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Analytical Considerations of HIC in Relation to the Proposed New FMVSS 201

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ANALYTICAL CONSIDERATIONS OF HIC IN RELATION TO THE PROPOSED NEW FMVSS 201

Summary Report

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16. Abstract

The reported study investigated the mathematical limits on reduction of HIC that are imposed by interior-trim design constraints on maximum deflection during head impact to a component of a vehicle interior. The analysis was based on head deceleration profiles of idealized square and triangular shape.

The results of the analysis suggest that the design goal for vehicle-interior components that can be contacted by the head should be to attain head deceleration profiles that are as nearly square in shape as possible (i.e., of constant deceleration level) and with minimal rebound. Tabular and graphical results are given.

Triangular head deceleration profiles are similar to ones that occur during actual head impacts and they are, therefore, a useful model for study. However, the use of a triangular profile imposes a force-deflection relationship of particular form, so a triangular deceleration pulse shape is not an entirely reasonable model. A dynamic model, one which uses specifiable mass and force-deflection properties, is recommended for studying Free Motion Headform impacts as described in the proposed, new FMVSS 201.

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Summary Report

INTRODUCTION

It is desirable to design vehicle-interior surfaces, including pillars, such that in the event of impact by the head, head injury will be minimized. A preliminary release by NHTSA of what is expected to become the new, revised FMVSS 201 in 1995 requires effective HIC values of 1000 or less for 15-mph head impacts against forward components of the vehicle interior and values of 800 or less for head impacts against lateral components, such as a B-pillar or a roof rail. The proposed new FMVSS 201 describes a Free Motion Headform (FMH) test in which vehicle-interior surfaces are impacted by a free-flying headform at 15 mph.

A preliminary study has been completed in which limitations on the lower bound for HIC imposed by interior-trim design constraints were investigated. The study was analytical in nature. It examined the implications of parameters for idealized triangular and square deceleration pulses that might result from head impact against a vehicle-interior component.

OBJECTIVES

The primary goal of this study was to determine the mathematical limits on reduction of HIC when particular constraints on deflection are given. Further, it was desired to provide some guidance in the design of vehicle interior trim with regard to maximally reducing HIC values that result from head impacts.

BACKGROUND

The quantity that is now called "HIC" was first defined in 1971.[1] The mathematical definition is a refinement of the definition of the Gadd Severity Index, and, like the Severity Index, it is based, in part, on the Wayne State Tolerance Curve (1966).[2]

The definition of HIC is as follows:

$$\mathrm{HIC} = \max_{t_1, t_2} \left[\left[\frac{\int_{t_1}^{t_2} a(t)\, dt}{t_2 - t_1} \right]^{2.5} (t_2 - t_1) \right]$$

t in seconds
a(t) in Gs

---

[1] J. Versace, "Review of the Severity Index," SAE 710881, *Proceedings of the 15th Stapp Car Crash Conference*, pp. 771-796, 1971.

[2] C. G. Gadd, "Use of a Weighted-Impulse Criterion for Estimating Injury Hazard," SAE 660793, *Proceedings of the 10th Stapp Car Crash Conference*, pp. 164-186, 1966.

Here, a(t) is the resultant linear acceleration-time history in Gs of the center of gravity of the head, and t_1 and t_2 are the two particular values of time that maximize the expression, with t_2 greater than t_1.

FMVSS 208 Section S6.1.2 specifies the Head Injury Criterion as the primary basis for quantifying the degree to which an occupant is at risk of brain injury from head accelerations during a head impact. Currently, a value of 1000 is set by FMVSS 208 as the maximum allowable limit in frontal barrier crash tests at 30 mph.

Since the original introduction of HIC, research has shown that, for proper interpretation of results *vis a vis* injury potential, the maximum permissable separation between t_1 and t_2 should be 36 ms, and for direct head impacts the separation should not be more than 15 ms. The associated calculations define what are called the 36-millisecond HIC and the 15-millisecond HIC. All analyses in the present study are consistent with the 15-millisecond HIC since only the head deceleration time histories related to direct head impacts are considered and pulse lengths do not exceed 15 ms.

METHODS

The primary relevant constraint on design of interior trim is the maximum deflection that can be accommodated. Therefore, the primary basis for limits on the lower bound of HIC is the relationship between HIC and displacement, i.e., deflection. This relationship is a mathematical one since HIC depends on head acceleration, as shown in the above equation, and displacement also depends on the acceleration, viz., as the second integral of the acceleration-time history. Additional limitations result from constraints on

$$\mathbf{x} = \iint a(t')\, dt'\, dt \leq \delta_{\lim} \qquad \text{(for deflection-related constraints)}$$

$$\mathbf{v} = \int a(t)\, dt \geq \mathbf{V}_{\lim} \qquad \text{(for rebound-energy related constraints)}$$

the effective energy restitution coefficient, R, for a particular design. Constraints on R are related to rebound speed and, thus, to the first integral of the acceleration-time history, i.e., velocity.

In this study, while deflection and velocity were determined directly from the analytical integrals of a(t), HIC was not determined directly from its definition, shown above. Rather, the conditions of mathematical maximization of HIC with respect to t_1 and t_2 require certain other analytical relationships to hold, and these are more directly useful for calculating HIC than is its defining equation.

The above equations and constraints *do not* constitute a dynamic model; i.e., they do not directly represent equations of motion for a physical (mechanical) system since mass and material properties, etc., are not variables in the relationships. Rather, the acceleration (deceleration), a(t), is assumed to have a particular form--square or triangular in this study--that is assumed to result from some unspecified inertial and material characteristics for a physical system. Thus, while the analysis might be called a model, it is not a *dynamic* model. Rather, it is basically a waveform analysis that serves as a means for examining the consequences of physical systems that produce specific shapes for head deceleration profiles. This type of analysis is particularly suitable for studying a system as simple as an FMVSS 201 Free Motion Headform test, which is essentially a one-degree-of-freedom, single-mass system.

RESULTS

This study has produced equations and MS-DOS computer programs for studying constrained, square and triangular deceleration pulses. Both direct and inverse solutions are available from the programs; i.e., either HIC or maximum allowed deflection can be specified and the other is found as a response. Energy restitution can be specified as well, either in terms of R, or the post-impact rebound speed, or the triangle shape index.[3] Summary outputs are printed and time histories for responses are calculated for optional plotting.

The Appendix includes tables that summarize square and triangular deceleration pulse results obtained in this study. Some of the results in these tables are revised from results previously sent to Venture, and this report should be considered to completely replace all earlier documents.

The analytical and computer studies indicate that square deceleration responses, of all possible shapes, produce the smallest HIC values for a given maximum allowed deflection and, also, the minimum deflection for any specified upper bound on HIC. Results are shown in Tables 1a and 1b for square and triangular deceleration pulses with energy restitution coefficients of zero. These results are for impact speeds of 15 mph (264 in/s). HIC values in the tables are for a quantity called HIC(d). HIC(d) is found by first calculating a quantity called FMH_HIC for the hypothetical case of deceleration of a single mass (FMH = Free Motion Headform). FMH_HIC is the value that corresponds to the definition of the FMVSS 208 HIC, as shown above, and, from an experimental point of view, it represents the HIC that would be found by direct processing of the acceleration-time history of the Free Motion Headform. HIC(d) is then calculated from FMH_HIC. It is an estimate of the equivalent HIC that would result from head impact if the head were attached through the neck to an anthropomorphic crash dummy, as defined by the proposed, new FMVSS 201: viz., HIC(d) = 0.75446 * FMH_HIC + 166.4 .

For a square deceleration, HIC(d) exceeds 1000 if the maximum allowed deflection is less than 0.6555 inches (16.6 mm), and it exceeds 800 for any maximum allowed deflection that is less than 0.7870 inches (20.0 mm). If there is any rebound at all (i.e., energy restitution coefficient, $R > 0$), then HIC values will be higher for any given maximum deflection. (See the Appendix.) The comparable triangular deceleration pulse (i.e., with $R = 0$) is seen to require much larger deflections than the square pulse for HIC(d) upper bound values of 800 and 1000. (See the Appendix for $R > 0$.)

It is seen in Tables 2a and 2b that the minimum theoretical value for HIC(d)--viz., for a square deceleration pulse--for a maximum allowed total deflection of 0.6 inches (15 mm) is 1118.2. For a triangular pulse the HIC(d) for this same deflection is 2209.0. For a triangular pulse with an energy restitution coefficient that is, more realistically, greater than zero, HIC(d) values are still larger. For example, if R is 0.25, HIC(d) for a maximum deflection of 0.6 inches is computed to be 3230.3.

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[3] A square acceleration pulse from an impact against any simple material or structure must always be associated with an energy restitution coefficient of zero. It is theoretically possible, however, to design a complex system that will produce both a square acceleration response and nonzero rebound speed (i.e., $R > 0$). If the acceleration response is to be square while $R > 0$, the system must be able to produce a constant force during rebound from maximum deflection.

Table 1a

PULSE:	Square-wave acceleration	
CONSTRAINED RESPONSE:	HIC(d); R = 0	
	HIC(d)	
RESPONSE	800	1000
Pulse Length (ms)	5.962	4.966
Acceleration (g)	114.685	137.701
Deflection (in)	**0.7870**	**0.6555**

Table 1b

PULSE:	Triangular acceleration	
CONSTRAINED RESPONSE:	HIC(d); R = 0	
	HIC(d)	
RESPONSE	800	1000
Pulse Length, T (ms)	7.440	6.196
Acceleration (g)	183.820	220.710
Max Deflection (in)	**1.3094**	**1.0905**

Table 2a

PULSE:	Square-wave acceleration				
CONSTRAINED RESPONSE:	Maximum deflection; R = 0				
	MAXIMUM DEFLECTION				
RESPONSE	0.6"	0.7"	0.8"	0.9"	1.0"
HIC(d) (s)	**1118.2**	921.7	784.6	684.5	608.8
FMH_HIC (s)	1261.6	1001.2	819.4	686.7	586.3
Pulse Length (ms)	4.545	5.303	6.061	6.818	7.576
Acceleration (g)	150.432	128.942	112.824	100.288	90.259

Note: 0.6" = 15 mm

Table 2b

PULSE:	Triangular acceleration				
CONSTRAINED RESPONSE:	Maximum deflection; R = 0				
ENERGY RESTITUTION COEF. = 0	MAXIMUM DEFLECTION				
RESPONSE	0.6"	0.7"	0.8"	0.9"	1.0"
HIC(d) (s)	**2209.0**	1787.3	1493.1	1278.3	1115.7
FMH_HIC (s)	2707.4	2148.5	1758.5	1473.7	1258.3
Peak accel (g)	401.152	343.845	300.864	267.435	240.691
Time, max acc/defl	3.409	3.977	4.545	5.114	5.682
PulseLength, T (ms)	3.409	3.977	4.545	5.114	5.682

Note: 0.6" = 15 mm

DISCUSSION

The results of analysis to date suggest that the design goal for vehicle-interior components that can be contacted by the head should be to attain head deceleration profiles that are as nearly square in shape as possible--i.e., of constant deceleration level--and with minimal rebound. Unfortunately, while it is possible to construct structures and materials that give approximately square force-deflection responses *for unit area of deformation*, it is impossible to attain, for a simple system, square deceleration response for impact by a head unless the area of deformation is not a function of the deformation depth (i.e., deflection). This is never the case, however. For the simple case of a (rigid) head impacting against a block of foam that crushes at constant force per unit area, it can be shown that the force as a function of deflection, δ, is

$$F(\delta) = 2\pi \mathrm{R} f(1 - \alpha)\delta \ , \quad \text{where} \quad \alpha = \delta/(2\mathrm{R}) \ ,$$

where R is the radius of curvature of the head and f is the constant force per unit area for deformation of the foam. The quantity α will be much less than 1 if δ is much less than R, which is normally the case since δ_{max} will, in general, not be larger than about 0.7 inches while R for the head is on the order of 3 to 4 inches. Thus, with δ ranging from 0.0 to about 0.7, the quantity α ranges from 0.0 to about 0.1, and $F(\delta)$ is proportional to the deflection, δ, to within a factor of 0.9 to 1.0. That is, even with "constant-force" crushable foam, the force against the head--and, hence, the acceleration--would not be constant (square) even in approximation. The reason for this is that the contact area is approximately proportional to the deflection.[4]

Triangular deceleration pulses come closer than square pulses to characterizing the dynamic response for such a force-deflection relationship, and the results of analysis of triangular pulses conducted in this study were instructive in this regard. The basic characteristics of an impact with rebound can be modeled with a triangular pulse if we start with a basic assumption, viz., that acceleration will have its maximum value at the same time that deflection is maximum. This is the same as saying that we want to represent a physical system in which the force is maximum when deflection is maximum. (The parameters of a triangular acceleration pulse are illustrated in Figure 1. Also, see the displacement and velocity plots on page 7.)

With regard to characterizing an impact with rebound, it may first be noted that if a coefficient of energy restitution, R, is specified, then the shape index of the triangle is determined. That this is so can be seen as follows. If t_p is the time of the peak of the triangular deceleration pulse and T is the duration of the pulse, then, by definition, the shape index is $k = t_p/T$. R is by definition equal to the square of the ratio of the rebound speed to the impact speed, i.e., $R = (v_f/v_o)^2$. If we require deflection as well as acceleration to be maximum at time t_p, then the velocity at that time must be zero. This means that the integral of the acceleration-time profile from $t=0$ to $t=t_p$ -- i.e., the area under the first segment of the triangle -- must be equal to the impact velocity, v_o. Similarly, the area under the second segment must equal the rebound speed, v_f. Consequently, it is necessary that $(T-t_p)/t_p = v_f/v_o$. Therefore, $R = (v_f/v_o)^2 = (1/k-1)^2$ and, inversely, $k = 1/(1+\sqrt{R})$. Thus, specifying v_o and R, or, equivalently, v_f, and any response quantity--such as the peak deceleration, or the maximum displacement, or HIC--completely determines the parameters of the requisite triangular pulse.[5]

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[4]Similarly, it may be shown that for the same crushable foam in the form of a strip of width that is small in comparison with the head radius, the force will be approximately proportional to the *square root* of the deflection.

[5]It may be noted that since R is in the range [0,1] for a real system, the triangle shape index, k, must be in the range [.5,1]. That is, the time of the peak of the triangle must be greater than half the pulse duration if the pulse is to represent a real system in any reasonable way.

Triangular Acceleration Pulse

Ap = peak acceleration   Tp = time at peak acceleration and peak deflection   T = pulse duration   k = shape index = Tp/T (>=0.5)

Vo = impact speed = 0.5*Ap*Tp   Vf = rebound speed = 0.5*Ap*(T-Tp)   R = energy restitution coefficient = (Vf/Vo)**2 = (1/k-1)**2

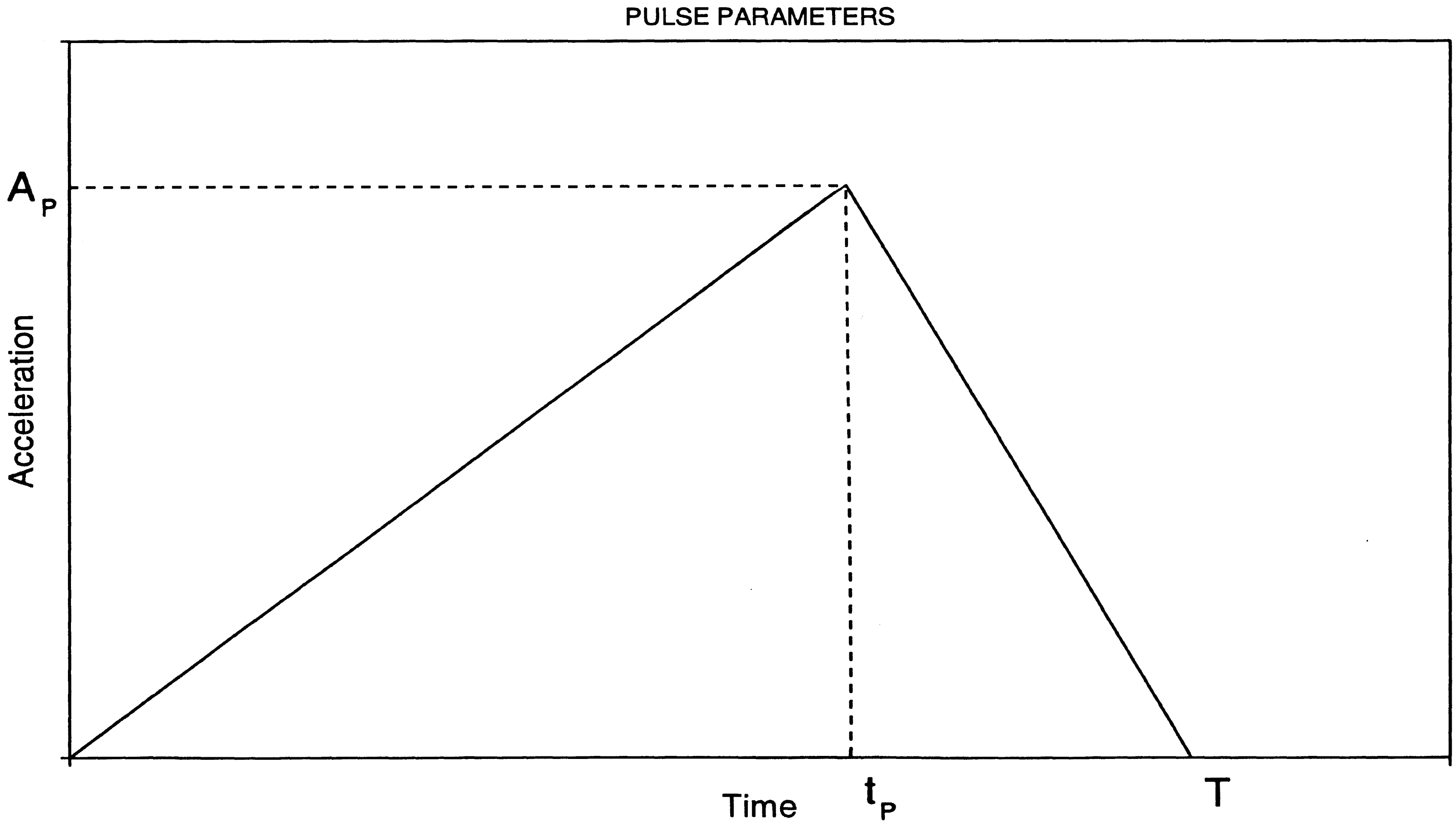

Figure 1. Parameters of a Triangular Acceleration Pulse

Responses for a Triangular Acceleration Pulse

Impact speed = 264 in/s (15 mph)

CONSTRAINTS: Maximum deflection = 0.6 inches Energy restitution coefficient = 0.25

HIC(d) = 3230 Peak acceleration = 401.15 Gs Time at maximum accel and defl = 3.409 ms Pulse length = 5.114 ms

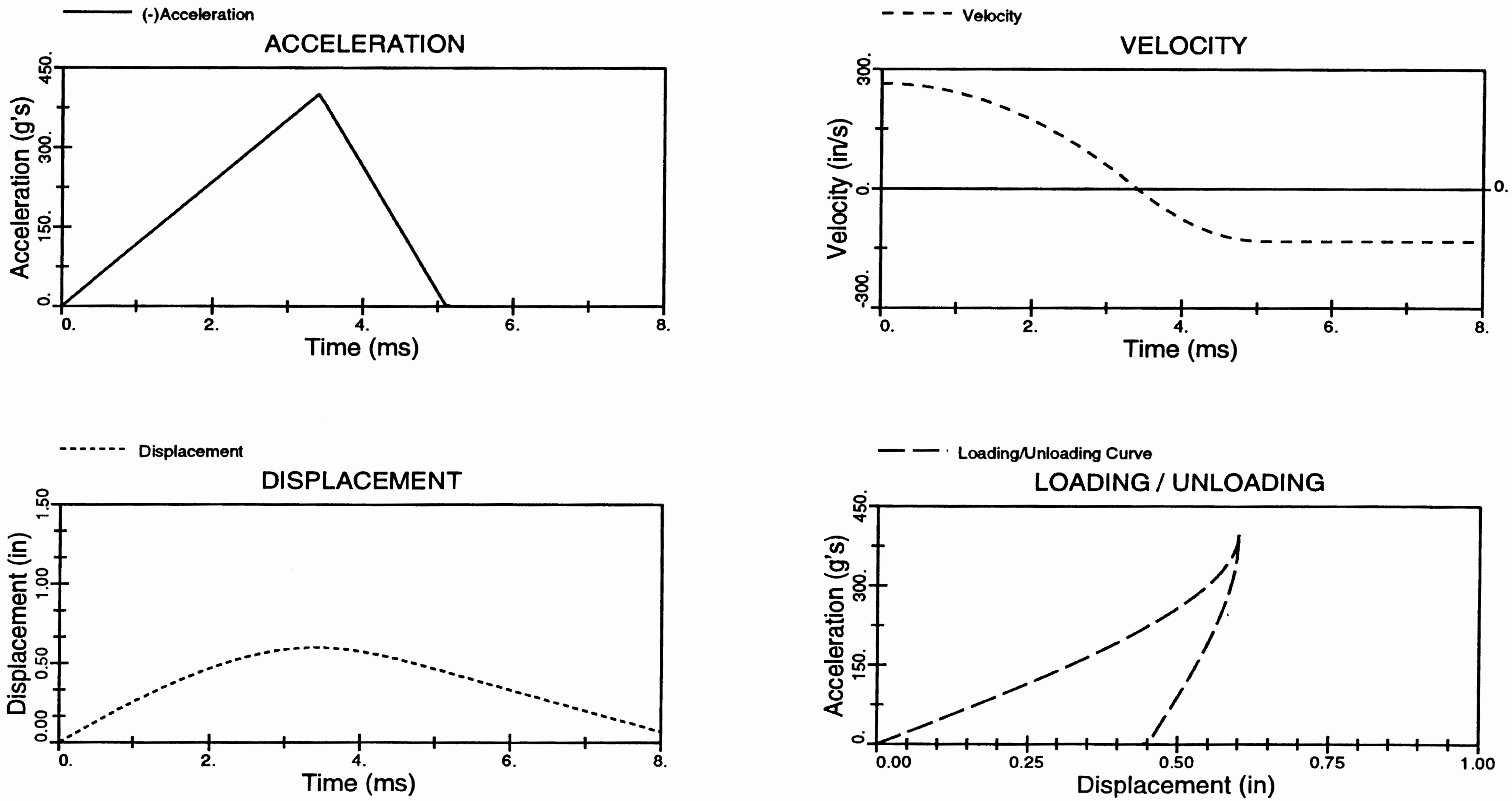

Figure 2. Responses for a Triangular Acceleration Pulse

Nonetheless, a triangular deceleration pulse shape is not an entirely reasonable approximation to pulses that result from real systems. The primary reason for this is that it dictates the character of the force-deflection curve for the structure and/or material. That is, the response characteristics for a particular prototype structure/material cannot be investigated by adjusting parameters of the triangle. The triangular pulse model is not a dynamic model since mass and material properties are not inputs (except for R) and equations of motion are not determined. However, with the assumption that the force on an impacting mass will be proportional to the deceleration, the nature of the effective force-deflection relationship for a triangular pulse may be seen by crossplotting *deceleration* against displacement. This is illustrated in the graph in the lower right-hand corner of the page 7 for v_o = 264 in/s (15 mph), R = 0.25, and a maximum deflection of 0.6 inches (15 mm). That plot, for deceleration versus deflection, shows that the corresponding (proportional), dictated force-deflection relationship is approximately linear through two-thirds of maximum deflection, and that it stiffens increasingly afterward. This is the character of the force-deflection curves that derive from all triangular deceleration pulses.

SUGGESTIONS FOR FUTURE WORK

Useful results have come from this work, but the study conducted to date is limited in the amount of guidance it can provide regarding design of components that the head may strike. The reason for this is that the study was restricted in scope to the analysis of head-deceleration waveforms that comply with specified design constraints (e.g., distance for deceleration). It did not model any physical system, but, rather, provided insight on the consequences of physical systems that produce *specific shapes* for head-deceleration pulses.

Additional study of pulse shapes, and elaboration of results already reported, would yield useful information. It is important, however, to model the dynamical system to obtain the most directly useful results. Further, it is *necessary* to model the dynamical system in order to investigate most nonlinear structures and materials that may be candidates for use in prototype designs. Waveshape analysis alone, as explained in this report, *assumes* a particular type of force-deflection relationship for each pulse shape; it does not permit specification of actual force-deflection relationships for structures and materials of interest.

Probably the most important reasons for developing a dynamic model are: (1) by supplementing physical testing, use of the model will reduce the number of tests needed in the design process; (2) by investigating theoretical responses for proposed designs, use of the model will guide the experimental program of trim design and headform impact testing and, additionally, reduce the number of prototype designs that need to be constructed for testing. Thus, a dynamic model for simulating FMVSS 201 Free Motion Headform impacts will simplify the overall design process.

The tasks listed below are proposed for a follow-on study. Most involve analytical development and computer program implementation. All items in the list fall into one of four categories: (1) development of an impact dynamics model specifically for simulation of FMVSS 201 tests (and use of the model on a PC); (2) use of an already existing occupant dynamics simulation model, such as ATB 3-D, CAL 3-D CVS, or MVMA 2-D CVS, for simulating FMVSS 201 tests; (3) development and implementation of a method for treating shared deflections (e.g., for head, trim, and structure); and (4) reporting of results.

No specific proposal for experimental work is made at this time. However, the Biosciences Division at UMTRI has a headform drop tower used for FMVSS 201 testing as well as other component impact test facilities that can be used to conduct experimental testing of materials for prototype development and/or model validation.

Tasks

1. develop a dynamics model for an FMVSS 201 Free Motion Headform (FMH) impact test with linear force-deflection properties; provide for linear and/or bilinear unloading [a closed-form solution can be obtained]

2. develop a dynamics model for an FMVSS 201 Free Motion Headform impact test with force that is proportional to the square root of deflection (for strip foam or a pillar) [a closed-form solution may be possible]

3. use an occupant dynamics model to simulate single-mass impacts in FMVSS 201 Free Motion Headform tests with general, real or proposed, structures and/or materials for the purpose of optimizing design [Only minimal, special need use of an occupant dynamics model for such an investigation is recommended. There are significant advantages to developing and using special purpose models instead.][6]

4. develop a shared-deflection algorithm for determining the effective force-deflection relationship for two nonlinear materials acting in series [such an algorithm can be used iteratively to determine the effective properties for three or more materials in series]

5. use the shared-deflection algorithm as a preprocessor for simulations done with the dynamic models identified in 1., 2., and 3. above

6. develop a general purpose FMVSS 201 test simulation program for use on PCs, incorporating the shared-deflection algorithm and allowing representation of head properties and general force-deflection characteristics for gap padding and structural features of a prototype design

7. determine the FMVSS 208 three-millisecond-average acceleration, in addition to HIC(d) and the peak acceleration, for each simulation

8. prepare a report that details methods and results

9. write a research paper for publication in a peer-reviewed journal

10. assist Venture in preparing proposals or product design reports for potential customers

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[6]The primary advantage of using an occupant dynamics model is that those models already exist, so model development work would be minimized. Additionally, MVMA 2-D (but no other) already has a shared-deflection capability. The disadvantages of relying on an occupant dynamics model are significant, however. First, while UMTRI has experience in their use and would not have difficulty using them for the proposed effort, the models are complex and their use by Venture would require a considerable amount of learning time. Second, occupant dynamics models are large and cumbersome–for any user–for the relatively simple application to which they would be put. Third, making special purpose modifications to such models for particular needs for FMVSS 201 FMH simulation would be difficult, whereas special features for the dynamics models described in items 1., 2., and 6. could be added at any time with relative ease.

APPENDIX

Bruce M. Bowman, UMTRI
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HIC(d) AND MAXIMUM TOTAL DEFLECTION FOR SQUARE-WAVE ACCELERATION PULSES FOR 15 MPH IMPACT VELOCITY

IMPACT AND REBOUND SPEEDS

264.00 in/s (15.00 mph) and 0.0 in/s (0.0 mph)
R = Energy Restitution Coefficient = 0.0

HIC(d) and the Free Motion Headform HIC

HIC(d) = 0.75446 * FMH_HIC + 166.4 ,

where FMH_HIC is the FMVSS 201 Free Motion Headform HIC

PULSE: Square-wave acceleration
CONSTRAINED RESPONSE: Maximum deflection; R = 0.0

RESPONSE	MAXIMUM DEFLECTION				
	0.6"	0.7"	0.8"	0.9"	1.0"
HIC(d) (s)	1118.2	921.7	784.6	684.5	608.8
FMH_HIC (s)	1261.6	1001.2	819.4	686.7	586.3
Pulse Length (ms)	4.545	5.303	6.061	6.818	7.576
Acceleration (g)	150.432	128.942	112.824	100.288	90.259

Note: 0.6" = 15 mm

PULSE: Square-wave acceleration
CONSTRAINED RESPONSE: HIC(d); R = 0.0

RESPONSE	HIC(d)	
	800	1000
Pulse Length (ms)	5.962	4.966
Acceleration (g)	114.685	137.701
Deflection (in)	0.7870	0.6555

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HIC(d) AND MAXIMUM TOTAL DEFLECTION FOR TRIANGULAR ACCELERATION PULSES FOR 15 MPH IMPACT VELOCITY

IMPACT SPEED

264.00 in/s (15.00 mph)

HIC(d) and the Free Motion Headform HIC

HIC(d) = 0.75446 * FMH_HIC + 166.4 ,

where FMH_HIC is the FMVSS 201 Free Motion Headform HIC

PULSE: Triangular acceleration
CONSTRAINED RESPONSE: Maximum deflection; R = 0

ENERGY RESTITUTION COEF. = 0	MAXIMUM DEFLECTION				
RESPONSE	0.6"	0.7"	0.8"	0.9"	1.0"
HIC(d) (s)	2209.0	1787.3	1493.1	1278.3	1115.7
FMH_HIC (s)	2707.4	2148.5	1758.5	1473.7	1258.3
Peak accel (g)	401.152	343.845	300.864	267.435	240.691
Time, max acc/defl	3.409	3.977	4.545	5.114	5.682
PulseLength, T (ms)	3.409	3.977	4.545	5.114	5.62

Note: 0.6" = 15 mm

PULSE: Triangular acceleration
CONSTRAINED RESPONSE: HIC(d); R = 0

	HIC(d)	
RESPONSE	800	1000
Pulse Length, T (ms)	7.440	6.196
Acceleration (g)	183.820	220.710
Max Deflection (in)	1.3094	1.0905

Notes: FMH_HIC = 839.806 for HIC(d) = 800
FMH_HIC = 1104.896 for HIC(d) = 1000

PULSE:	Triangular acceleration				
CONSTRAINED RESPONSE:	Maximum deflection; R = 0.25				
ENERGY RESTITUTION COEF. = 0.25	MAXIMUM DEFLECTION				
RESPONSE	0.6"	0.7"	0.8"	0.9"	1.0"
HIC(d) (s)	3230.3	2597.8	2156.5	1834.2	1590.4
FMH_HIC (s)	4061.1	3222.7	2637.8	2210.6	1887.4
Peak accel (g)	401.152	343.845	300.864	267.435	240.691
Time, max acc/defl	3.409	3.977	4.545	5.114	5.682
PulseLength, T (ms)	5.114	5.966	6.818	7.670	8.523

Note: 0.6" = 15 mm

PULSE:	Triangular acceleration	
CONSTRAINED RESPONSE:	HIC(d); R = 0.25	
	HIC(d)	
RESPONSE	800	1000
Pulse Length, T (ms)	14.623	12.179
Acceleration (g)	140.281	168.433
Max Deflection (in)	1.7158	1.4290

Notes: FMH_HIC = 839.806 for HIC(d) = 800
FMH_HIC = 1104.896 for HIC(d) = 1000

Bruce M. Bowman, UMTRI
October 25, 1994
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HIC(d) AND MAXIMUM TOTAL DEFLECTION FOR TRIANGULAR ACCELERATION PULSES FOR 15 MPH IMPACT VELOCITY

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DEPENDENCE ON ENERGY RESTITUTION COEFFICIENT

IMPACT SPEED

264 in/s (15 mph)

HIC(d) and the Free Motion Headform HIC

HIC(d) = 0.75446 * FMH_HIC + 166.4 ,

where FMH_HIC is the FMVSS 201 Free Motion Headform HIC

PULSE: Triangular acceleration
CONSTRAINED RESPONSE: HIC(d) = 800

ENERGY RESTITUTION COEFFICIENT, R	RESPONSES					
	Max Accel(g)	Max Defl(in)	Time at Max(ms)	Pulse Length(ms)	Shape k	Residual Defl(in)
0.0	183.820	1.3094	7.440	7.440	1.00000	1.3094
0.1	153.052	1.5726	8.935	11.761	0.75975	1.4154
0.2	143.672	1.6753	9.519	13.776	0.69098	1.3402
0.3	137.382	1.7520	9.954	15.407	0.64611	1.2264
0.4	132.586	1.8154	10.315	16.838	0.61257	1.0892
0.5	128.692	1.8703	10.627	18.141	0.58579	0.9351
0.6	125.408	1.9193	10.905	19.352	0.56351	0.7677
0.7	122.567	1.9638	11.158	20.493	0.54447	0.5891
0.8	120.063	2.0047	11.390	21.578	0.52786	0.4009
0.9	117.824	2.0428	11.607	22.618	0.51317	0.2043
1.0	115.799	2.0785	11.810	23.620	0.50000	0.0000

Notes: 0.6" = 15 mm; FMH_HIC = 839.806 for HIC(d) = 800

PULSE: Triangular acceleration
CONSTRAINED RESPONSE: HIC(d) = 1000

ENERGY RESTITUTION COEFF., R	RESPONSES Max Accel(g)	Max Defl(in)	Time at Max(ms)	Pulse Length(ms)	Shape k	Residual Defl(in)
0.0	220.710	1.0905	6.196	6.196	1.00000	1.0905
0.1	183.767	1.3098	7.442	9.795	0.75975	1.1788
0.2	172.504	1.3953	7.928	11.473	0.69098	1.1162
0.3	164.953	1.4592	8.291	12.832	0.64611	1.0214
0.4	159.194	1.5119	8.591	14.024	0.61257	0.9072
0.5	154.519	1.5577	8.850	15.109	0.58579	0.7788
0.6	150.576	1.5985	9.082	16.117	0.56351	0.6394
0.7	147.164	1.6355	9.293	17.068	0.54447	0.4907
0.8	144.157	1.6696	9.487	17.972	0.52786	0.3339
0.9	141.469	1.7014	9.667	18.838	0.51317	0.1701
1.0	139.038	1.7311	9.836	19.672	0.50000	0.0000

Notes: 0.6" = 15 mm; FMH_HIC = 1104.896 for HIC(d) = 1000

Dependence of Maximum Deflection on Energy Restitution Coefficient for Triangular Acceleration Pulses

Impact speed = 264 in/s (15 mph)

HIC(d) = 800 and 1000