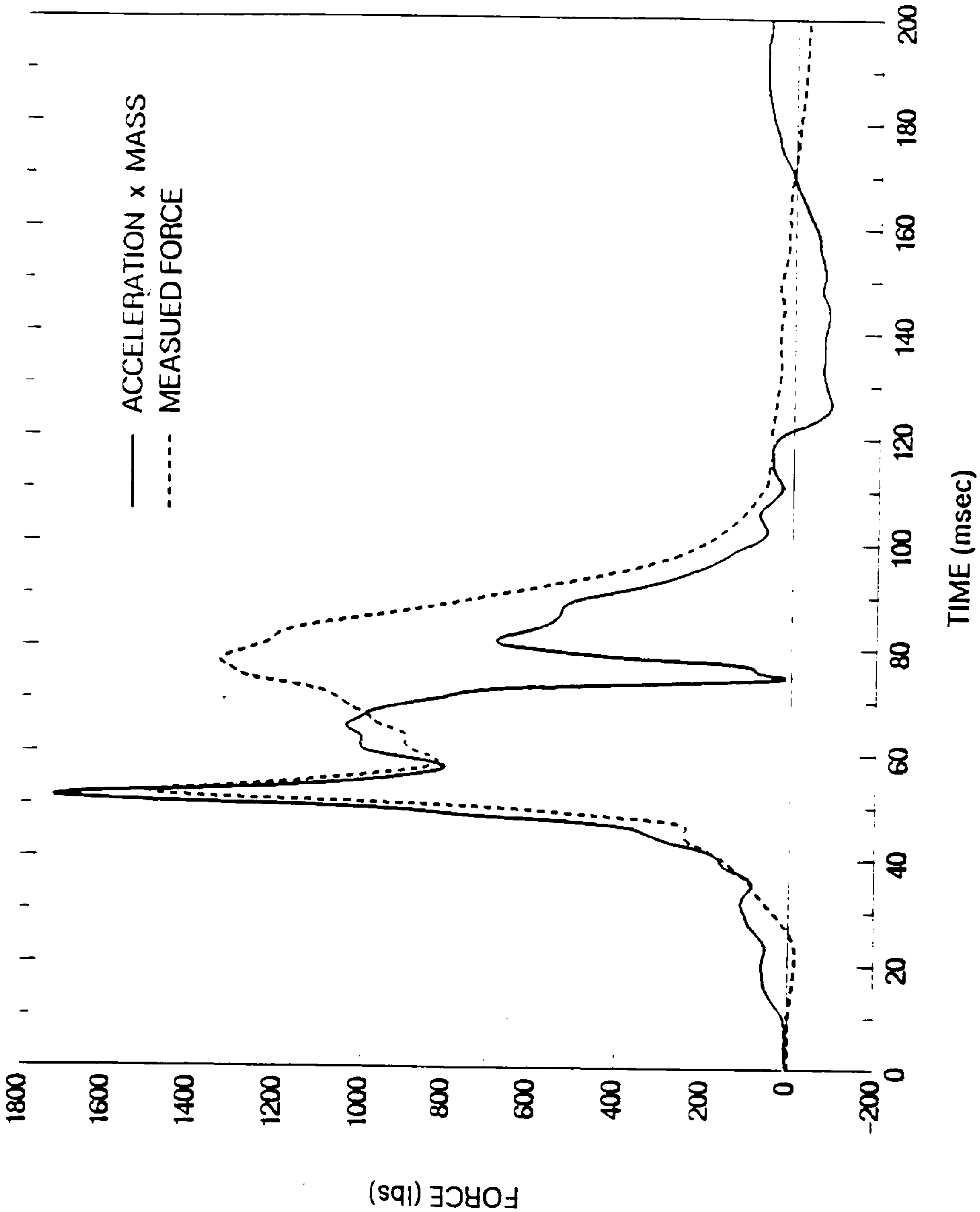


Fig. 4

PASSENGER FEMUR FORCE



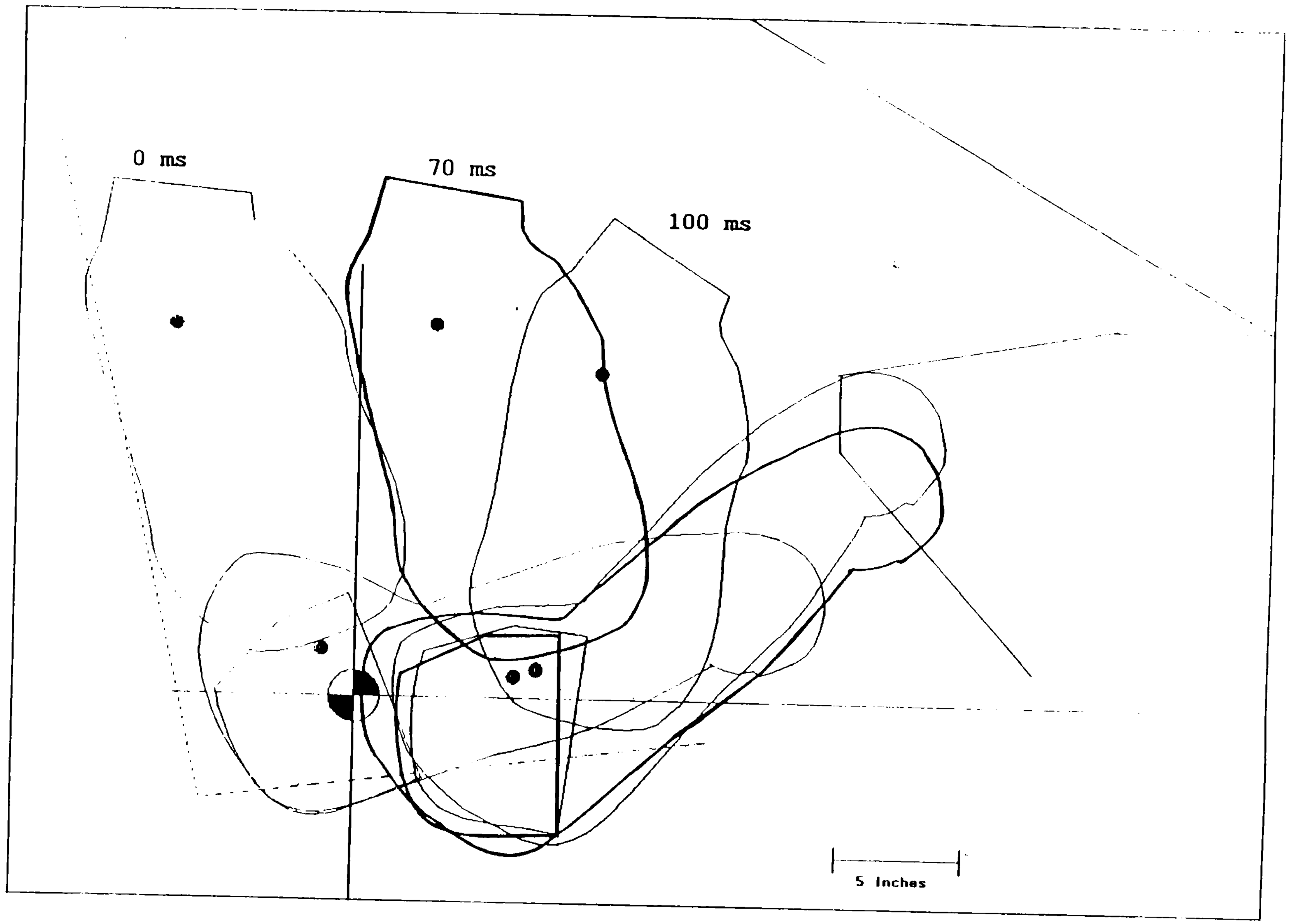
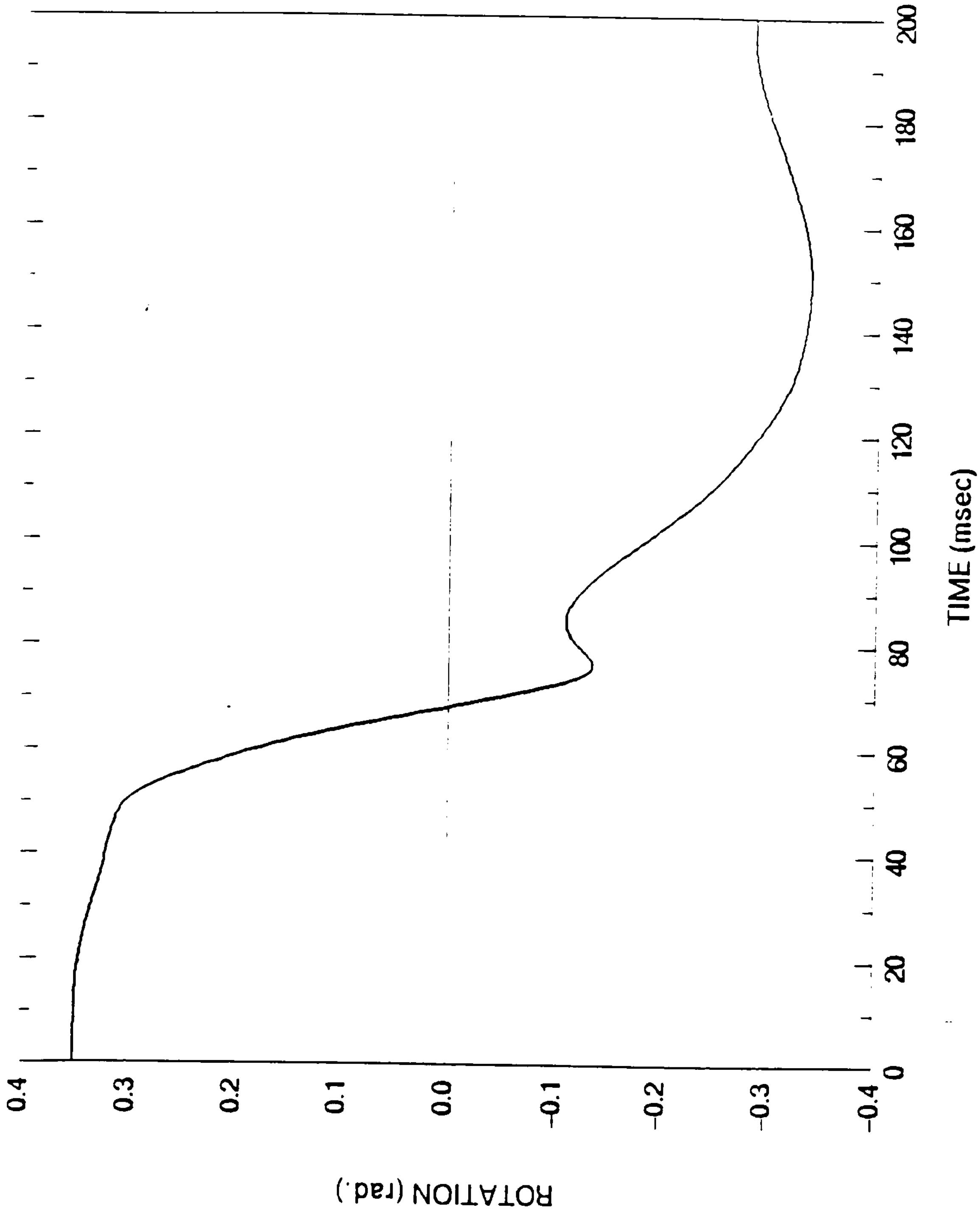


Fig. 5 PELVIS, UPPER AND LOWER TORSO POSITION

Fig. 6

PASSENGER PELVIS ROTATION



DISCUSSION

PAPER: **Chest/Pelvis Interaction During Air Bag Deployment**

SPEAKER: Guy Nusholtz, Chrysler Motors

QUESTION: Soichiro Okudaira, Toyota Motor Corp.

We also have the same problem in the Hybrid III dummy in frontal crash, and we submitted the petition to the rulemaking last month on this issue. We observed this phenomena and we concluded that it caused problems between the femur bone and the pelvic bone at the pelvic joint. The rotation stop at the pelvic joint on the Hybrid III limits the movement of the femur. We compared with human beings and Hybrid III dummy. Hybrid III dummy it's rotation angle is very limited in comparison with human beings. That conclusion, how do you think about it?

A: Well we've seen the same thing. In fact, in some cases when the two collide, then you stop the pelvis rotation and then, since you stopped the pelvis rotation, the upper spine keeps going and you eventually get that sharp torque that occurs in the upper spine. But it can also occur without striking the stops. If you adjust the dummy to just allow more rotation, that will solve some of the problem. In fact, there are many situations in which that is the cause and you can get rid of the cause, but there are conditions which can occur when you don't get those large angles between the pelvis and the femurs and you can still get the spike and that's when the pelvis can actually rotate enough so that it's now trying to rotate the spine down, plus it's over here and so it is yanked back. So what you are saying is true, not necessarily true but that's what we've observed also and we can see that it can also happen in other situations. So there is more changes that need to be made to the dummy as well as that one.

Q: OK. Thank you.

Q: Rolf Eppinger, NHTSA

Guy, I must say I missed something as I watched your presentation. You suggest as the knee/IP load gradually increases and you are driving them back, the head of the femur applies a rearward force low on the pelvis. You also suggest that the lumbar spine, because it is restraining the torso's and spine's forward movement, applies a forward force to the top of the pelvis, and, as a result, you have rapid pelvis rotations which cause sharp spikes on both the pelvic and spinal accelerometers. What I don't understand, in your explanation is what causes the sharp discontinuities to occur?

A: In one case, as one example of what happens, is the femur angle reaches a certain point and then the pelvis goes into the femur.

Q: The pelvis goes into the femur?

A: Yes.

Q: You mean bumps?

A: Yes. Bumps into the femur. The femur rotates like this and the pelvis rotates down and so those two lock up.

Q: You can demonstrate that on a dummy that you can physically take the femur up at the angles that you are experiencing and actually have physical interference.

A: Well, I don't know that I can but he can (pointing to Mr. Okudaira).

Q: Are you describing his problem or your problem? That's what I don't understand. I'm trying to understand what you presented here and I don't understand how we can suddenly create these very large torques.

A: I gave that as one example.

Q: But that wasn't how you had tried to explain it.

A: What happens is that if you rotate the pelvis far enough forward, the top part moves differentially and let's say it pulls. It will rotate to a certain point and then the pelvis can no longer rotate or else it's going to rotate down. You are going to increase the distance between that and the spine and so it develops a large force between the two.

Q: Why does it do it so rapidly? I can see this is a continuous system where things would sort of slowly, or, at least, occur smoothly but this thing looks like it went click. On your traces, I'll believe the traces but I don't the explanation. That seems to be some sort of physical interference going on at this point. But you are trying to explain it with a little additional bending going on here, but I can't see why, if I have a little additional bending, I would have a sharp discontinuity.

A: Well, if you have, let's say you have two balls attached by a string and one of them is moving. It starts over here and it's moving along. Eventually it's going to come to the end and you are going to have a very sharp spike. If you look at those, what happens is, it's not completely sharp. It comes up and then it starts to turn and it's fairly rapid, but it is not the type of thing that you have an instantaneous type of spike. There is still some transition between the two.

Q: You're going to have a rubber part produce a continuous spike next to the pelvis.

A: But you have a steel cable that comes through.

Q: Are you suggesting the steel cable was snapping.

A: The steel cable is part of it but it's holding that.

Q: It's pre-tensioned.

A: It's pre-tensioned up to a point in the normal condition.

Q: So tension would increase and gradually increase by some functional relative rotations and everything, but I don't yet sense an explanation why suddenly I have something that increases rather rapidly.

A: It does increase somewhat, but you get to a certain point where it increases rapidly. It's the geometry of the situation. Because you start with a bend, the spine is somewhat bent in the beginning and so when it comes up there is a little bit of compression there and then, at a certain point, it cannot move any further because it is going to increase the length much more than what it was doing before.

Q: I still don't understand it. Thank you very much.