STATIC ANALYSIS USING THE INERTIA RELIEF TECHNIQUE TO EVALUATE A HOOD STRUCTURE FOR SLAM/DROP LOADS

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<u>STATIC ANALYSIS USING THE INERTIA RELIEF TECHNIQUE</u>

<u>TO EVALUATE A HOOD STRUCTURE FOR SLAM/DROP LOADS</u>

Objective

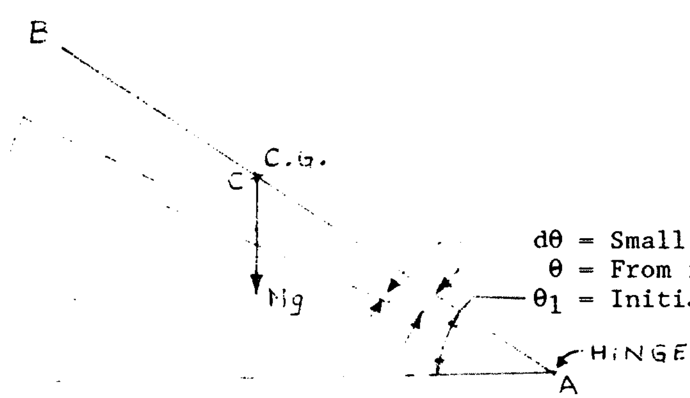
To develop a static analysis technique to analyze a hood structure under slam/drop type loading, using finite element methodology and to apply the technique to a typical hood structure.

Background

Due to the complexity of the impact phenomenon, it is difficult to develop routine design criteria for this type of dynamic loading . Dynamic transient FEA methods have been tried in the past but because of lengthy time requirements, cumbersome procedures, and substantial computer cost involvement, a simpler procedure was sought by the authors. The Inertia Relief method takes into account the dynamic effects but utilizes the static analysis methodology, thus saving a substantial amount of time and computer costs.

Basic Calculations

The following sketch shows the typical configuration of a hood.



$d\theta$ = Small displacement from θ
θ = From initial opening
θ_1 = Initial hood opening

Iyy = M.I. about hinge
M = Mass of hood
g = Acceleration due to gravity
a_2 = Distance AC

$$\text{Torque} = I_{yy}\ \ddot{\theta} = M\ g\ a_2 \cos(\theta_1 - \theta)$$

$$\ddot{\theta} = \frac{M\ g\ a_2 \cos(\theta_1 - \theta)}{I_{yy}}$$

$$= \frac{M\ g\ a_2 \cos(\theta_1 - \theta)}{M\ a_2^2}$$

$$= \frac{g \cos(\theta_1 - \theta)}{a_2} \qquad (1)$$

When, $\theta = \theta_1$ (just before hood closing),

$$\ddot{\theta} = \frac{g}{a_2} \qquad (2)$$

$$\text{Kinetic Energy} = \text{K.E.} = \int_0^{\theta_1} T\ d\theta$$

$$= \int_0^{\theta_1} Mg\ a_2 \cos(\theta_1 - \theta)\ d\theta$$

$$= \left[-Mg\ a_2 \sin(\theta_1 - \theta)\right]_0^{\theta_1}$$

$$= -Mg\ a_2 \left[\sin(0) - \sin\theta_1\right]$$

$$= Mg\ a_2 \sin\theta_1 \qquad (3)$$

Also using equations of motions for linear displacements,

$$v = u + gt \qquad (4)$$

$$v^2 = u^2 + 2gs \qquad (5)$$

Where:
- v = final velocity
- u = initial velocity = 0
- s = vertical traveled distance
- t = time taken to travel distance s

We can compute from (5)

$$v^2 = 2g\ (a_2 \sin\theta_1)$$

or

$$v = \sqrt{2g\ a_2 \sin\theta_1} \qquad (6)$$

from (4)

$$t = \sqrt{\frac{2a_2 \sin\theta_1}{g}} \qquad (7)$$

Also using equations of motions for angular displacements

$$\omega_2 = \omega_1 + \ddot{\theta} t \qquad (8),$$

$$\omega_2^2 = \omega_1^2 + 2\ \ddot{\theta}\ \theta \qquad (9),$$

Where: ω_2 = final angular velocity

ω_1 = initial angular velocity = 0

θ = angle turned through (small)

We can compute from (2), (7) & (8)

$$\omega_2 = \frac{g}{a_2}\sqrt{\frac{2a_2 \sin \theta_1}{g}}$$

$$= \sqrt{\frac{2\, g \sin \theta_1}{a_2}}$$

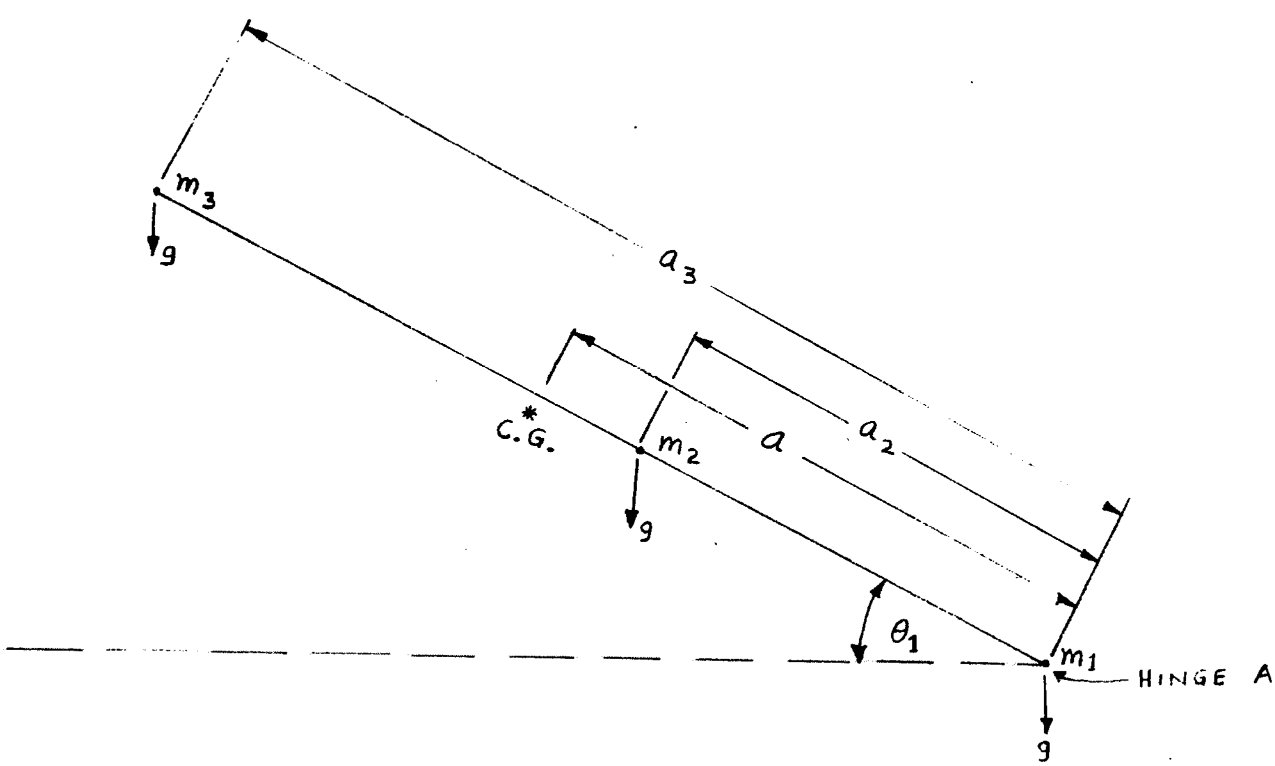
Also,

$$K.E. = 1/2\ I_{yy}\,\omega_2^2$$

$$= 1/2\ M\, a_2^2 \left(\frac{2g \sin \theta 1}{a_2}\right)$$

$$= M\, g\, a_2 \sin \theta_1 \quad \text{(check)} \qquad (10)$$

Now let us assume a system with the following configuration, and try to determine if an arbitrarily distributed mass system results in the same hood dynamics as a centroidal mass system.



Let us assume $a_2 = \frac{1}{3} a_3$, $m_2 = \frac{1}{4} m_3$ and $m_1 = \frac{1}{3} m_3$ (11)

Total mass $M = (m_1 + m_2 + m_3)$ (12)

From (11) and (12),

$$M = \frac{1}{3} m_3 + \frac{1}{4} m_3 + m_3 = \frac{19}{12} m_3$$

i.e., $M = m_1 + m_2 + m_3 = \frac{19}{12} m_3$ (13)

Taking moments about the hinge shall yield the C.G. location as follows:

$$m_3 g (a_3 \cos \theta_1) + m_2 g (a_2 \cos \theta_1) = Mg (a \cos \theta_1)$$

or $m_3 a_3 + m_2 (\frac{1}{3} a_3) = (\frac{19}{12} m_3) a$

Thus, $a = (\frac{13}{19}) a_3$ (14)

Now, the moment of the equivalent system is

$$I_{yy} \ddot{\theta} = (m_1 + m_2 + m_3) a^2 \ddot{\theta}$$

By substituting various values on right hand side we obtain,

$I_{yy} \ddot{\theta} = (\frac{19}{12} m_3) (\frac{13}{19} a_3)^2 \ddot{\theta}$ (15)

Taking moments of all forces about the hinge we obtain total moment

$$T = (\frac{1}{4} m_3 g) (\frac{1}{3} a_3) (\cos \theta_1) + m_3 g (a_3) (\cos \theta_1)$$

$= m_3 g (\frac{13}{12} a_3) (\cos \theta_1)$ (16)

Equating (15) and (16) we obtain

$$(\frac{19}{12} m_3) (\frac{13}{19} a_3)^2 \ddot{\theta} = m_3 g (\frac{13}{12} a_3) (\cos \theta_1)$$

$$\ddot{\theta} = \frac{m_3 g (\frac{13}{12} a_3) \cos \theta_1)}{(\frac{19}{12} m_3) (\frac{13}{19} a_3)^2}$$

$$\ddot{\theta} = \frac{g \cos \theta_1}{(\frac{13}{19} a_3)}$$

$$\ddot{\theta} = \frac{g \cos \theta_1}{a}$$

$$\ddot{\theta} = \frac{g}{a} \text{ when } \theta_1 = 0$$

Hence, in general, a distributed mass system hood dynamics is equivalent to a centroidal mass system hood dynamics.

Inertia Relief in MSC/NASTRAN

If the time rate of change of the applied loads is small compared to the frequency of the lowest elastic mode of the system, an approximate state of equilibrium exists between the applied load (gravity in this case) and the inertia forces due to acceleration. The time rate varies between .0025 to .0036 seconds depending upon the initial hood opening and C.G. location. The lowest elastic mode frequencies would have to be between 275 and 400 Hz in order to cause any resonance. A hood structure is not known to have any major resonant frequencies in this range, therefore, it is assumed that the Inertia Relief procedure should provide accurate answers. The following brief treatment of the Inertia Relief approach in MSC/NASTRAN is outlined.

1. Select r-set using the SUPORT card. In this case, rotation about the hinge (θy) is selected due to the obvious rigid body rotation of the hood. The analysis set (a-set) is partitioned into r and ℓ sets.

$$\begin{bmatrix} K_{\ell\ell} & K_{\ell r} \\ K_{\ell r}^T & K_{rr} \end{bmatrix} \begin{Bmatrix} U_\ell \\ U_r \end{Bmatrix} = \begin{Bmatrix} P_\ell \\ P_r^* \end{Bmatrix} \qquad (1)$$

Since $U_r = 0$, constrained to zero motion, we obtain

$$\left[K_{\ell\ell}\right]\left\{U_\ell\right\} = \left\{P_\ell\right\} \qquad (2)$$

and the reactions at the r-coordinates (SUPORT) are

$$\begin{aligned} q_r &= -\left\{P_r\right\} + \left[K_{\ell r}^T\right]\left\{U_\ell\right\} \\ &= -\left\{P_r\right\} + \left[K_{\ell r}^T\right]\left[K_{\ell\ell}\right]^{-1}\left\{P_\ell\right\} \\ &= -\left\{P_r\right\} - \left[D_{\ell r}\right]^T\left\{P_\ell\right\} \end{aligned} \qquad (3)$$

Where: $\left[D_{\ell r}\right] = -\left[K_{\ell\ell}\right]^{-1}\left[K_{\ell r}\right]$

and $\left[D_{\ell r}\right]^T = -\left[K_{\ell r}^T\right]\left[K_{\ell\ell}\right]^{-1}$

$$\left[K_{\ell\ell}\right]\left[D_{\ell r}\right] = -\left[K_{\ell r}\right] \qquad (4)$$

$^*P_r = P_r$ (loads at r-set) + q_r (reaction forces at r-set)

Eq. (4) is used to evaluate free body inertia properties of the structure.

The mass matrix is also partitioned into ℓ and r sets and the reduced mass matrix referred to U_r coordinates is given by

$$\left[M_r\right] = \left[M_{rr}\right] + \left[M_{\ell r}\right]^T\left[D\right] + \left[D\right]^T\left[M_{\ell r}\right] + \left[D\right]^T\left[M_{\ell\ell}\right]\left[D\right]$$

2. Next accelerations $\{\ddot{U}_r\}$ due to applied loads $\{P_a\}$, are found as

$$\left[M_r\right]\{\ddot{U}_r\} = \{\bar{P}_r\} = -\{q_r\}$$

Where: $\{\bar{P}_r\}$ = applied load vector reduced to U_r coordinates.

$$\{\ddot{U}_r\} = -\left[M_r\right]^{-1}\{q_r\}$$

3. Acceleration at all other points U_ℓ and their inertia forces are given by

$$\{\ddot{U}_\ell\} = \left[D\right]\{\ddot{U}_r\} \quad \text{Uniform rigid body acceleration}$$

$$\begin{bmatrix} M_{\ell\ell} & M_{\ell r} \\ M_{\ell r} & M_{rr} \end{bmatrix} \begin{Bmatrix} \ddot{U}_\ell \\ \ddot{U}_r \end{Bmatrix} = \begin{Bmatrix} P^i \\ P^i_r \end{Bmatrix} = \text{Inertia Forces*}$$

$$\begin{aligned} \{P^i_\ell\} &= -\left[M_{\ell\ell}\right]\{\ddot{U}_\ell\} - \left[M_{\ell r}\right]\{\ddot{U}_r\} \\ &= -\left[M_{\ell\ell}\right]\left[D\right]\{\ddot{U}_r\} - \left[M_{\ell r}\right]\{\ddot{U}_r\} \\ &= -\left[\left[M_{\ell\ell}\right]\left[D\right] + \left[M_{\ell r}\right]\right]\left[M_r\right]^{-1}\{q_r\} \end{aligned}$$

4. Add inertia force vector to the applied load vector and solve for the displacements while the structure is restrained at U_r points. The strain energy computed gives the measure of these forces.

*Inertia Forces Will Have Negative Sign

Rigid Body Error Ratio Check

From eq. 1,

$$\left[K_{\ell r}\right]^T \left\{U_\ell\right\} + \left[K_{rr}\right]\left\{U_r\right\} = \left\{P_r\right\}$$

or

$$\left[K_{\ell r}\right]^T \left[D\right] \left\{U_r\right\} + \left[K_{rr}\right]\left\{U_r\right\} = \left\{P_r\right\}$$

or

$$\left[K_{rr}\right] + \left[D\right]\left[K_{\ell r}\right]^T \left\{U_r\right\} = \left\{P_r\right\} = -\left\{q_r\right\}$$

With unit displacement at u_r coordinates, the reaction forces $\{q_r\}$ should be zero. That is satisfied only if

$$\left[K_{rr}\right] + \left[D\right]\left[K_{\ell r}\right]^T = 0 = \left[X\right]$$

Rigid Body Error Ratio = $\epsilon_i = \dfrac{X\ (i,\ i)}{K_{rr}(i,\ i)}$

Strain Energy = $1/2\ K\ \Delta = 1/2\ K$, if $\Delta = 1$ or $2\ (S.E.) = K$

Therefore, each diagonal term of [X] represents twice the strain energy for the unit r-set motion.

In order to obtain accurate calculations, one should see that ϵ_i (the largest diagonal term) and strain energy should be close to zero. The strain energy or ϵ may be nonzero for one or more of the following reasons.

1. Round-off error accumulation.
2. U_r is overdetermined - (high S. E.)
3. U_r is underdetermined - singular K_{rr} - (high ϵ)
4. Multipoint constraints are incompatible (high S.E. and ϵ). This includes rigid elements with nonzero lengths.
5. Too many single point constraints (high S.E. & ϵ).
6. Scalar elements with nonzero lengths are not oriented along one of the basic coordinate axes (high S.E. & ϵ).

Sample Problem:

A sample problem sketch along with its NASTRAN bulk data is as shown in attachment 1. The overall dimensions are 24 in. long X 12 in. wide X 0.075 in. thick. The SUPORT point model (G.P. 100 and associated RBARS) is detailed in attachment 2.

Notes:

1. G.P.s 1 and 11 are coincident.
2. G.P.s 7 and 17 are coincident.
3. Hinges are simulated by RBAR connections with rotation about Y-axis not connected.
4. A mass of .01 lb-sec^2/in. magnitude is assigned at each of 1 through 9 G.P.s.
5. Plate and bar elements are massless.
6. $\theta_1 = 45^o$

   Total mass = .09 lb-sec^2/in.

   C.G. is at G.P. 5 location

   $$I_{yy} = 21.6 \text{ lb. sec}^2\text{-in}$$

   $$g = 32.2 \times 12 = 386.4 \text{ in/sec}^2$$

   $$\ddot{\theta} = \frac{386.4}{12} = 32.2 \text{ radians/sec}^2$$

   $$v = \sqrt{2 \times 386.4 \times \sin 45^o} = 23.38 \text{ in/sec (at C.G.)}$$

   $$t = \sqrt{\frac{2 \times 12 \times \sin 45^o}{386.4}} = .01 \text{ sec.}$$

   $$K.E. = (.09)\ (386.4)\ (12)\ (\sin 45^o) = 295.08 \text{ in.-lb.}$$

NASTRAN STRATEGY

Solution 24 of MSC/NASTRAN (Version 64A, CRAY X-MP) was used to calculate the inertia force distribution at each of the grid points. The procedure file shown in attachment 2 is used to accomplish the task. Grid point 100 in direction 5 (θ_y) is used as the SUPORT degree of freedom while a moment (M_y) is applied at the same grid point. This My may be calculated as follows to obtain the inertia load distribution.

$$My = I_{yy} \ddot{\theta} = 21.6 \times 32.2 = 695.52 \text{ in. lb.}$$

An ALTER 153 is inserted to convert the PLI matrix (Inertia Load), which is in the internal sequence, to the external sequence with the associated grid degrees of freedom for each element. Each element of the PLIGEXT matrix is a number computed by multiplying the mass at a grid point by the acceleration generated due to the appropriate external force. Also DMIG cards are punched so that the file can be used for later analysis with different constraints. For a large model, one can obtain mass and inertia properties from the Grid Point Weight Generator (GPWG) by inserting the ALTER 80 and EXIT $ cards in the Executive Control Deck and GRDPNT nnnn in bulk data, where nnnn is the grid ID about which the properties are to be computed.

Attachment 3 shows the inertia load distribution in terms of DMIG cards.

Inertia Forces Check:

$$\ddot{\theta} = \frac{695.52}{21.6} = 32.2 \text{ radians/sec}^2.$$

At GP 2, $m\ddot{z}$ = .01 X 32.2 X 12 = 3.864 lb.

At GP 3, $m\ddot{z}$ = .01 X 32.2 X 24 = 7.728 lb.

The Inertia force values calculated above check with the numbers obtained from the Inertia Relief run as shown in the attachment 3.

Next, solution 61 is run as shown in the procedure file (attachment 4). Note that the bulk data cards relating to SUPORT were deleted since they were no longer needed for a normal static analysis run. New bumper constraints (GP 3 and 9) are inserted in the bulk data and the P2G = PLIGEXT card is inserted in the case control deck, where PLIGEXT is the name of the inertia load matrix. All other cards for a typical superelement run are used as usual.

An Alter 339 was added in order to multiply the inertia load distribution by a factor so that the resulting strain energy in the structure is the same as the kinetic energy calculated earlier. This is accomplished as follows:

$$\text{Load Factor} = \sqrt{\frac{KE}{(SE)_1}}$$

Where, $(SE)_1$ = Strain energy with load factor of 1.0.

KE = Kinetic energy calculated earlier.

The load factor for the sample problem

$$= \sqrt{\frac{295.08}{0.72}} = 20.24$$

Line 300, attachment 4 shows this factor. We are assuming here that all the kinetic energy attained by the system must convert into strain energy at the bumper hit. In reality, some energy may convert into noise, heat and some may be imparted to air and some may be consumed for permanent set during the hit. Therefore, the results obtained may be on the higher side due to this assumption.

The stress and deformation contour plots are as shown in Figures 1 and 2 respectively.

TYPICAL HOOD SLAM ANALYSIS

A half hood model consisting of about 1900 elements and 1800 Grid Points was available for the analysis. The hood inner panel connections to hood outer panel were simulated by CELAS cards with their appropriate stiffness properties. Also the welds were simulated by RBAR cards. The following modifications were made in the model for the application of the Inertia Relief technique.

1. Noncoincident RBAR connecting points were made coincident to remove noncompatibility during the inertia relief run.
2. CELAS cards create constraints if they are not along one of the basic coordinate axes and have nonzero lengths. Many CELAS elements were found to be oriented along other than basic coordinate axes because of the nature of the grid coordinate definition. For simplicity, all CELAS cards were converted to massless CBARs with appropriate equivalent properties.
3. CBARS of very low stiffness values (massless) were also added at hinge locations so that stiffness terms corresponding to θ_y will be available and singularity of K_{rr} will not occur.
4. The left half (driver side) of the hood model was created and common symmetry points were eliminated. This is necessary for the Inertia Relief run since any extra constraints (such as at the symmetry plane) cause added strain energy and ϵ resulting in inaccurate inertia forces.

The following mass and inertia properties were obtained for this model.

I_{yy} = 1.544761 + 04 N - sec - mm

a_2 = 6.8395 + 02 mm

M = 2.4384 - 02 N - sec^2/mm

The hood is assumed to be dropped from an angle of 47° from the closed position (θ_1 = 47°). This translates to about 1098.55 mm (43 1/4 inch) drop height.

$$K.E. = mga_2 \sin \theta_1 = (2.4384 \times 10^{-2})\,(9814)\,(684) \sin 47^{\circ}$$

$$= 119{,}906 \text{ N - mm}$$

$$\ddot{\theta} = \frac{g}{a_2} = \frac{9814}{6.8395 \times 10^2} = 14.35 \text{ radians/sec}$$

$$M_y = 14.35\,(1.544761 \times 10^4) = (2.217 \times 10^5) \text{ N.-mm}$$

A finite element model of the half hood (passenger side) is shown in Fig. 3. The bumper pocket area at Hood Inner which resists a significant amount of load during the hit is as shown in Fig. 4.

Bumper Model

The bumper rubber material deforms substantially and makes significant contact to the pocket area of the hood inner during the impact. Based upon test observations, a bumper model was developed as shown in Figure 5. Typically, an averaging type element RBE3 was created with grid point 10 being dependent in directions xyz (123). Grid point 10 is connected to a coincident point 20 by spring elements (CELAS2) which is grounded assuming that radiator support to which the bumper is attached is rigid. A stiffness of 400 Newtons/mm was used for the rubber material based upon test data.

Inertia Relief Run

An RBE2 card connecting hinge pins and vicinity points around the hinge pins as dependents and a point midway on a line connecting hinge pins as independent was created. A SUPORT degree of freedom in direction θy is defined. A moment force of 2.217 X 10^5 N-mm calculated earlier was applied. A NASTRAN DMIG card file is created. After removing cards pertaining to the driver side, the resulting file is catalogued for subsequent analysis.

Inertia Load Application Run

Next, the bumper model as described earlier was included and only one half of the model with symmetric boundary conditions was used. Solution 61, as described for the sample problem was used to obtain stresses and deformations. Stresses (Von Mises) and deformation contour plots for the hood outer are shown in Figure 6 and 7 and the corresponding plots for the hood inner in Figure 8 and 9 respectively.

Assumptions and Discussions

A linear elastic analysis is attempted for this problem. However, one can analyze the bumper pocket area with nonlinear analytic methods by isolating it and applying boundary loads. These methods are successfully applied to buckling and other nonlinear problems. By using linear methods, one can establish trends and timely design directions.

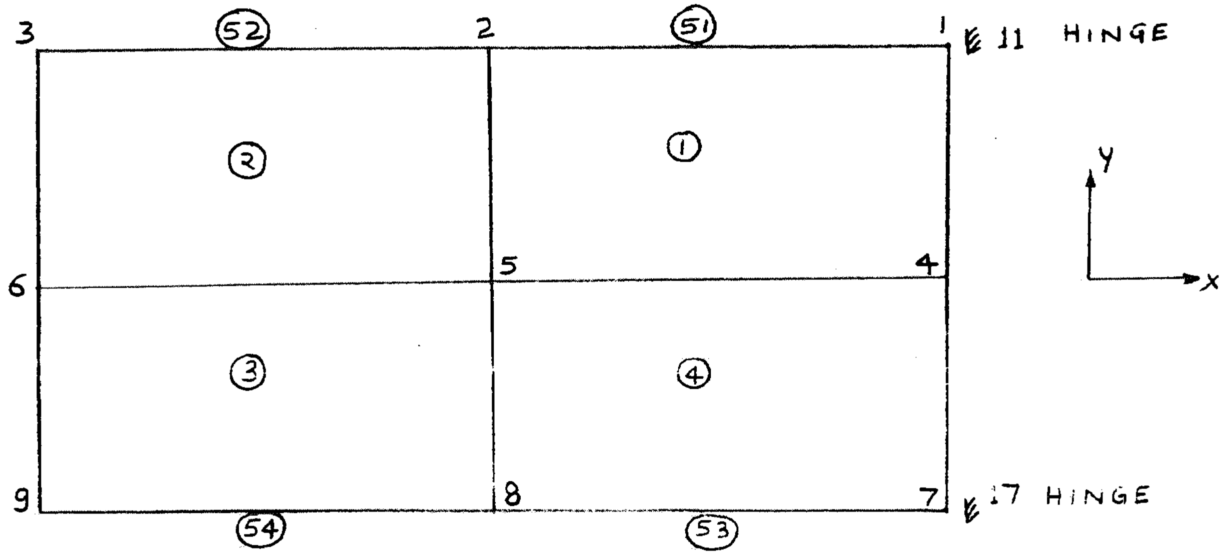
The fact that stress levels thus computed are too high suggests that all the kinetic energy available may not be converted to strain energy; some may dissipate as heat, and noise. Also, because of the bouncing effects, the total energy may remain in the form of kinetic and strain energies at different locations in the hood at any instant. However, the assumption is more conservative and the results should provide good design direction.

Conclusions and Recommendations

1. A methodology has been developed which utilizes the Inertia Relief technique of MSC/NASTRAN to analyze slam type of loading on a structure.
2. The procedure has been successfully applied to analyze the production design of a typical hood structure; test results obtained subsequently correlated well with analytical data.
3. The stress levels in the hood pocket area exceed the yield stress of the material. Therefore, a modification and further analysis is recommended for this area.
4. The hood bumper model should be developed further to account for nonlinearities. Energy participation may further be investigated by experiments and analyses.

Acknowledgement

This study would not have been complete without the contributions of Mr. Roy Dunton (Body & Chassis Engineering, Ford Motor Company) and Dr. P. R. Kurudiyara (Vehicle Systems NVH, Ford Motor Company). Mr. Dunton coordinated the test program and Dr. Kurudiyara debugged the ALTER package; their efforts helped develop this methodology. Sincere gratitude is also owed to Mrs. Lisa English for the timely and skillful typing of this paper.



GRID	1		0.	6.	0.		
GRID	2		-12.	6.	0.		
GRID	3		-24.	6.	0.		
GRID	4		0.	0.	0.		
GRID	5		-12.	0.	0.		
GRID	6		-24.	0.	0.		
GRID	7		0.	-6.	0.		
GRID	8		-12.	-6.	0.		
GRID	9		-24.	-6.	0.		
CQUAD4	1	1	1	2	5	4	
CQUAD4	2	1	2	3	6	5	
CQUAD4	3	1	5	6	9	8	
CQUAD4	4	1	4	5	8	7	
PSHELL	1	1	.075	1			
MAT1	1	30+06		.28			
CONM2	11	1		.01			
CONM2	12	2		.01			
CONM2	13	3		.01			
CONM2	14	4		.01			
CONM2	15	5		.01			
CONM2	16	6		.01			
CONM2	17	7		.01			
CONM2	18	8		.01			
CONM2	19	9		.01			
GRID	11		0.	6.	0.		
GRID	17		0.	-6.	0.		
CBAR	51	1	1	2	0.	0.	1
CBAR	52	1	2	3	0.	0.	1.
CBAR	53	1	7	8	0.	0.	1.
CBAR	54	1	8	9	0.	0.	1.
PBAR	1	1	.06	.0003	.0003	.0006	
RBAR	61	11	1	123456			12346
RBAR	62	17	7	123456			12346

SAMPLE PLATE PROBLEM

ATTACHMENT 1

```
JOB,JN=EXAMP,T=100,MFL=250000.
ACCESS,DN=$PROC,PDN=PROCLIB,ID=PUBLIC,OWN=SYSTEM.
FETCH,DN=BULK1,DF=CB,TEXT=¬
'ATTACH,BULK1,BULK,ID=EXAMPLE,MR=1.'.
NASTRAN,MFL=240000,DMAP=RFALTS.
REWIND,DN=FT07.
DISPOSE,DN=FT07,DC=PU,SDN=DMIG,TID=FFFFFF.
*C RF24D41,RF24D74
*DECK PANL
ID STATIC ANALYSIS
APP DISP
SOL 24
TIME 40
DIAG 8,33
*READ RFALTS
ALTER 153 $ PLI IS IN INTERNAL SEQUENCE
VEC USET/VATOG/G/L/COMP $ RELATION BETWEEN G AND L SET
MERGE PLI,,,,,VATOG/PLIG/V,Y,SYM=0/ $ EXPAND TO G-SIZE (INTERNAL SEQ.)
MATGEN EQEXIN/INTEXT/9/0/LUSET $ RELATION BETWEEN INT. & EXT. SEQ.
MPYAD INTEXT,PLIG,/PLIGEXT/1/1 $ EXT. SEQ. ,
MATMOD PLIGEXT,EQEXIN,,,,/MATPOOL1,/16/1 $ DMIG CARDS PUNCHED
TABPT MATPOOL1// $
CEND
TITLE= INERTIA RELIEF PANEL ASY
SUBTITLE= EXAMPLE PROBLEM
LABEL=
ECHO=SORT
STRESS(VONMISES)=ALL
DISP(PRINT)=ALL
SPC=100
SPCFORCES=ALL
GPFORCE=ALL
OLOAD=ALL
SUBCASE 25
LOAD=1
BEGIN BULK
*READ BULK1
MOMENT          1       1               695.52      0.      1.0       0.
$ SUPORT POINT MODEL
GRID            100             0.         0.         0.
RBAR,101,100,1,123456,,,5
RBAR,102,100,7,123456,,,5
SUPORT,100,5
$
SPC1,100,123456,11,17
PARAM,AUTOSPC,YES
PARAM,GRDPNT,1
PARAM,NEWSEQ,3
PARAM,EPZERO,1.-06
PARAM,NUMOUT,-1
PARAM,BIGER,7.0
$
ENDDATA
```

PROCEDURE FILE, INERTIA RELIEF RUN

ATTACHMENT 2

```
DMIG    PLIGEXT        0       9       1       0
DMIG*   PLIGEXT                        1               0
*                      2               3-3.864000000E+00
*                      3               3-7.728000000E+00
*                      4               3-2.516742370E-14
*                      5               3-3.864000000E+00
*                      6               3-7.728000000E+00
*                      8               3-3.864000000E+00
*                      9               3-7.728000000E+00
-
```

DMIG FILE (SAMPLE PLATE PROBLEM)

ATTACHMENT 3

```
JOB,JN=EXAMP,T=100,MFL=250000.
ACCESS,DN=$PROC,PDN=PROCLIB,ID=PUBLIC,OWN=SYSTEM.
FETCH,DN=BULK1,DF=CB,TEXT=¬
'ATTACH,BULK1,BULK,ID=EXAMPLE,MR=1.'.
FETCH,DN=INER,DF=CB,TEXT=¬
'ATTACH,INER,DMIGCARDS,ID=EXAMPLE,MR=1.'.
NASTRAN,MFL=245000,DMAP=RFALTS.
REWIND,DN=FT14.
DISPOSE,DN=FT14,DC=PU,SDN=EXPL,TID=FFFFFF.
*C RFO
*DECK PANL
ID STATIC ANALYSIS
APP DISP
SOL 61
TIME 40
DIAG 8,33
*READ RFALTS
ALTER 339
ADD P2J,/P2XX/(20.24,0.0) $
EQUIV P2XX,P2J/ALWAYS $
CEND
TITLE= INERTIA LOAD INPUT (FACTOR 20.24)
SUBTITLE= EXAMPLE PROBLEM
LABEL=
ECHO=SORT
STRESS(VONMISES,PRINT,PLOT)=ALL
DISP(PRINT,PLOT)=ALL
SPCFORCES=ALL
GPFORCE=ALL
OLOAD=ALL
SEALL=ALL
SUBCASE 25
P2G=PLIGEXT
SPC=100
OUTPUT(PLOT)
SET 102=1,THRU,4
PTITLE= SIMPLE PLATE
AXES Z,X,Y
VIEW 0.,0.,0.
FIND,SCALE,ORIGIN 2,SET 102
CONTOUR,MAXSHEAR,EVEN 4,MAX
PLOT,CONTOUR,SET 102,ORIGIN 2,OUTLINE
CONTOUR,ZDISP,EVEN 4
PLOT,CONTOUR,SET 102,ORIGIN 2,OUTLINE
BEGIN BULK
*READ BULK1
*READ INER
SPC1,100,123456,11,17
SPC1,100,3,3,9
PARAM,AUTOSPC,YES
PARAM,GRDPNT,0
PARAM,NEWSEQ,3
PARAM,EPZERO,1.-06
PARAM,NUMOUT,-1
PARAM,BIGER,7.0
$
ENDDATA
```

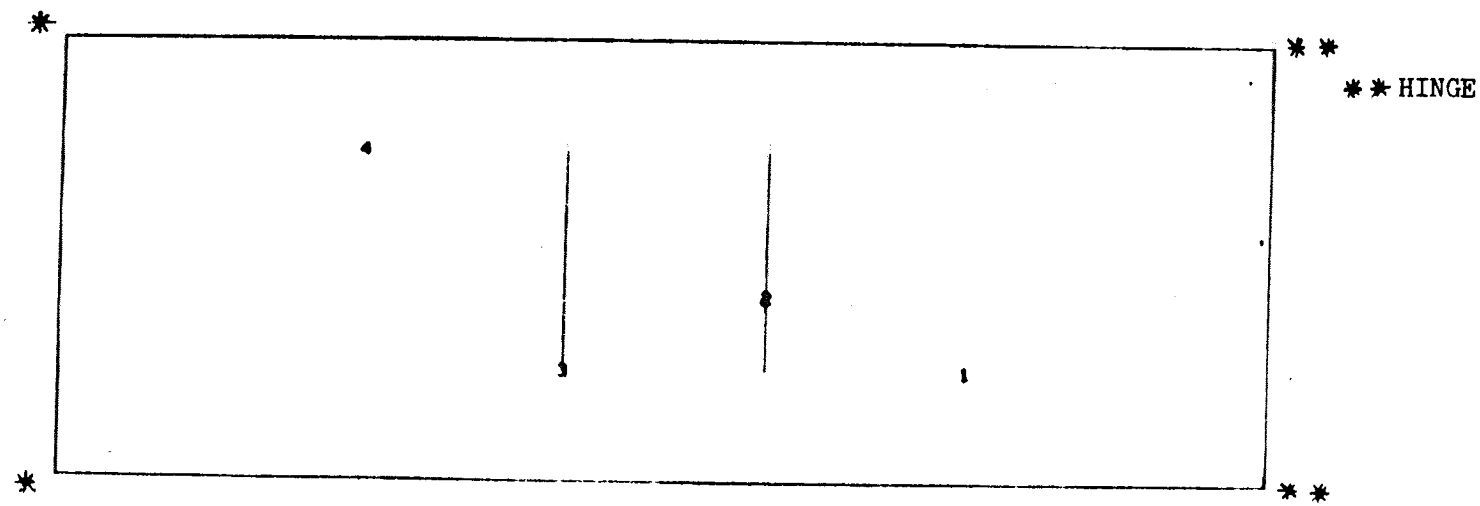
PROCEDURE FILE, INERTIA LOAD APPLICATION

ATTACHMENT 4

STRESS LEVELS (VON MISES) PSI

1 1 SIMPLE PLATE 5/ 8/87

SYMBOL	VALUE
1	2.348668E+04
2	2.483949E+04
3	2.619230E+04
4	2.754510E+04



* BUMPER CONSTRAINTS (Z)

INERTIA LOAD INPUT (FACTOR 20.24)
EXAMPLE PROBLEM
STATIC STRESS SUBCASE 25 LOAD 0

FIGURE 1

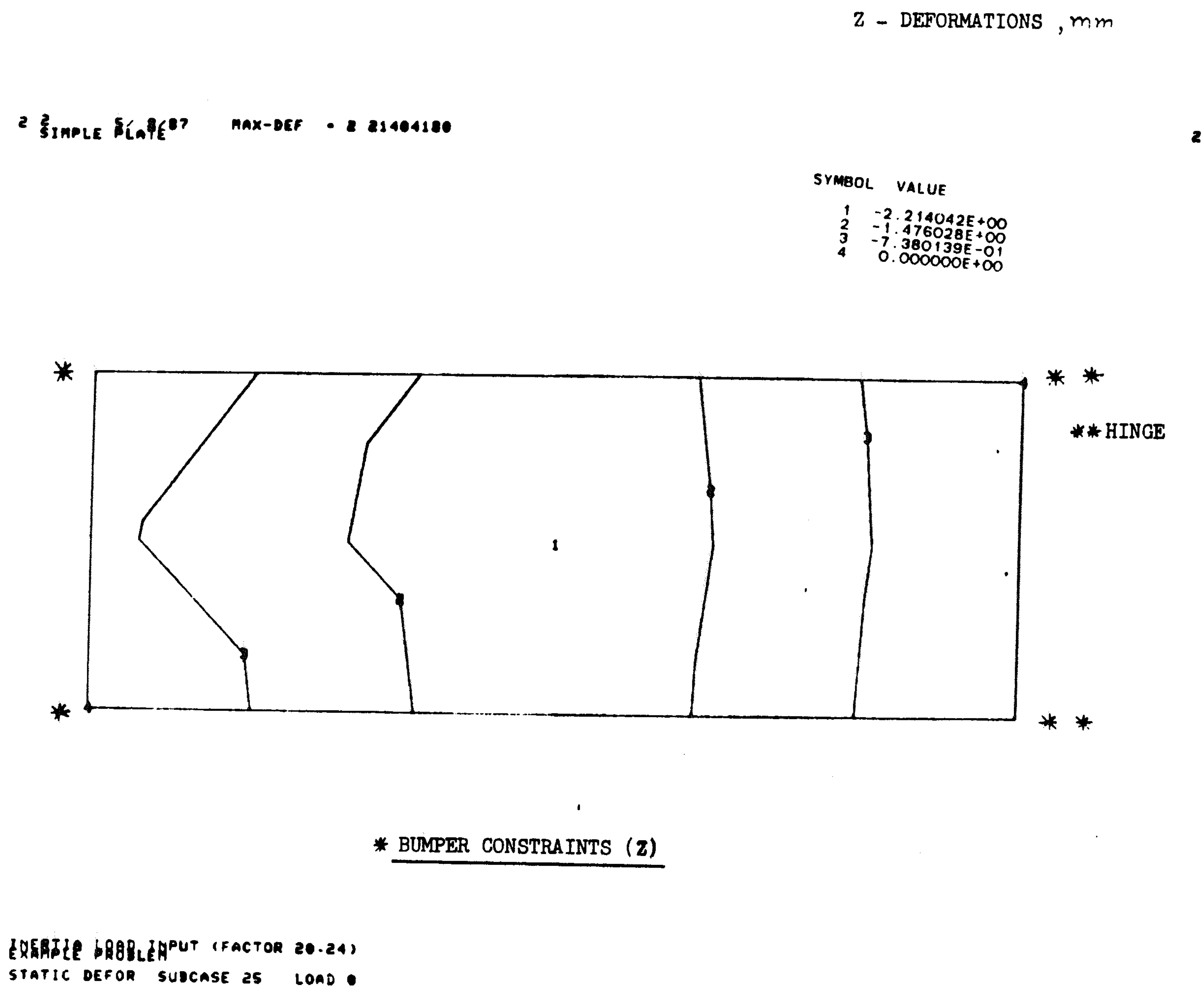
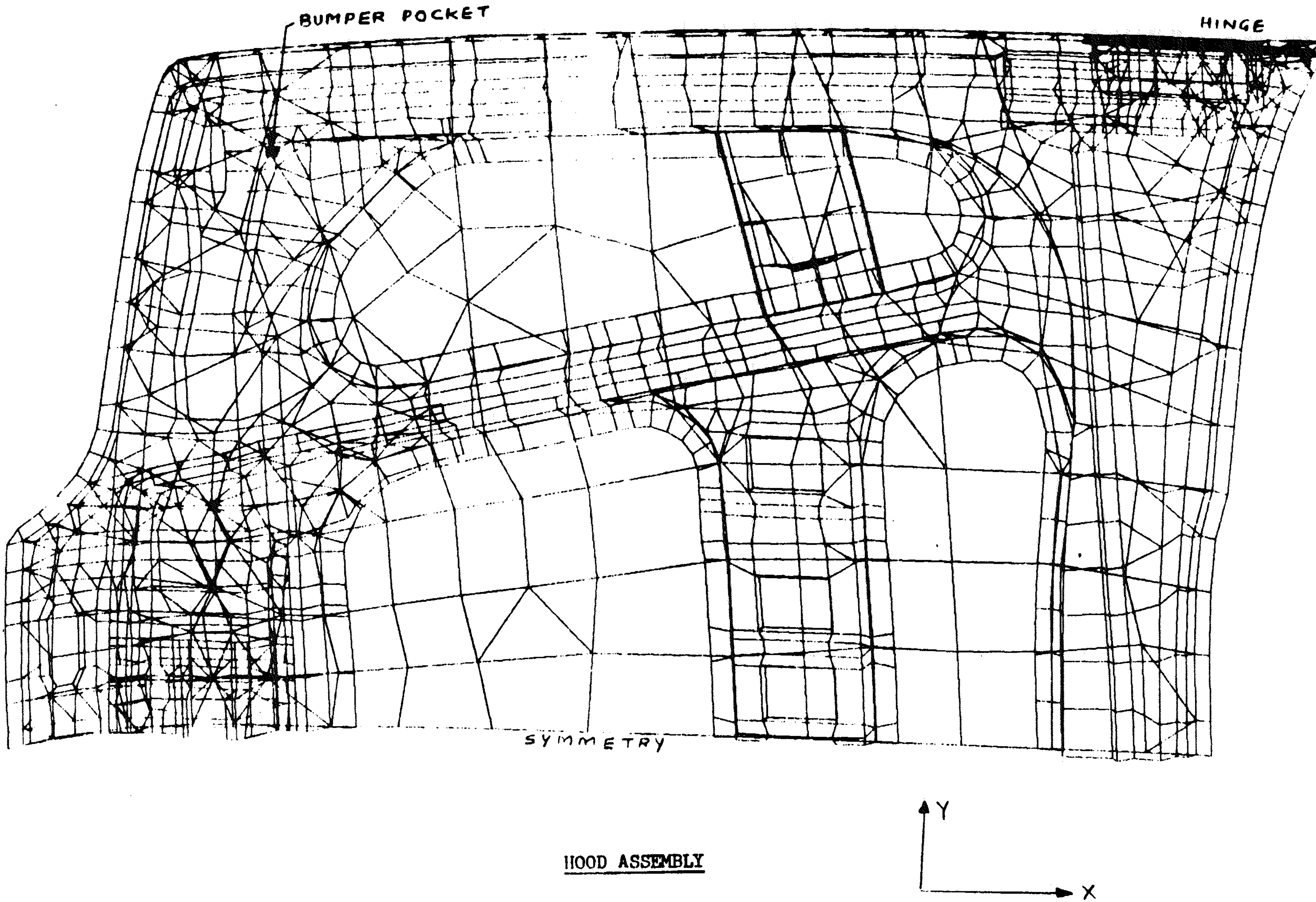
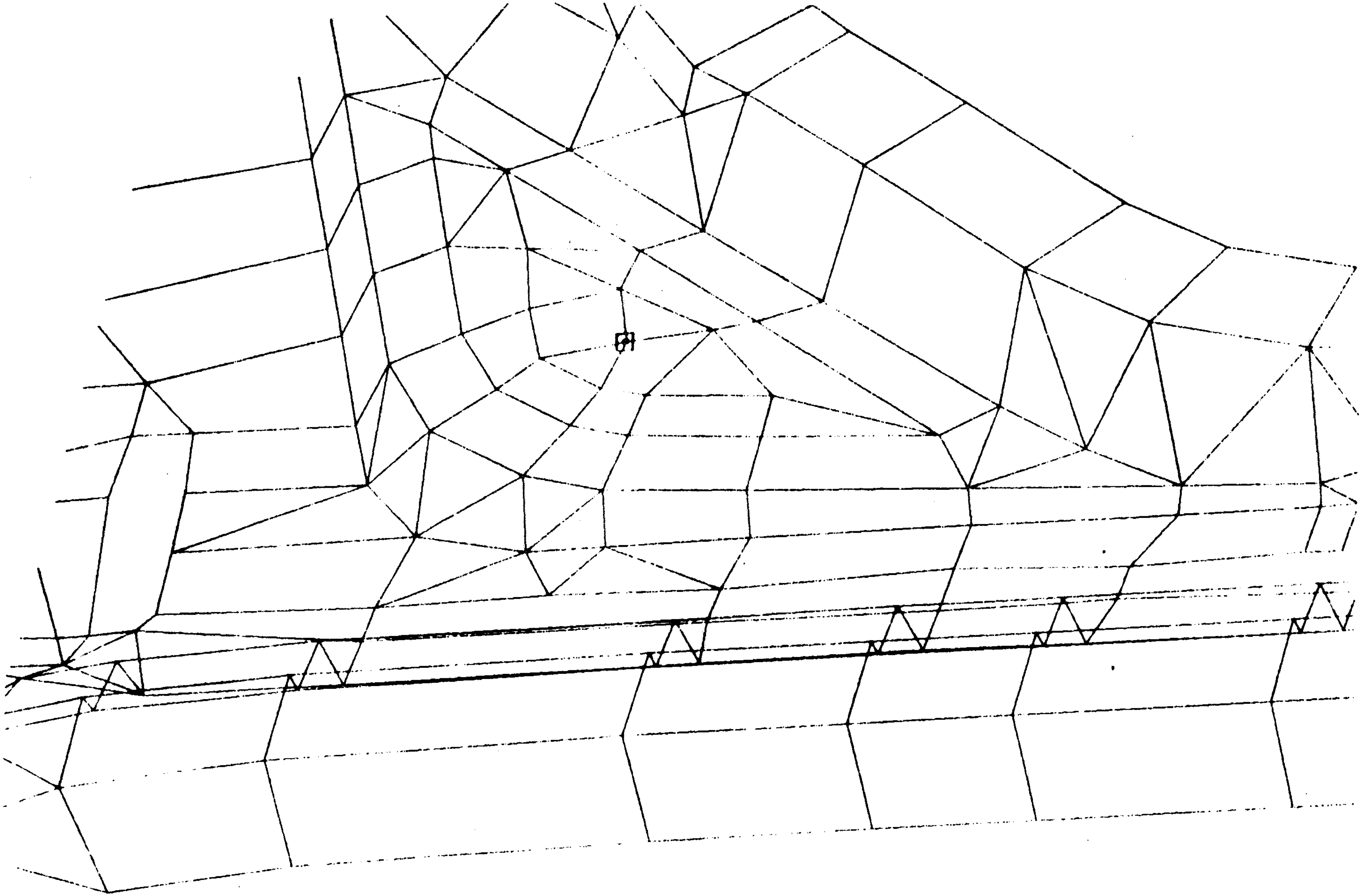

Z - DEFORMATIONS , mm
SIMPLE PLATE
MAX-DEF
SYMBOL VALUE
1 -2.214042E+00
2 -1.476028E+00
3 -7.380139E-01
4 0.000000E+00
** HINGE
* BUMPER CONSTRAINTS (Z)
EXAMPLE PROBLEM
STATIC DEFOR SUBCASE 25 LOAD

FIGURE 2



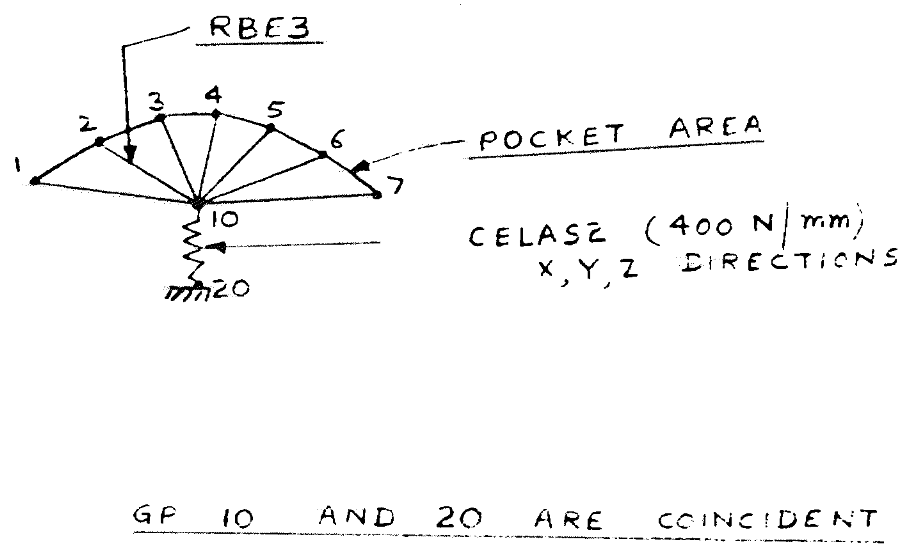
HOOD ASSEMBLY

FIGURE 3



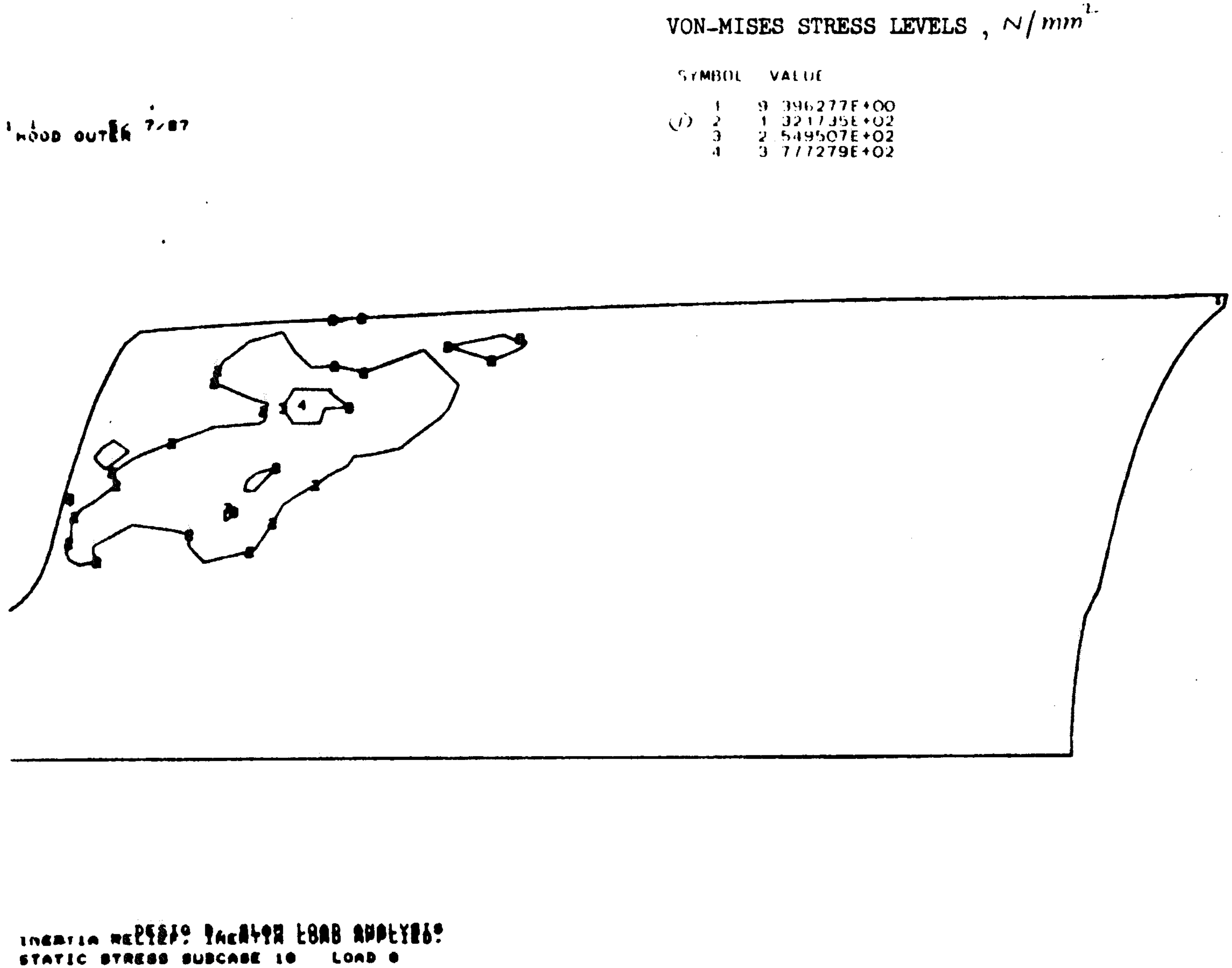
BUMPER POCKET AREA

FIGURE 4



BUMPER SIMULATION (TYPICAL)

FIGURE 5



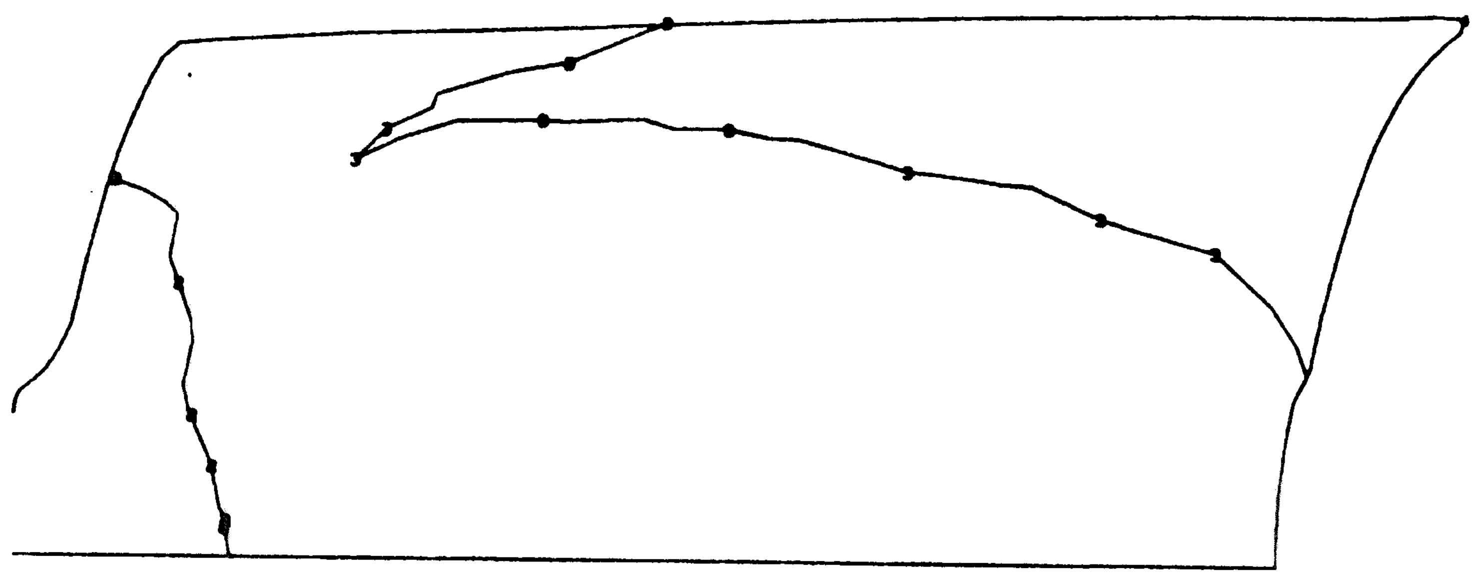
HOOD OUTER (STRESSES)

FIGURE 6

2 3
HOOD OUTER 7/87 MAX-DEF. = 44.8884440

VERTICAL DEFLECTION LEVELS, mm

SYMBOL	VALUE
1	-4.425644E+01
(2) 2	-2.995668E+01
3	-1.565691E+01
4	-1.357150E+00



INERTIA RELIEF: INERTIA LOAD APPLIED
STATIC DEFOR. SUBCASE 10 LOAD 0

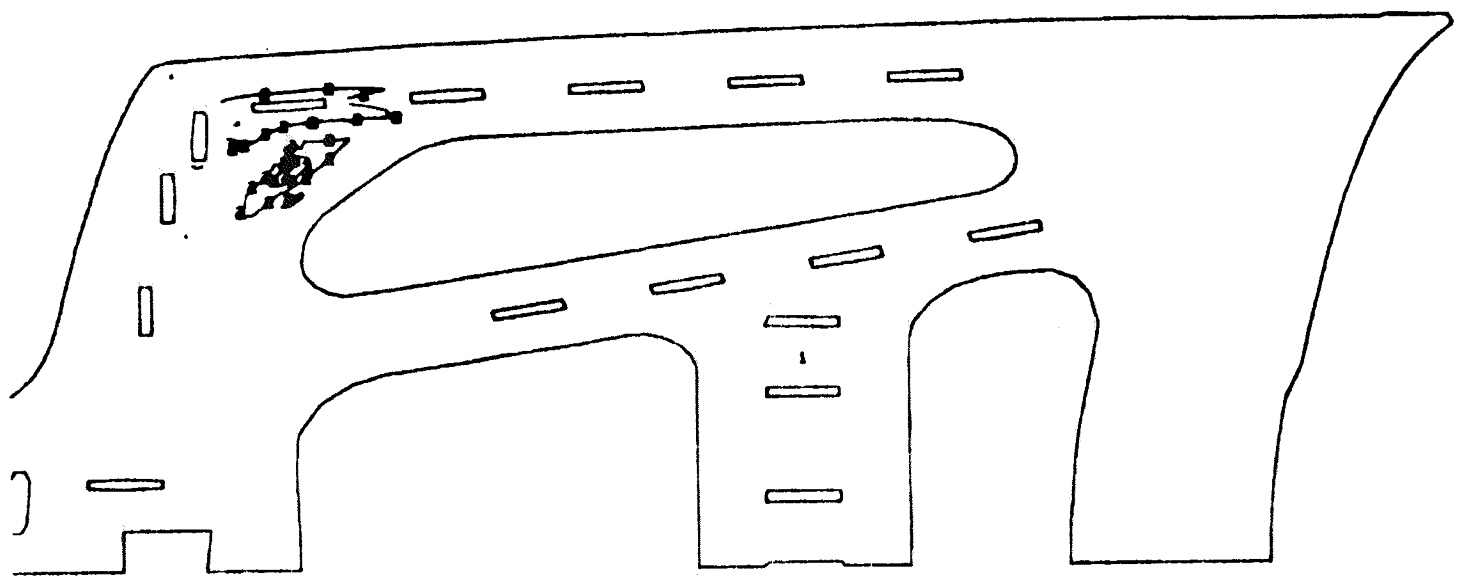
HOOD OUTER (DEFLECTIONS)

FIGURE 7

VON-MISES STRESS LEVELS (N/mm^2)

SYMBOL	VALUE
1	1 197061E+00
2	6 119741E+02
3	1 222751E+03
4	1 833528E+03

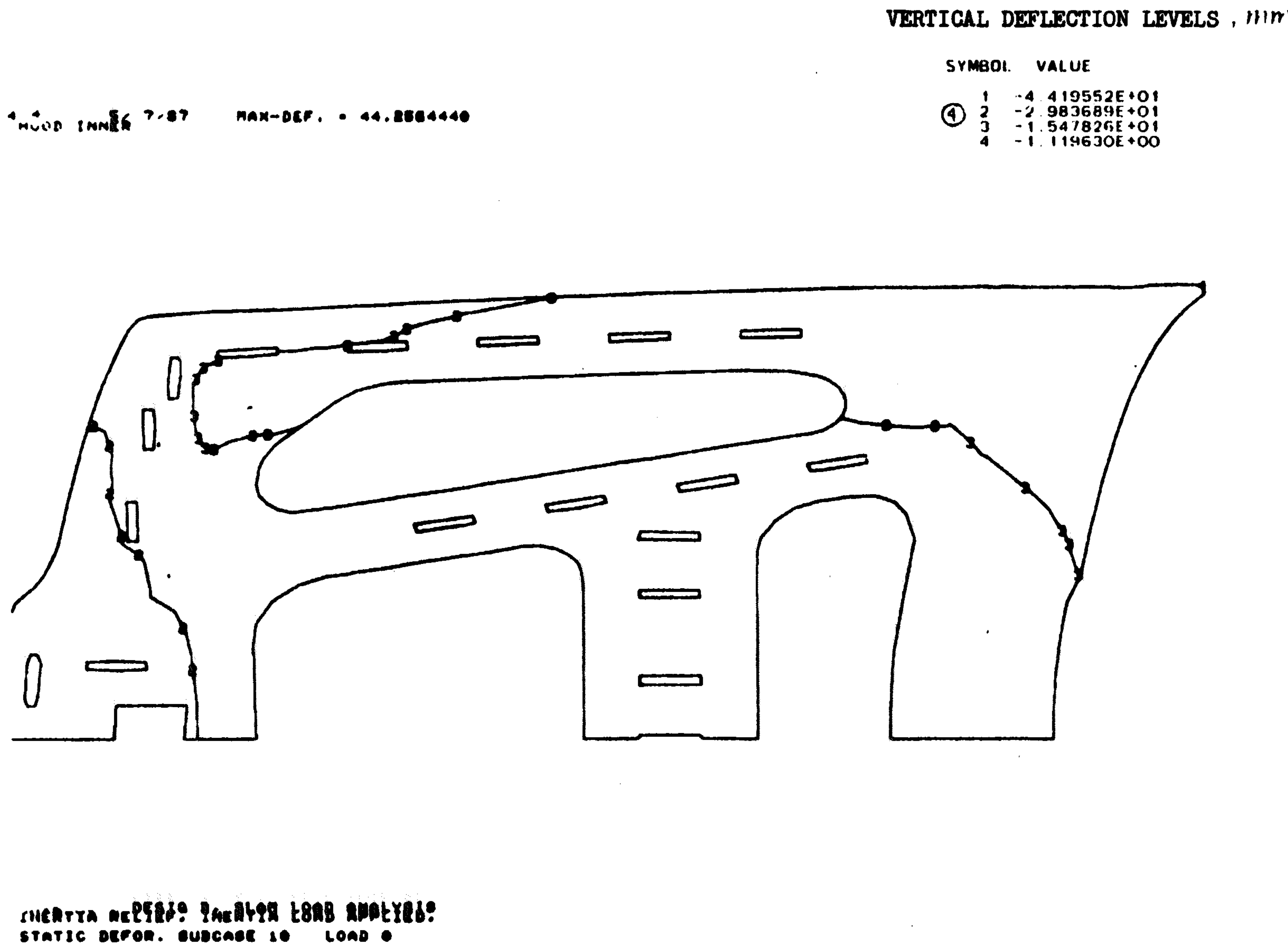
HOOD INNER 7/87



INERTIA RELIEF, INERTIA LOAD APPLIED
STATIC STRESS SUBCASE 10 LOAD 0

HOOD INNER (STRESSES)

FIGURE 8



HOOD INNER (DEFLECTIONS)

FIGURE 9