Centre for Mechanical Engineering

TNO Building and
Construction Research

TNO-report

94-CMC-R0539 Manual for SHOCK3D, version 2.0
Computer program for non-linear shock response

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Computer program for non-linear shock response

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Het rekenprogramma SHOCK3D werd indertijd geschreven in opdracht van de Koninklijke Marine, Afdeling Scheepsbouw, teneinde toegepast te kunnen worden bij nieuwbouw projecten waar schokeisen gesteld werden aan apparatuur, dit i.v.m. de noodzaak de gevolgen van onderwaterexplosies te kunnen doorstaan.
Veel werktuigen en apparaten zijn verend opgesteld, waarbij tijdens deze extreem zware schokbelastingen veelal sprake is van een sterk niet-lineair gedrag van de veren.
SHOCK3D werd geschreven om de schokreducerende eigenschappen van deze verende opstellingen te kunnen beoordelen en tevens om de schokresponsie van de apparatuur meer gedetailleerd te kunnen voorspellen. De input schokbewegingen, op de top van de scheepsfundaties, zijn o.m. gestandaardiseerde pulsvormen, zoals die bijv. in Nederlandse, Engelse en Duitse Marine schokspecificaties zijn vastgelegd. Het 3-dimensionale systeem waaraan gerekend wordt, mag bestaan uit meerdere starre en uit meerdere flexibele lichamen, onderling en met de verschillende fundaties verbonden door niet-lineaire veren. Daarbij bestaat de mogelijkheid veerkarakteristieken te genereren voor zeer uiteenlopende veertypen.
Stap voor stap in de tijd (transient response) worden de resultaten zichtbaar gemaakt.
Het voorliggende manual heeft betrekking op een nieuwe versie (2.0) van SHOCK3D.
Het programma is ook geschikt voor PC gebruik, mits het systeem geen flexibele lichamen bevat.

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1. INTRODUCTION.

By it's nature, much equipment being designed for the military services, during peace time is exposed to shocks which are rather well known. In times of war some of this equipment should withstand a very severe shock environment, as laid down in specifications. Predicting the shock response, based on a mathematical model of the equipment, is one of the main efforts carried out as a part of the fundamental shock research program of TNO-DO.
Stimulated by the interest of the Royal Netherlands Navy in building ships having a sufficient degree of shock resistance against the effects from non-contact underwater explosions, several computer programs have been developed. The earliest programs [1] [2] already included nonlinearity but they only dealt with single degree of freedom systems. Once having extended the program to a mass spring system with three degrees of freedom [3] the approximate shock response of many rigid pieces of equipment, installed on non-linear mountings could be determined. An early example concerns the Tyne gasturbine on board the S-frigates [4]. It was realised that in many cases the flexibility of the equipment itself could not be neglected. In a next program [5] the structure could be modeled as a two dimensional grid of beam elements. This program for instance has been applied to simulate a shock test on an Olympus gasturbine [6], and to predict the response to recoil forces of a Leopard tank of the Army [7].

The SHOCK3D program permits the structure of interest to be modeled three-dimensionally with the wide range of finite elements as already available in a general purpose finite element program.
The first version of the SHOCK3D program was completed in 1978 [18].
It was used for instance to calculate for the Walrus-class submarines the shock response of dieselgenerators [19] and the resiliently mounted deck [20]. Another application was in the modelling of the TNO light weight shock testing machine [21].

The present version 2.0 differs from the previous version in the following respects.

(a) The input format now is free.
(b) A second, more rapid integration procedure has been added.
(c) Coulomb damping is added as spring type no. 5.
(d) Prescribed base motions in the form of BV043 input can be handled (double sine).
(e) The plot program COMEDI not longer being operational, an interface has been added to the plotprogram TECPLOT [15].
(f) The latest available version of the finite element program (ASKA v90/r11) is used. Therefore some of the ASKA-processors, wich were specially developed by TNO in relation to SHOCK3D, had to be modified.

2. BROAD DESCRIPTION OF THE PROGRAM.

A rough sketch of a three-dimensional structure as can be handled by the program is given in figure 2.1.

The structure may be an assembly of various elastic and rigid parts, interconnected by non-linear elements.

These elements (see section 3.1.), having three translations as degrees of freedom at each of their two nodal points, can transmit forces which may vary non-linearly with the deformations of the elements. These elements are meant to simulate in particular different types of shock mountings which often behave quite nonlinearly during shock.

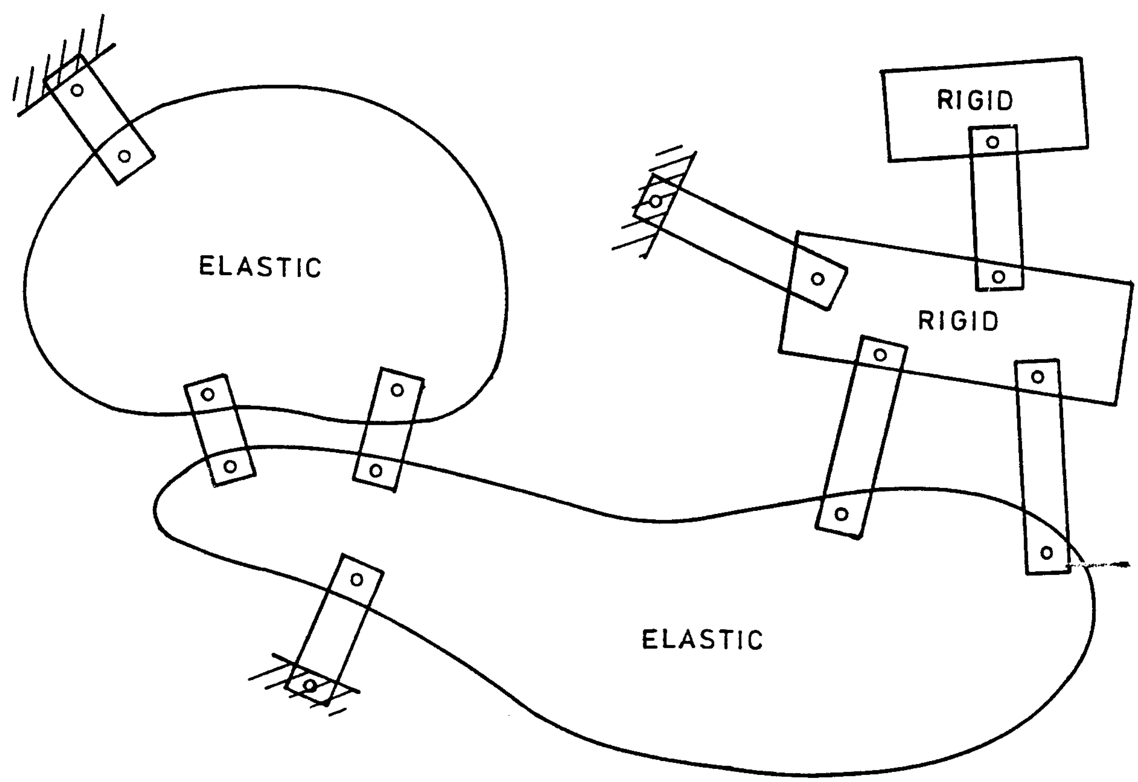

Fig. 2.1

Stiffness and mass matrices of elastic parts of the structure are most efficiently obtained when using one of the existing general purpose finite element programs. In this case the ASKA computer program [8] is being used. Special routines (see section 3.4.1.) have been written to facilitate the input of ASKA results into SHOCK3D. Shock response displacements as calculated with SHOCK3D are written on disk and treated as loading cases in ASKA in order to obtain with that program the stress distribution within the elastic part(s) of the structure.

In practice, many times, parts of the structure can be considered as rigid as compared to the rest of the structure. In order to avoid the necessity of dividing such stiff parts into finite elements, which apart from the large effort involved also would introduce very high natural frequencies and consequently very small computation steps, it was decided to introduce into SHOCK3D rigid bodies with separate equations of motion for their centres of gravity.

The structure may be shock loaded either by prescribed motions or by external forces. These motions may be prescribed at nodal points of the nonlinear elements (foundations) as well as nodal points of the elastic structure. They may be given analytically as well as numerically with certain time intervals. See section 4.

The equations of motion normally are solved numerically with a Runge-Kutta method, as in previous programs [3] [6], but a second order extrapolation method is also available (see section 5).

Shock3D is written in Fortran. It is implemented on the IRIS computer at CMC, Delft. It contains about 3800 statements divided over some 80 subroutines. By means of a vector storage concept SHOCK3D achieves dynamic storage allocation bounded by only a single variable. This results in a problem limitation that is bounded only by the maximum number of words available on the computer where the program is being run.

Shock3d, when combined with the F.E.M. package ASKA, cannot be run on a personal computer (PC).
If however the model does not include any flexible bodies, then SHOCK3D may run on a PC. Then this manual can be applied as well, whereas for specific information regarding PC usage one is referred to appendix B.

3. DETAILED DESCRIPTION OF PARTS OF THE SHOCK LOADED STRUCTURE.

3.1. *Non-linear elements.*

Fig. 3.1.1 shows the global coordinate system x, y, z for the complete structure to be analyzed. The global coordinates of the three nodal points P1, P2 and P3 determine the position of a single non-linear element, shown schematically as a cylinder between nodal points P1 and P2. The local coordinate system of this nonlinear element is such that the x'-axis points from P1 to P2. The y'-axis is normal to the x'-axis and oriented towards point P3. The z'-axis is normal to x' and y'. They constitute a right hand system (x', y', z').
The non-linear properties of the element are specified for these local directions. By means of a coordinate transformation matrix displacements in the global system are translated into displacements in the local system and by means of the inverse matrix forces in the local system are translated into forces in the global system.

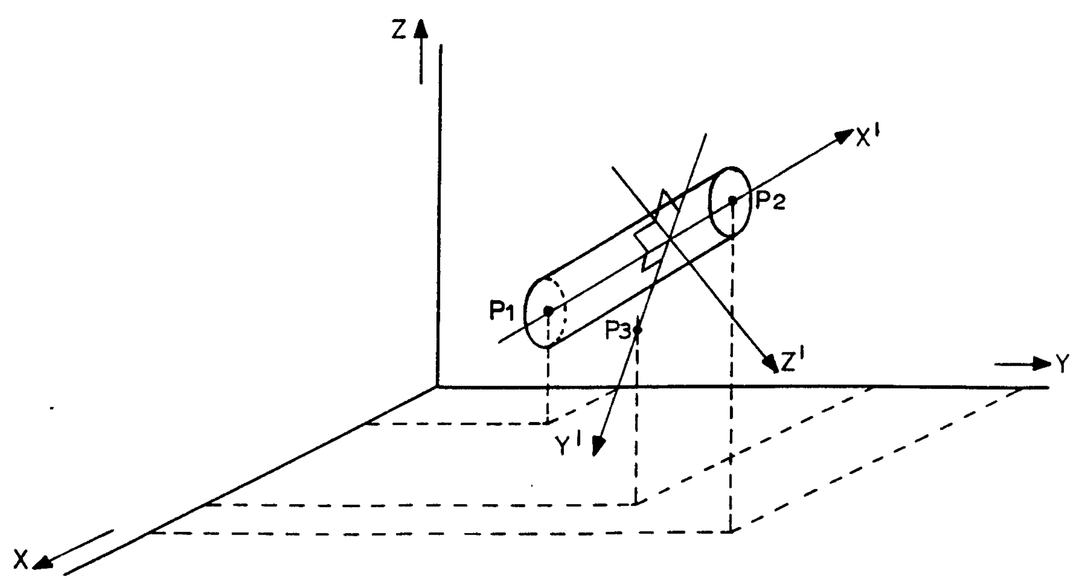

Fig. 3.1.1

Denoting the displacements of P_1 and P_2 in x' direction by $q_1^{1\prime}$ and $q_1^{2\prime}$, in y' direction by $q_2^{1\prime}$ and $q_2^{2\prime}$ and in z' direction by $q_3^{1\prime}$ and $q_3^{2\prime}$ we have the following deformation of the non-linear element in the local directions:

$q_1^{1\prime} - q_1^{2\prime} = (\Delta l)_1'$, a compression of the non-linear element in it's main direction.

$q_2^{1\prime} - q_2^{2\prime} = (\Delta l)_2'$, shear in the y' direction.

$q_3^{1\prime} - q_3^{2\prime} = (\Delta l)_3'$, shear in the z' direction.

In each of the three local directions of the nonlinear element a relation can be specified between a so defined deformation Δl and the force F which is exerted by the nonlinear element on it's nodal point P_2 in the corresponding positive local direction. At the moment five different types of relations, simply called "springs" can be specified.
Typical examples are shown in figure 3.1.2.

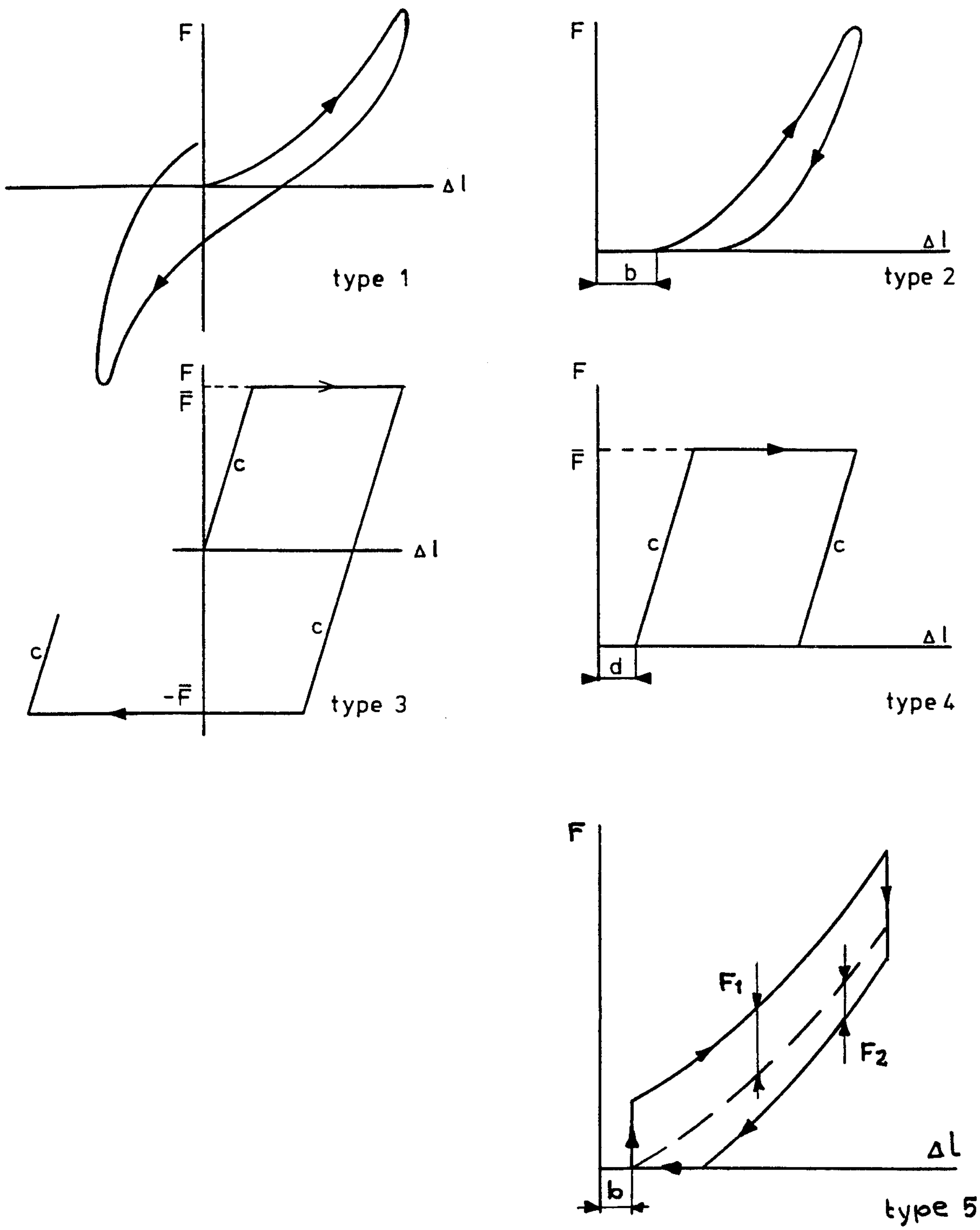
F
Δl
type 1
F
Δl
b
type 2
F
F̄
c
Δl
c
c
-F̄
type 3
F
F̄
c
c
Δl
d
type 4
F
F₁
F₂
Δl
b
type 5

Figure 3.1.2

Spring type 1 : resilient mounting for compression and tension.

$$F = \sum_{j=1}^{n} Cj \ (\Delta l)^{j} + K|\Delta \dot{i}|\Delta \dot{i} + \overline{K}\Delta \dot{i}$$

Spring type 2 : resilient mounting for compression only.

A clearance b can be simulated.

$$F = \sum_{j=1}^{n} Cj \ (\Delta l - b)^{j} + K|\Delta \dot{i}|\Delta \dot{i} + \overline{K}\Delta \dot{i} \quad \text{for } F > 0$$

Spring type 3 : constant force device for compression and tension.

The maximum transmitted force is $\overline{F}$ during compression and $-\overline{F}$ during tension. The elastic stiffness is C. When yielding stops, the device again has an elastic behaviour. The transmitted force F is a function of the previous loading history which is indicated by γ being the point of intersection between the momentary elastic line and the Δl-axis.

At $t = 0 \quad \gamma = 0$

If $|C(\Delta l-\gamma)| < \overline{F}$ then $F = C\ (\Delta l-\gamma)$ and γ does not change.

If $|C(\Delta l-\gamma)| \geq \overline{F}$ then $F = \overline{F}$ Sign $[C\ (\Delta l-\gamma)]$ and $\gamma = \Delta l - \overline{F}/C$

Spring type 4 : constant force device for compression only.

A clearance d can be simulated.
Having the same meanings for $\overline{F}$, C and γ:
At $t = 0 \quad \gamma = d$
If $C(\Delta l-\gamma) \leq 0$ then $F = 0$ and γ does not change.
If $0 < C(\Delta l-\gamma) < \overline{F}$ then $F = C(\Delta l-\gamma)$ and γ does not change.
If $C(\Delta l-\gamma) > \overline{F}$ then $F = \overline{F}$ and $\gamma = \Delta l - \overline{F}/C$

Spring type 5 : Coulomb damping superimposed on undamped resilient mounting for compression only.

If $\Delta\dot{l} > 0$ and $\Delta l > b$ (the clearance):

$$F = \sum_{j=1}^{n} Cj \ (\Delta l - b)^j + F1$$

If $\Delta\dot{l} < 0$ and $\Delta l > b$:

$$F = \sum_{j=1}^{n} Cj \ (\Delta l - b)^j + F2$$

F1 and F2 are the Coulomb damping forces which depend on the sign of the compression velocity. F2 usually is negative. Spring type 5 cannot transmit tensile forces. So when the above formulas lead to a negative value for F, then F is taken as zero instead.

In the program all non-linear elements are given different numbers, even when they have exactly the same properties. The numbering sequence is arbitrary. Several non-linear elements may be connected to the same nodal point (s). All springs are given different numbers, but when they are of the same type and when also the same numerical values apply, they can be given the same spring number which is done to limit the spring input information. The numbering sequence is arbitrary. A detailed input description is given in section 6.1.

A last remark concerns the spring types 1, 2 and 5. The static characteristics of these springs are given by the coefficients C_j, which very seldom are directly available. Usually the static tangential stiffness is known for different compressions. So an option is available to read in N combinations of

Δl and $\frac{dF}{d\Delta l}$ for spring type 1 or

$\Delta l - b$ and $\frac{dF}{d(\Delta l - b)}$ for spring types 2 and 5.

In the program N equations are solved to find the coefficients C_j. To use this option the spring types are resp. -1, -2 and -5 instead of 1, 2 and 5.

3.2. *Rigid bodies.*

The rigid bodies are numbered in an arbitrary sequence. Their position is specified by the coordinates of their centres of gravity. These nodal points have 6 degrees of freedom: three translations and three rotations all related to the global coordinate system. The inertia of a rigid body is specified by it's mass m and it's moments of inertia I_x, I_y and I_z. For each rigid body the numbers of the following nodal points must be specified:

1) the first one concerns the centre of gravity.
2) the sequence of the other ones is arbitrary.
   They include
   a) the numbers of all the connection points with the non-linear elements
   b) the numbers of points of interest of the rigid body for which the shock response must be obtained.

There is the possibility to suppress degrees of freedom of the rigid body. This is for instance necessary when only half the structure has been modeled for reasons of symmetry and up to this the centre of gravity lies in this plane of symmetry. In such a case the global coordinate system must be chosen carefully. Section 9.4 presents an application.

3.3. *Foundations.*

In fact the foundations themselves are not parts of the structure to be analyzed. They are that part of the boundary between the structure and it's surrounding, where non-linear elements are located. It is assumed that the shock motions of these foundations are known (see section 4.1.). Of course this does not mean that for instance real shipboard foundations with their inherent flexibility could not be included in the structure to be analyzed. In such a case that foundation is modeled as an elastic substructure (section 3.4.) having itself suppressed and/or prescribed degrees of freedom. See for example section 9.4. where a part of a ship's deck is treated as such.

3.4. *Linear elastic substructures.*

Each linear elastic substructure is treated as a single net in the ASKA computer program [8] . This program is used to build stiffness- and mass matrices and to carry out if necessary a static condensation. Neglecting damping, the general equations using ASKA-notation are written in the following form.

$$\begin{vmatrix} K_{LL} & K_{LC} & K_{LP} & K_{LS} \\ K_{LC}^T & K_{CC} & K_{CP} & K_{CS} \\ K_{LP}^T & K_{CP}^T & K_{PP} & K_{PS} \\ K_{LS}^T & K_{CS}^T & K_{PS}^T & K_{SS} \end{vmatrix} \begin{vmatrix} r_L \\ r_C \\ r_P \\ r_S \end{vmatrix} + \begin{vmatrix} M_{LL} & M_{LC} & M_{LP} & M_{LS} \\ M_{LC}^T & M_{CC} & M_{CP} & M_{CS} \\ M_{LP}^T & M_{CP}^T & M_{PP} & M_{PS} \\ M_{LS}^T & M_{CS}^T & M_{PS}^T & M_{SS} \end{vmatrix} \begin{vmatrix} \ddot{r}_L \\ \ddot{r}_C \\ \ddot{r}_P \\ \ddot{r}_S \end{vmatrix} = \begin{vmatrix} R_L \\ R_C \\ R_P \\ R_S \end{vmatrix} \qquad (1)$$

The stiffness matrix K and the mass matrix M are stored in separate data books according to the freedom families:

- L = local degree of freedom
- C = external degree of freedom
- P = prescribed degree of freedom
- S = suppressed degree of freedom

The right hand side of the equation represents the external forces.
Taking into account that:

a) $r_S = \ddot{r}_S = 0$

b) R_S is not of immediate interest.

c) R_P is not of immediate interest.

d) $R_L = 0$

(1) simplifies to

$$\begin{vmatrix} K_{LL} & K_{LC} \\ K_{LC}^T & K_{CC} \end{vmatrix} \begin{vmatrix} r_L \\ r_C \end{vmatrix} + \begin{vmatrix} M_{LL} & M_{LC} \\ M_{LC}^T & M_{CC} \end{vmatrix} \begin{vmatrix} \ddot{r}_L \\ \ddot{r}_C \end{vmatrix} = \begin{vmatrix} - K_{LP} \; r_P - M_{LP} \; \ddot{r}_P \\ R_C - K_{CP} \; r_P - M_{CP} \; \ddot{r}_P \end{vmatrix} \qquad (2)$$

When using the above equation it has been assumed that external degrees of freedom have been chosen

a) "equally distributed" to describe the expected natural modes which may be excited by the shock.

b) at those places and in those directions where concentrated excitation forces are acting, being either directly given as a function of time or transmitted by the non-linear elements.

A restriction in ASKA is that prescribed degrees of freedom may only be coupled to external degrees of freedom, or $K_{LP} = 0$ and $M_{LP} = 0$. This means that the number of external degrees of freedom is increased and also that very high natural frequencies are being introduced into the net, which results in extremely small time steps in the numerical integration procedure.
To get rid of this serious limitation the further derivation has been based on the assumption that $K_{LP} \neq 0$ and $M_{LP} \neq 0$
By means of static condensation the number of unknowns (L+C) is reduced to the number of external degrees, which are then called master degrees of freedom (M).

By means of the transformation matrix $T = K_{LL}^{-1} K_{LC}$
the local degrees of freedom are expressed in the master degrees of freedom:

$$r_L = -K_{LL}^{-1} \quad K_{LC} \quad r_M$$

By substituting $\begin{vmatrix} r_L \\ r_C \end{vmatrix} = \begin{vmatrix} -T \\ I \end{vmatrix} \quad r_M$ in (2)

and by premultiplying with

$$\begin{vmatrix} -T^T & I \end{vmatrix}$$

we have the following equation for the master degrees of freedom:

$$K_{MM} \, r_M + M_{MM} \, \ddot{r}_M = (T^T \quad K_{LP} - K_{CP}) \; r_P + \quad (T^T \quad M_{LP} - M_{CP}) \; \ddot{r}_P + R_C$$

All the matrices K_{MM}, M_{MM}, T, K_{LP}, K_{CP}, M_{LP} and M_{CP} are being made in ASKA. In all cases K_{MM} is needed from ASKA. The condensed mass matrix also may be made by ASKA. Another possibility is to estimate a mass-distribution and to read in directly from an inputfile the diagonal terms of a mass matrix.
If there are prescribed degrees of freedom and there is no coupling with local degrees of freedom K_{CP} and M_{CP} are needed. These matrices (as well as other ones) can be generated on tape by the processor CALL TNOPRI.
If prescribed degrees of freedom are coupled with local degrees of freedom in SHOCK3D we need to know K_{CP} - T^TK_{LP} instead of K_{CP} and M_{CP} - T^TM_{LP} instead of M_{CP}.
Transposing, multiplying and subtraction is easily done within ASKA by the processors

CALL MULTH (4HBTbb, 4HBKLP, 4HBKCP, -1, 2, 1) and
CALL MULTH (4HBTbb, 4HBMLP, 4HBMCP, -1, 2, 1).

In general ASKA nodal point numbers of a substructure will be different from the numbers as given to these nodal points in the program SHOCK3D. The user of this program has to specify in the input both numbers. Up to this in the ASKA-job he must use the processor(s) CALL TNOINF in order to get list(s) of nodes and nodal freedom numbers belonging to the specific freedom families. Because coordinate systems in ASKA and in SHOCK3D are parallel, the nodal freedom numbers:

1 = translation in direction of x-axis
2 = translation in direction of y-axis
3 = translation in direction of z-axis
4 = rotation about x-axis
5 = rotation about y-axis
6 = rotation about z-axis

are the same in both programs.
Having this information available, SHOCK3D can handle the stiffness and mass coefficients as produced by ASKA. Apart from the print-output of SHOCK3D, results in the form of displacements can be written on disk. Processor CALL TNOREN reads these displacements from disk and creates the ASKA-books SRC (SRL when there are no external degrees of freedom) and SRP in case of prescribed degrees of freedom. Stresses and strains can then be obtained with the ASKA program.

3.4.1. *Additional ASKA-processors.*

A complete description of the ASKA-processors, which were specifically developed by TNO-IWECO in relation to SHOCK3D, is given below.

A) <u>CALL TNOINF (IC, JUNIT)</u>
This processor generates a list of node and nodal freedom numbers belonging to freedom family IC on tape JUNIT.
The <u>arguments</u> are:

IC = 1 local freedoms
2 external freedoms
3 prescribed freedoms
4 suppressed freedoms

JUNIT = n Fortran unit number
= 99 file output

This processor needs book SA

B) <u>CALL TNOPRI (4Haaaa, JUNIT)</u>
This processor generates hypermatrix book aaaa on tape JUNIT.
The <u>arguments</u> are:

aaaa = label of the hypermatrix book wanted.
JUNIT = n Fortran unit number
= 99 file output

C) CALL TNOREG (JUNIT)

This processor produces the output desired by program SHOCK3D on a sequential data set.

The argument is:

JUNIT = n output on data set with FORTRAN unit number n.
= 99 output to file.

The processor needs books -SA- and -SKM- (or -BKLL-) and if prescribed displacements are incorporated book -BKCP- (or -BKLP-).

Furthermore if the mass matrix is to be delivered by the ASKA system book
-SMM- (or -BMLL-) and if necessary book -BMCP- (or -BMLP-) are needed.

TNOREG is a multi-processor performing the following steps:

```
                          CALL TNOINF (3     , JUNIT)
if there are externals:   CALL TNOPRI (4HBKCP, JUNIT)
                          CALL TNOPRI (4HBMCP, JUNIT)
                   else:  CALL TNOPRI (4HBKLP, JUNIT)
                          CALL TNOPRI (4HBMLP, JUNIT)
if there are externals:   CALL TNOINF (2     , JUNIT)
                          CALL TNOPRI (4HSKMb, JUNIT)
                          CALL TNOPRI (4HSMMb, JUNIT)
                   else:  CALL TNOINF (1     , JUNIT)
                          CALL TNOPRI (4HBKLL, JUNIT)
                          CALL TNOPRI (4HBMLL, JUNIT)
```

D) CALL TNOREN (JUNIT, ILC, ISTAP, TIME)

This processor reads from tape the displacements given by program SHOCK3D at time -TIME- and at stepnumber -ISTAP-.

Book -SRC- (or -SRL-) is created and when prescribed freedoms are incorporated also book -SRP- is created. Book -SA- is needed.

The arguments are:

JUNIT = Fortran unit number
ILC = loading case number in the present ASKA - run.
ISTAP = integration stepnumber in SHOCK3D at which the displacements for loading case ILC must be taken.
TIME = time in SHOCK3D at which the displacements for loading case ILC must be taken.

Remarks: Either ISTAP or TIME should be given the proper value.

When using more loading cases one should be aware of the fact that Fortran unit JUNIT is a sequential data set so that one has to rewind the data set if one chooses an earlier time for the next loading case.

PROCESSOR	MEMBERS NEEDED	BOOKS NEEDED	BOOKS CREATED	NETS
TNOINF	IWECO	SA (SAM)	-	M,N
TNOPRI	IWECO		-	M,N
TNOREG	IWECO	SA (BKCP or BKLP) (BMCP or BMLP) SKM or BKLL (SMM or BMLL)	-	M,N
TNOREN	IWECO	SA	SRC or SRL (SRP)	M,N

4. SHOCK LOADING.

4.1. *Prescribed freedoms.*

The nodal points of the structure, as dealt with in SHOCK3D, which can be given prescribed shock motions are:

a) Nodal points of the nonlinear elements on the foundation side.
b) Nodal points of elastic substructures.

The nodal freedom numbers have to be specified.

Shock motions may be defined in four categories:

(1) Analytical shock pulse as often prescribed in naval shock specifications of several Navies (a.o. the UK, The Netherlands).
The velocity as a function of time (see fig. 4.1.1) is given by two formulas.
The first applies to the initial part of the pulse up to the time T_1 at which the maximum velocity occurs.

$$\dot{y} = \beta \frac{\dot{y}_{max}}{2} \left(1 - \cos\frac{\pi}{T_1} t\right)$$

For subsequent times, the velocity is given as

$$\dot{y} = \beta B \cos \left[2\pi f_w (t-T_1) \right] + \beta K (\dot{y}_{max} - B)\, e^{-\mu \left[\frac{2\pi}{T_2}(t-T_1) - \phi\right]} \cos\left[\frac{2\pi}{T_2}(t-T_1) - \phi\right]$$

This function is fully described by numerical values for 7 different parameters:

$X1 = \beta$ = shock level factor
$X2 = \dot{y}_{max}$ = maximum velocity [m/s]
$X3 = B$ = bodily velocity [m/s]
$X4 = f_w$ = frequency bodily motion [s^{-1}]
$X5 = T_1$ = time to max velocity [s]
$X6 = T_2$ = period of local vibration [s]
$X7 = \mu$ = damping factor

ϕ is found by applying tg $\phi = \mu$
K is found by applying $Ke^{\mu\phi} \cos\phi = 1$

A further explanation as to these pulses is beyond the scope of this manual. We refer to [16], page 5.4.

If the same set of numerical values X1 to X7 applies to several prescribed degrees of freedom they receive the same shock number and they have to be read in only once.

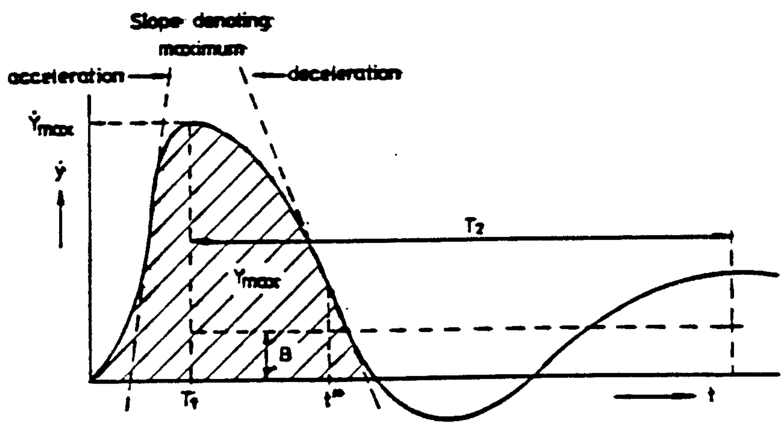

Fig. 4.1.1 Velocity as a function of time (shock).

(2) A double sine acceleration pulse, the shock spectrum of which approximates a design shock spectrum as laid down in naval shock specifications of another group of Navies (a.o. Germany [17]).

Such a design shock spectrum is composed from three straight lines:
(a) in the low frequency range a line of constant relative displacement d_o [m].
(b) in the high frequency range a line of constant absolute acceleration a_o [m/s²].
(c) in between a line of constant pseudo velocity v_o [m/s].

The double sine acceleration pulse as shown in fig. 4.1.2 is defined by four numerical values for a_2, a_4, t_1 and t_2.

If the relation with the shock design spectrum is such that

$$a_2 = 0,5\ a_o$$

$$t_1 = \frac{\pi\ v_1}{2\ a_2}$$

$$v_1 = \frac{2}{3}\ v_o = v_2$$

$$a_4 = \frac{-\pi\ v_1}{2\ t_2}$$

$$t_2 = \frac{2\ d_o}{v_1} - t_1$$

then there is a reasonable agreement between the shock design spectrum as required and the shock spectrum of the double sine pulse.

Because, normally, the design shock spectrum is given, the values
$X1 = d_o$
$X2 = v_o$
$X3 = a_o$
are used as input to define the pulse, using the above formulas.

On the other hand, if instead of the design shock spectrum, the pulse parameters a_2, t_1 and t_2 are given, the user of the program should first calculate these X-values by using the following formulas:

$$X1 = d_o = \frac{a_2\ t_1}{\pi}\ (t_1 + t_2)$$

$$X2 = v_o = \frac{3a_2\ t_1}{\pi}$$

$$X3 = a_o = 2a_2$$

Please note that here again it is assumed that the pulse velocity is zero at $t_1 + t_2$.
So the acceleration a_4 must satisfy the relation

$$a_4 = \frac{-t_1}{t_2}\ a_2$$

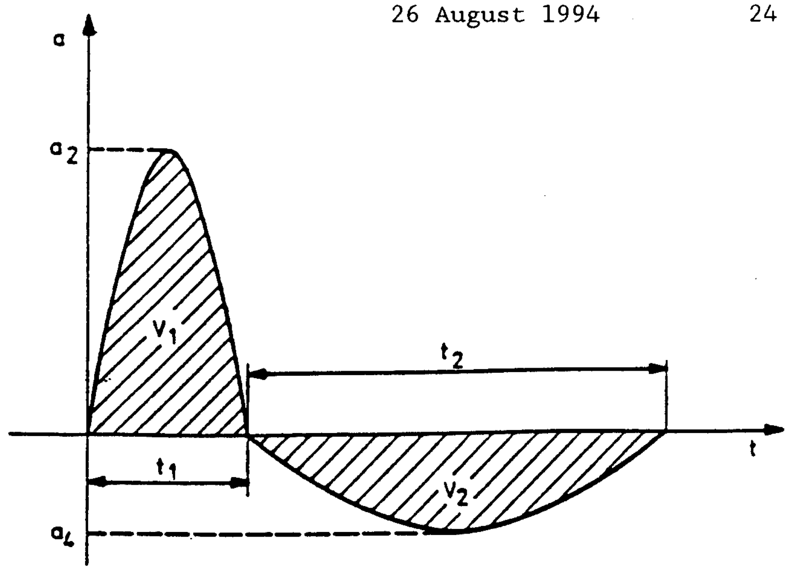

Fig. 4.1.2 Acceleration as a function of time (schock)

Note: to make a distinction between the pulses as specified in category (1) (fig 4.1.1) and category (2) (fig 4.1.2) in the detailed input description (chapter 6) the word "shock" is used for category (1) and the word "schock" is used for category (2).

(3) The prescribed freedom has zero-values for its displacement, velocity and acceleration. This option is used when the motion of a foundation has to be suppressed.

(4) The prescribed freedom is a digitised time history of the displacement, the velocity or the acceleration. Such a signal may have been divided into a number of subsequent sections, each having a different sampling rate. For each section should be specified: the number of values in the section, the time at the beginning, the timestep, a multiplication factor for the values, and the values themselves. The division into sections facilitates the input of shock motions which often are very irregular at the beginning, needing a higher sampling rate than later on when the high frequency content disappears by damping. The multiplication factor makes it possible to read in digitised values on an arbitrary scale. If the same time history applies to several prescribed freedoms they receive the same signal number and have to be read in only once. When solving numerically the differential equations, excitation values are interpolated linearly. When one of the histories (displacement, velocity or acceleration) is being read in, the other two are determined as well by numerical integration and/or differentation.

4.2. *Prescribed forces.*

The nodal points of the structure, as dealt with in SHOCK3D, on which prescribed forces and moments may act are:

a) nodal points of the elastic substructure.

b) nodal points representing the centres of gravity of the rigid bodies.

The nodal freedom numbers have to be specified. A prescribed force may be given as a digitised time history in the same way as was described in the previous section for a prescribed freedom. It is also possible to specify the prescribed forces as analytical functions of time. To use this option subroutine FORFUN has to be rewritten by the user in such a way that the relation between time and prescribed force is incorporated.

5. SOLUTION OF THE DIFFERENTIAL EQUATIONS.

5.1. *The equations.*

A first set of equations concerns the elastic substructure(s). For each substructure we have for the master degrees of freedom the following equations (see section 3.4.)

$$K_{MM}\ r_M + M_{MM}\ \ddot{r}_M = (T^T K_{LP} - K_{CP})\ r_P + (T^T M_{LP} - M_{CP})\ \ddot{r}_P + R_C$$

All matrices are known as well as the prescribed freedoms r_p. The load vector R_C combines the directly prescribed forces and the forces transmitted by the nonlinear elements. The second set of equations concerns the equilibrium of the rigid bodies. For each rigid body we have 6 equations for the 6 freedoms of the centre of gravity.

$$M\ddot{q} = F$$

The loading vector F combines the directly prescribed forces and the forces transmitted by the nonlinear elements.

5.2. *Initial conditions.*

In most practical problems at time t = 0 all displacements and velocities are zero. The program provides however an option to specify non-zero values for displacements and/or velocities at the time t = 0.

5.3. *Integration procedures.*

There are two options:

1) The equations of motion are solved numerically with the explicit "Fourth Order Runge Kutta" formulas. This method has been used as well in the previous programs as mentioned in the introduction. It is described for instance in [9] and [10].

2) The equations of motion are solved using a second order extrapolation. This additional option, added by VAN VUGT, is described in [21]. The calculations per time step are less extensive than for the Runge-Kutta method. The results however are less accurate.
   The second order extrapolation is recommended in particular for an initial survey of the shock response of large models, whereas the final results should be based on the Runge-Kutta integration method.

Attention should be paid to the definition of time step (or stepsize) h as it is used in the present program. In previous programs the number of samples per second should be specified: NSASEC.
The relation is given by

$$\frac{1}{NSASEC} = \tfrac{1}{2}\,h.$$

The total number of steps must be specified. Output may be asked for every n steps. There is a restart possibility when data belonging to the last time step has been written to tape.

5.4. *Stability of the solution.*

A disadvantage of these explicit direct integration methods is that the solution can become unstable when the time step h is not small enough. To be on the safe side the time step h should not exceed 1/10 of the period of the higher vibration mode as present in the model [11] . There is some good experience however with a time step of only 1/5 of that period [12]. In fact vibration modes should be calculated on forehand in order to estimate the time step.

This was done in a previous program [5] where the eigenvalue problem was solved for the structure with the non-linear elements having their stiffest position. SHOCK3D does not present this option. It is possible however to solve eigenvalue problems with separate ASKA-runs.
When no eigenvalues are being calculated, it is recommended to run SHOCK3D twice with different time steps in order to detect any instabilities if present. In order to limit computer costs specially for the larger problems one should choose the time step as large as possible. Having in mind that anyhow the highest vibration modes as present in the model, are not reliable, the model should be composed in such a way that extremely high natural frequencies are absent. This is the case when very stiff parts of the structure are treated as rigid bodies. The master degrees of freedom should be chosen carefully and scarce in parts with a high stiffness and a small mass. As mentioned in section 3.4. prescribed degrees of freedom may be coupled to local degrees of freedom.

6. DETAILED INPUT DESCRIPTION.

6.1. *File input.*

The file input for program SHOCK3D consists of four parts: title line, parameter lines, model data lines and lines for mass, stiffness and/or initial velocities input.
Each part, except the first one, consist of a number of header lines, each of which may be followed by a prescribed number of continuation lines.
Each header line has a special meaning which is given by an alphanumeric name in columns 2 until 10. Column 1 is filled with an asterisk (*) and in the columns 11 until 80 a number of integers (format 14I5) may be given to set some variable(s), or to switch on some option(s).
When necessary the continuation line(s) give(s) the input belonging to the specific option given in the header line. When an option is not chosen or the default option is used, no input for this option is required.
The order in which the header lines are read in is free. The only requirements are:

a) first line is the title line
b) title line is followed by the parameter lines which end with the *END PARAM line.
c) parameter lines are followed by the model data lines which end with the *CONTINUE line.
d) input is finished with the mass, stiffness and initial velocity lines which end with the *END DATA line.

Each group of lines may appear more than once in the input deck. Depending on the contents the first information is overwritten or extended with the latter.

6.1.1. *Title line.*

The first line contains the title of the problem that has to be analyzed. The full line length (80 columns) can be used for this title.

6.1.2. *Parameter lines.*

The parameter lines are used to switch on certain options and to determine the size of the problem. Each parameter line starts with an asterisk (*) in column 1. Columns 2 until 10 contain the name of the chosen option while in the columns 11 until 80 a number of integers (Format 14I5) may be read in. Some parameter lines have a number of continuation lines which contain additional information. The continuation lines are format free; the variables have to be separated by at least one space. When a certain option is not used one does not have to use the corresponding parameter line.

a) Name : *ASKANETS
Integers : NASKA, JDIAG
Meaning : NASKA is the number of ASKA substructures in the problem.
JDIAG = 0 mass matrix of ASKA substructures is read in from input file (see 6.1.4.) and is a diagonal matrix.
JDIAG = 1 mass matrix of ASKA substructures is packed symmeric, is read in from tape and assembled within ASKA
Cont.lines: NASKA
Contents : K, NFDASK(K), NPDASK(K), NODASK(K)
Meaning : K is the number of the ASKA substructure.
NFDASK(K) is the number of external*) freedoms in substruct.K
NPDASK(K) is the number of prescribed freedoms in substruct.K
NODASK(K) is the number of nodal points in substructure K which contain external*) and/or prescribed freedoms.
Remark*) : If there are no external freedoms, external should be replaced by local.

b) Name : *RIGBOD
Integers : NBODY
Meaning : NBODY is the number of rigid bodies in the problem.
Cont.lines: NBODY
Contents : K, NODBOD(K)
Meaning : K is the number of the rigid body.
NODBOD(K) is the total number of nodal points of the rigid body K.

c) Name : *NONLIN
Integers : NEL (NEL $\neq$ 0)
Meaning : NEL is the number of nonlinear elements in the problem.
Cont.lines: None

d) Name : *SPRINGS
Integers : NSPRI
Meaning : NSPRI is the number of **different** springs in the problem.
Cont.lines: None

e) Name : *NODPOINTS
Integers : NP
Meaning : NP is the number of nodal points
Cont.lines: None

f) Name : *PRESCRIBE
Integers : NPRES
Meaning : NPRES is the number of freedoms which have a prescribed shock motion.
Cont.lines: None

g) Name : *SHOCKS
Integers : NSHOCK
Meaning : NSHOCK is the number of analytical naval shock functions (of category (1)) with different parameter values.
Cont.lines: None.

h) Name : *SCHOCKS
Integers : NSHOCK
Meaning : NSHOCK is the number of analytical naval shock functions (of category (2)) with different parameter values.
Note : Only one of the parameter cards *SCHOCKS and *SHOCKS can be present.

i) Name : *NODFORCE
Integers : NFORC
Meaning : NFORC is the number of freedoms on which a prescribed external point load is acting.
Cont.lines: None

j) Name : *SIGNALS
Integers : NSPRS, NSFOR
Meaning : NSPRS is the number of different tabulated signals presenting a prescribed freedom.
NSFOR is the number of different tabulated signals presenting an external force.
Cont.lines: None

k) Name : *SUPPRESS
Integers : NSUPP
Meaning : NSUPP is the number of freedoms belonging to rigid bodies which are suppressed (e.g. due to symmetry)

Cont.lines: None

l) Name : *INTPROC
Integers : NTPR
Meaning : INTPR is the number of the integration procedure.
INTPR = 1 Runge-Kutta
INTPR = 2 Second Order Extrapolation method.
Cont.lines: None

m) Name : *SOLUTION
Integers : None
Cont.lines: 1
Contents : NSTAP, TIME, STAP
Meaning : NSTAP is the number of time steps in the integrationprocedure.
TIME is the time at the start of integration.
STAP is the time step

n) Name : *END PARAMETERS
Integers : None
Meaning : The input of the parameter lines is completed.

6.1.3. *Model data lines.*

The model data lines are used to define the calculation model. The lines are divided in a number of groups, each of which consists of a header line followed if necessary by a number of continuation lines. Each header line starts with an asterisk (*) in column one. Column 2 until 10 contain the name of the group while in the columns 11 until 80 a number of integers (format 14 I 5) may be read in.

a) Group to read in data of an ASKA substructure.

Name : *ASKANETS
Integers : K, ITAP
Meaning : K is the number of the substructure for which the following information is valid.
Default value is 1.
ITAP is the number of the tape to read in the stiffness and/or mass matrices and other ASKA information.
Input file = 5.

Cont.lines	: 2
Contents line 1	: ISLV1 (i), i = 1, NODASK(K) (See parameter line * ASKANETS)
Meaning	: ISLVI (i) is the nodal point number as used in SHOCK3D
Contents line 2	: ISLV2 (i), i = 1, NODASK(K)
Meaning	: ISLV2 (i) is the nodal point number as used in ASKA
Remark	: If ITAP is default and the ASKA output information is read from lines, these should be inserted here. Otherwise the output from ASKA is read in from file ITAP at this stage of the job.

b) Line to rewind a tape.

Name	: *REWIND
Integer	: ITAP
Meaning	: At this stage of the input, tape ITAP is rewinded.
Cont. lines	: None

c) Group to read in data of a rigid body.

Name	: *RIGBOD
Integer	: K
Meaning	: K is the number of the rigid body for which the following information is valid. Default value is 1.
Cont. lines	: 2
Contents line 1	: ISLV (i), i = 1, NODBOD(K) (See parameter line *RIGBOD)
Meaning	: ISLV (i) is the nodal point number i of this rigid body. (ISLV(1) is the number of the centre of gravity)
Contents line 2	: XM, IX, IY, IZ
Meaning	: XM is the mass of this rigid body*) IX is the moment of inertia around x-axis*) IY is the moment of inertia around y-axis*) IZ is the moment of inertia around z-axis*) *) ALways non zero values must be specified.

d) <u>Group to read in data of non-linear elements.</u>

Name : *NONLIN
Integers : None
Cont. lines : NEL (see parameter line *NONLIN)
Contents : N, NP(1), NP(2), NP(3), IX, IY, IZ
Meaning : N is element number

NP(1), NP(2), NP(3): three nodal points of element N

IX is the spring number*) in local x-direction
IY is the spring number*) in local y-direction
IZ is the spring number*) in local z-direction
*) Zero, when no spring present.

e) <u>Group to read in spring information</u>.

Name : *SPRINGS
Integers : None
Cont. lines : 3 x NSPRI
Contents line 1 : N, IC, NT
Meaning : N is spring number
IC is spring type
NT is number of coefficients Cj (for spring types 1, -1, 2, -2, 5, -5; meaningless for spring type 3,4).
Contents line 2 : X1, X2, X3.
Meaning : X1 is K (spring type 1, -1, 2, -2)
is C (spring type 3, 4)
is F1 (spring type 5, -5)
X2 is $\overline{K}$ (spring type 1, -1, 2, -2
is $\overline{F}$ (spring type 3, 4)
is F2 (spring type 5, -5)
X3 is meaningless (spring type 1, -1)
is b (spring type 2, -2, 5, -5)
is meaningless (spring type 3)
is d (spring type 4)
Contents line 3 : (CC (j), j = 1, NN)
NN = NT for spring types 1, 2, 5.
= 2 x NT for spring types -1, -2, -5.
Line 3 is not used for spring types 3 or 4.
Meaning : CC(j) = coefficient Cj (spring type 1, 2 or 5)

CC(1) = dl for spring type -1
= dl-b for spring type -2, -5
CC(2) = dF/dΔl for spring type -1
= dF/d(Δl-b) for spring type -2, -5
Etc. until CC (2xNT-1) and CC (2xNT)

Note : In case the spring type number is negative, SHOCK3D calculates the coefficients Cj. In the print output (see section 7.1) only these coefficients Cj are mentioned and not the tangential stiffnesses and corresponding compressions. Consequently also the minus sign for the spring type number is then deleted in the print output.

f) <u>Group to read in nodal point coordinates</u>.

Name	: *COORD
Integers	: NNI
Meaning	: NNI is the number of nodal points for which coordinates have to be read in. Nodal points of substructures, not connected to non linear elements can be excluded.
Cont.lines	: NNI
Contents	: N, X, Y, Z.
Meaning	: N is the nodal point number X, Y, Z are the coordinates of N

g) <u>Group to read in prescribed freedom information.</u>

Name	: *PRESCRIBE
Integers	: None
Cont.lines	: NPRES (see parameter line *PRESCRIBE)
Contents	: N, INOD, IFRD, INUM
Meaning	: N is continuation number. INOD is nodal point number. IFRD is nodal freedom number (1, 2, 3, 4, 5 or 6). INUM > 0 prescribed values are given by shock number INUM. INUM = 0 prescribed values are zero INUM < 0 prescribed values are given by signal number INUM.

h) Group to read in category (1) shock information.

Name   : *SHOCKS
Integers   : None
Cont.lines: NSHOCK (see parameter line *SHOCKS)
Contents   : INUM, X1, X2, X3, X4, X5, X6, X7
Meaning   : INUM is the shock number
X1, X2, X3, X4, X5, X6, X7 } Coefficients of the analytical naval shock function, category (1)

i) Group to read in category (2) shock information.

Name   : *SCHOCKS
Integers   : None
Cont.lines: NSHOCK (see parameter line *SCHOCKS)
Contents   : INUM, X1, X2, X3
Meaning   : INUM is the shock number
XI, X2, X3 } Coefficients of the analytical naval shock function, category (2)

j) Group to read in prescribed force information.

Name   : *NODFORCE
Integers   : None
Cont.lines: NFORC (see parameter line *NODFORCE)
Contents   : N, INOD, IFRD, INUM
Meaning   : N is the continuation number.
INOD is the nodal point number
IFRD is the nodal freedom number.
INUM >0 prescribed values are given by force function INUM, which is defined by the user-subroutine FORFUN
INUM <0 prescribed values are given by signal number -INUM.

k) Group to read in a tabulated signal.

Name	: *SIGNALS
Integers	: INUM, NTRAJ, IC
Meaning	: INUM is the number of the signal NTRAJ is the number of sections to read in this signal IC = 0 signal for prescribed force = 1 signal for prescribed displacement = 2 signal for prescribed velocity = 3 signal for prescribed acceleration
Cont.lines	: 2 x NTRAJ
Contents line 1	: NVAL, STV, DTV, FAC
Meaning	: NVAL is the number of values in this section STV is the time at the beginning of the section DTV is the timestep in the section FAC is a multiplication factor for this section.
Contents line 2	: (VAL(j), j = 1, NVAL)
Meaning	: VAL(j) is value of the signal at time STV + (j-1) x DTV

l) Group to read in suppressed freedom information.

Name	: *SUPPRESS
Integers	: None
Cont. lines	: NSUPP (see parameter line *SUPPRESS)
Contents	: N, INOD, IFRD
Meaning	: N is the continuation number INOD is the nodal point number IFRD is the nodal freedom number 1, 2, 3, 4, 5, 6
Remark	: this option is only used to suppress freedoms of rigid bodies.

m) Group to control print output.

Name	: *OUTPUT
Integers	: None
Cont. lines	: 1
Contents	: NOUT
Meaning	: output is given every NOUT integration steps

n) Group to control plot output.

Name	: *PLOT
Integers	: None
Cont. lines	: 1
Contents	: NPLOT.
Meaning	: information for plot program TECPLOT is written every NPLOT integration steps.

o) Group to control restarts.

Name	: *RESTART
Integers	: None
Cont. lines	: 1
Contents	: IREST1, NREST1, IREST2, NREST2.
Meaning	: Restart information is written on tape IREST2 every NREST2 integration steps (only when IREST1 not equals zero). A restart is made at integration step NREST1 from tape IREST1 (only when IREST2 not equals zero).

p) Group to control ASKA post-processing output.

Name	: *TAPEASKA
Integers	: None
Cont.lines	: 1
Contents	: NTAPE, (ITAPE(j), j = 1, NASKA) (see parameter line *ASKANETS)
Meaning	: The displacements belonging to the local, external and/or prescribed freedoms of ASKA-structure j are written to tape ITAPE (j) every NTAPE integration steps.

q) Line to close model data input.

Name	: *CONTINUE
Integers	: None
Meaning	: This line gives control back to the main driver routine HEADER.

6.1.4. *Mass-, stiffness- and/or initial velocity input.*

This is additional information to read in a diagonal mass matrix for the ASKA substructures and/or to change some mass- or stiffness terms of these substructures. Furthermore the user has the opportunity to define initial displacements and/or velocities.

a) Group to read in mass terms.

Name	: *MASS
Integers	: K, ICARD
Meaning	: K is the number of the ASKA substructure ICARD is the number of mass terms to be read in
Cont.lines	: ICARD
Contents	: a) if diagonal mass matrix is applied (see parameter line *ASKANETS) : INOD, IFRD, VAL. b) if a full mass matrix is applied (see parameter line *ASKANETS) : INODI, IFRD1, INOD2, IFRD2, VAL.
Meaning	: INOD is the nodal point number as used in SHOCK3D. IFRD is the nodal freedom number VAL is the mass term to be inserted in the mass matrix. INOD1 is the column nodal point number IFRD1 is the column nodal freedom number. INOD2 is the row nodal point number. IFRD2 is the row nodal freedom number. VAL is the mass term to be added to the mass matrix.
Remark	: Symmetric terms must be read in only once.

b) Group to read in stiffness terms.

Name	: *STIFFNESS
Integers	: K, ICARD
Meaning	: K is the number of the ASKA substructure ICARD is the number of stiffness terms to be read in.
Cont.lines	: ICARD
Contents	: INOD1, IFRD1, INOD2, IFRD2, VAL.
Meaning	: INOD1 is the column nodal point number IFRD1 is the column nodal freedom number INOD2 is the row nodal point number. IFRD2 is the row nodal freedom number.

	VAL is the stiffness term to be added to the stiffness matrix.
Remark	: Symmetric terms must be read in only once.

c) Group to read in initial velocities or displacements.

Name	: *INITIAL
Integers	: ISORT, ICARD
Meaning	: ISORT = 0 initial velocity input = 1 initial displacement input. ICARD is the number of freedoms for which an initial velocity or displacement (different from zero) is read in.
Cont.lines	: ICARD
Contents	: INOD, IFRD, VAL
Meaning	: INOD is the nodal point number IFRD is the nodal freedom number VAL is the initial velocity or displacement.

d) Line to close file input.

Name	: *END DATA
Integers	: None
Meaning	: This line terminates line input. All lines following this one are not read in by program SHOCK3D.

6.2. *Tape input.*

Tape input may consist of two parts. The first part is the information given by the ASKA-processor TNOREG (see section 3.4.1.). The second part is the restart input, which is produced in an earlier run by program SHOCK3D itself.

6.2.1. *ASKA-output as input for SHOCK3D.*

As mentioned this input is produced by ASKA-processor TNOREG. It can also be read in from an input file. The contents of the tape consists of:

a) A list of prescribed freedoms (node number and nodal freedom number) if present.
b) Book - BKCP - or - BKLP - if present.
c) Book - BMCP - or - BMLP - if present.
d) A list of external or local freedoms (node number and nodal freedom number).
e) Book - SKM - or - BKLL -.
f) Book - SMM - or - BMLL - if present .

If a tape is used for this input all information is available in unformatted FORTRAN records. Real numbers are given in double precision.

6.3. *Restart input.*

This input is produced in an earlier run of program SHOCK3D and can only be read in from a tape. The contents of the tape consists of:

a) Stepnumber and time.
b) Displacements and velocities of the non-prescribed freedoms.
c) Accumulated clearance of spring types 3 and 4.

7. DETAILED OUTPUT DESCRIPTION.

The output of program SHOCK3D consists of four parts:
a) print output.
b) output to be processed by ASKA.
c) output to be processed by plotprogram TECPLOT.
d) output for restart jobs with program SHOCK3D itself.

7.1. *Print output.*

The first two pages of the print output contain the program name and the title of the job. The second part of the print output gives information about the model and about the options used. The last part of the print output gives the solution at the times **desired** by the user through option *OUTPUT This part of the output consists of:
a) compression of the non-linear elements.
b) forces in the non-linear elements.
c) prescribed freedoms.
d) prescribed forces.
e) shock response.

All pages have a page heading with the title of the job, time of solution and page number.
An example of a part of the print output is given in section 9.1.

7.2. *Output to be processed by ASKA.*

It is possible to calculate with the displacements at a certain time the stresses, strains and/or reaction forces in the elastic structure. To do so we use program ASKA, so it must be able to write the displacements to a file and read them in with ASKA-processor TNOREN.

The output given by SHOCK3D to accomplish this consists of:
a) time and stepnumber.
b) displacements of the ASKA-freedoms.

This output is given for each ASKA-structure at each desired step at the file(s) given in the line input. For different substructures different files have to be used.

7.3. *Output to be processed by SH3DPOST.*

In order to make plots with the aid of the plotting program TECPLOT [15] a separate program SH3DPOST will postprocess the output of the program SHOCK3D.
In case plots are requested SHOCK3D generates 5 outputfiles viz.
- element.out (non-linear element response),
- prfreed.out (prescribed freedom information),
- prforce.out (prescribed force information),
- shrespt.out (nodal point response, translation),
- shrespr.out (nodal point response, rotation).

These files contain as time histories the input motions and/or input forces and as well as the response of the mountings (the non-linear elements) and all motions of the nodal points as defined in SHOCK3D. Much more than usually is of interest for plotting.
With the aid of SH3DPOST that information can be extracted wich is needed for plotting, e.g. for specific non-linear elements or for specific nodal points.
All response data can be plotted as time histories. In addition, the load -deflection curves of the non-linear elements in their local directions, as occurring during the analysis, can be plotted as well.
Motions of the nodal points can be shown as a displacement, a velocity or an acceleration, either in the global x-, y- of z-direction.
These choices are to be made with the aid of a control file as input for SH3DPOST (as described on the next page).

The postprocessing program will be started by typing SH3DPOST followed by <ENTER> ; then the user will be asked for the name of the above mentioned control file.

The program SH3DPOST will generate 5 plotfiles in TECPLOT format viz. :
- element.dat
- prfreed.dat
- prforce.dat
- shrespt.dat
- shrespr.dat

Control file for SH3DPOST

An example of the control file for the program SH3DPOST is given below.

```
2                          ! number of non-linear elements
3   1 1 0   1 0 0   0 0 1 ! elem.nr | th c cv | x'y'z'| e d t |
7   1 1 0   1 0 0   0 0 1 !         |         |       |       |

2                          ! number of shock input motions
1   0 1 0                  ! INUM    | d v a |
2   0 1 0                  !         |       |

3                          ! number of shock input forces
2                          ! INUM
3                          !
1                          !

4                          ! number of nodal points (translation)
2   0 1 1   1 0 0          ! nod.point nr.| d v a | x y z |
6   0 1 0   1 0 0          !              |       |       |
5   0 1 0   1 1 1          !              |       |       |
8   0 1 0   1 0 0          !              |       |       |

1                          ! number of nodal points (rotation)
8   0 1 0   0 0 1          ! nod.point nr.| d v a | x y z |
```

Elucidation to the control file for the program SH3DPOST.

There are always 5 data blocks in this file having the sequence as shown.
All input figures are integers separated by at least one space.
But for the first column, all input figures are either "zero" or "one".
The meaning of 0 resp. 1, is that a certain type of plot is not, resp. is required. So 0 means disabled and 1 means enabled.
There is one exception in the first data block, where in the second column the meaning of 0 and 1 is a bit different. There 1 means a time history plot and 0 means a load deflection plot.
With one line, information for several plots may be extracted.
The sequence of the element numbers or the nodal point numbers is arbitrary.
All information after the exclamation mark will be considered as comment.

Concise description :

First line : number of different non-linear elements for wich plotting is required. [1]

New line for **each** element containing the following items :
- element number
- choice of time-history plot (=1) or load-deflection plot (=0)
- choice of compression of the non-linear element
- choice of compression-velocity of the non-linear element
- choice of local x'-direction
- choice of local y'-direction
- choice of local z'-direction
- choice of elastic force
- choice of damping force
- choice of total force

Next line : number of different shock input motions which must be plotted.[1]

New line for **each** prescribed motion containing the following items :
- number of the prescribed motion (INUM = shock number)
- choice of displacement
- choice of velocity
- choice of acceleration

Next line : number of different shock input forces which must be plotted.[1]

New line for **each** prescribed force containing the following items :
- number of the prescribed force (INUM = shock number)

Next line : number of nodal points for wich plotting is required (translation).[1]

New line for **each** nodal point containing the following items :
- nodal point number in SHOCK3D
- choice of displacement
- choice of velocity
- choice of acceleration
- choice of translation in global x-direction
- choice of translation in global y-direction
- choice of translation in global z-direction

---

[1] In case this number is zero the next lines of this block can be ignored.

Next line : number of nodal points for wich plotting is required (rotations).[1)]

New line for **each** nodal point containing the following items :

- nodal point number in SHOCK3D
- choice of angular rotation
- choice of angular velocity
- choice of angular acceleration
- choice of rotation around the global x-axis
- choice of rotation around the global y-axis
- choice of rotation around the global z-axis

7.4. *Restart output.*

In order to be able to continue a calculation after analysing the first part or to continue it after changing the time step a restart feature has been built in program SHOCK3D. The restart tape contains:

a) stepnumber and time.

b) displacements and velocities of non-prescribed freedoms.

c) Accumulated clearance of spring types 3 and 4.

8. PC-VERSION OF SHOCK3D.

Appendix B presents the information on running a shortened version of SHOCK3D on a personal computer (PC).

This shortened version does not include modelling of flexible bodies, as there is no possibility to run the finite element program ASKA on a PC. However all other options remain and for a first orientation of the shock response of a system composed from rigid bodies only, the shortened version is considered a valuable tool.
In those cases where the equipment installed is stiff as compared to it's mounting system, such simplified calculations are often considered to be sufficient as a final analysis.

The detailed input description for SHOCK3D (and for SH3DPOST), as described in chapter 6 (and chapter 7.3) remains valid for the PC-version.

However the input should not contain :

- parameterlines	*ASKANETS
- model data lines	*ASKANETS
	*TAPEASKA
- mass and stiffness terms	*MASS
	*STIFFNESS

The reader may skip chapter 3.4 on linear elastic structures.
But in all other respects the SHOCK3D manual may be used, taking into account the appendix B.

9. TEST PROBLEMS.

Information about the size of the problems, the number of nonlinear elements, rigid bodies, etc. has been summarized in table 1. In fact it contains nearly the same information as the parameter lines (section 6.1.2).
The first version of the SHOCK3D manual [18] included a description of, and results for, 6 different test problems (numbered 1-6), at that time being run at a CYBER 175 computer at ECN, Petten and on the IBM 370/158 at the Delft University.
After a few years SHOCK3D was installed on the VAX computer of TNO-IWECO. When running these same test problems on the VAX, the same shock response results were found. For 5 of the 6 test problems the print outpunt of these VAX-runs was still available.
Recently the same test problems as well as a new test problem (no 7) were used on the IRIS computer now available at TNO-CMC.
For the old test problems, using both the first version and the present version of SHOCK3D, the same results were obtained as on the VAX computer. Table 2 presents a survey of the run numbers, denoted to these test runs on various computers.

PARTICULARS		TEST PROBLEM											
		1	2	3	4	5	6	7	2b				
Number of ASKA substructures		1	0	0	1	2	0	0	0				
Diagonal mass matrices, user defined		x				x							
Mass matrices, assembled by ASKA					x								
Substr. 1	Number of external d.o.f.	41			56/23	2							
	Number of prescribed d.o.f.	0			12	0							
	Number of nodal points containing external and/or prescribed d.o.f.	41			35	2							
Substr. 2	Number of external d.o.f.					3							
	Number of prescribed d.o.f.					0							
	Number of nodal points containing external and/or prescribed d.o.f.					3							
Number of rigid bodies			1	1	1	2	1	1	1				
Number of nodal points in rigid body 1			4	3	8	1	2	2	4				
Number of nodal points in rigid body 2							1						
Number of nonlinear elements		4	2	2	7	4	1	2	2				
Number of different springs		1	2	2	7	2	1	2	2				
Number of nodal points		49	8	7	45	9	4	4	8				
Number of prescribed freedoms		4	4	2	13	0	1	1	4				
Number of category (1) shock functions with different parameter values		1	2	1	1	0	0	1	0				
Number of category (2) shock functions with different parameter values		0	0	0	0	0	0	0	2				

Table 1

PARTICULARS	TEST PROBLEM											
	1	2	3	4	5	6	7	2b				
Number of freedoms on which an external point load is acting	0	0	0	0	0	1	0	0				
Number of different tabulated signals presenting a prescribed freedom	0	0	0	0	0	1	0	0				
Number of different tabulated signals presenting an external force	0	0	0	0	0	1	0	0				
Number of suppressed rigid body freedoms		0	0	1	0	0	5	0				
Number of time steps	250	500	500	500/ 260	100	37	200					
Time step (milliseconds)	0.02	0.2	0.2	0.02/- 0.1	1	0.2	0.5	0.2				
Integration proc. Runge-Kutta	x	x	x	x	x	x	x	x				
Integration proc. Second order extrapolation		x	x		x	x						
Dimension	2	2	1	3	1	1	1	2				
Non-zero initial conditions					x							
Spring type 1			x	x	x							
Spring type 2			x		x	x						
Spring type 3		x						x				
Spring type 4	x	x						x				
Spring type 5							x					
Restart	x											
Plot output	x						x					
Feed-back to ASKA	x			x								

Table 1 continued

SHOCK 3D VERSION	COMPUTER	YEAR	TEST PROBLEM							
			1	2	3	4	5	6	7	2b
1	IBM 370/158	1978	28			23 26				
1	CYBER 175	1978		16	18		30	32		
1	VAX	1980	45	40	41		42	43		
1	IRIS	1993		1	2		3	4		
2.0	IRIS	1993	27	17	19	28	29	23	25	26
run no [ref] for comparison			[13]	15	17	[14]	-	31		

Table 2 Administrative information of various run numbers.

9.1. *Testproblem 1.*

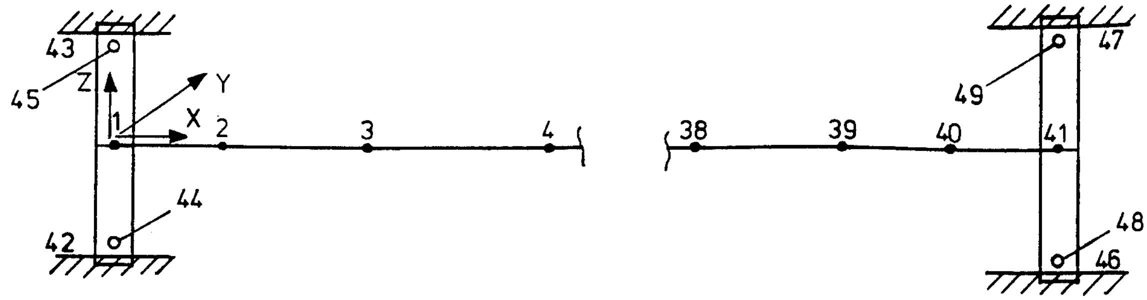

Fig. 9.1.1

The structure is a single beam, consisting of 40 elements with different stiffnesses against bending and shear and 41 nodal points with lumped masses. By means of four nonlinear elements the structure is connected to foundations.

These elements only contain in their main direction the spring type 4. The four foundations are following the same prescribed analytical naval pulse in z-direction.

This is the test problem as originally distributed by the former Naval Construction Research Establishment of the Royal Navy (UK). All numerical data are given in two Iweco-memo's [12] [13]. They also contain the shock response as obtained with the former program [5]. The beam has now been considered as an ASKA substructure. The nodal freedom numbers 3 have been chosen as external degrees of freedom. The ASKA processors are shown on the upper half of page 54 (run 2). A listing of the SHOCK3D input (run 28) is shown on page 55 and 56.

Pages 57 to 59 are a copy of a part of the print-output of SHOCK3D (run 28). The input data is shown, as well as the response at t = 5 ms.

From previous calculations it was known that the highest natural frequency is 7467 Hz. A time step h was chosen of 0,02 ms, which is about 1/7 of the smallest period T.

The differences in the response as obtained with SHOCK3D and as obtained previously [13] are extremely small.

For instance after 250 time steps the differences in nodal point velocities are less than 0,1%.

Results in the form of displacements at t = 2,6 ms have been fed back into ASKA. The processorlist (run 4) is shown on the lower part of page 54. The bending moments and shear forces so obtained agree very well with those obtained in [13].

Results have been postprocessed by the program SH3DPOST and plotted by the program TECPLOT.
Fig. 9.1.2 shows the velocity of nodal point 1 and fig. 9.1.3 shows the force transmission by the nonlinear element 1. These graphs can directly be compared with those in [13]. Page 61 shows the input data for the postprocessing program SH3DPOST. This problem 1 has also been used to test the restart option (run 5).

```
C ASKA APC PROGRAM TESTPROBLEM 1 (a)
C
      CALL START(1,1)
      CALL SA
      CALL INFEL
      CALL INFUNK
      CALL DATIN(0,4HEOF )
      CALL ELCO
      CALL SK
      CALL BK
      CALL INFBK
      CALL TRIA
      CALL BTLC
      CALL SKM
      CALL TNOREG(20)
      END
```

```
C ASKA APC PROGRAM TESTPROBLEM 1 (b)
C
      CALL START(1,1)
      CALL SA
      CALL DATIN(0,4HEOF )
      CALL ELCO
      CALL SK
      CALL BK
      CALL TRIA
      CALL BTLC
      CALL SKM
      CALL TNOREN(21,1,130,.00260)
      CALL SRLC
      CALL USR
      CALL DATEX(0,4HUSR )
      CALL SP
      CALL ST
      CALL SIGEX(0,0)
      CALL BP
      CALL BRR
      CALL REAK
      CALL DATEX(0,4HREAK)
      END
```

```
TESTPROBLEM 1 SHOCK3D
*ASKANETS      1    0
    1   41   0   41
*NONLIN        4
*NODPOINTS    49
*SPRINGS       1
*SHOCKS        1
*PRESCRIBE     4
*INTPROC       1
*SOLUTION
250    0.        .00002
*END PARAM
*NONLIN
 1   42    1   44    1    0    0
 2   43    1   45    1    0    0
 3   46   41   48    1    0    0
 4   47   41   49    1    0    0
*COORD        10
 1   0.        0.        0.
41   1.462     0.        0.
42   0.        0.       -2.
43   0.        0.        2.
44   0.        2.       -2.
45   0.       -2.        2.
46   1.462     0.       -2.
47   1.462     0.        2.
48   1.462     2.       -2.
49   1.462    -2.        2.
*PRESCRIBE
1    42    3    1
2    43    3    1
3    46    3    1
4    47    3    1
*ASKANETS      1    20
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
    21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
    21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41
*OUTPUT
5
*TAPEASKA
10   21
*PLOT
1
*SPRINGS
1    4    0
390000000.    300000.    .00075
*SHOCKS
1  1.0  3.962  .361  6.666666  .00055  .0026  .2
*CONTINUE
```

```
*MASS          1   41
        1   3  1.35
        2   3  2.7
        3   3  5.45
        4   3  8.2
        5   3  8.2
        6   3  8.2
        7   3  14.9
        8   3  21.6
        9   3  21.6
       10   3  21.6
       11   3  21.6
       12   3  21.6
       13   3  21.6
       14   3  21.6
       15   3  16.05
       16   3  10.5
       17   3  10.5
       18   3  10.5
       19   3  12.75
       20   3  15.0
       21   3  15.0
       22   3  15.0
       23   3  12.3
       24   3  9.65
       25   3  9.65
       26   3  9.65
       27   3  9.65
       28   3  9.65
       29   3  9.65
       30   3  9.65
       31   3  13.5
       32   3  17.37
       33   3  17.37
       34   3  17.37
       35   3  13.42
       36   3  9.45
       37   3  9.45
       38   3  9.45
       39   3  6.19
       40   3  2.95
       41   3  1.47
 *END DATA
```

TESTPROBLEM 1 SHOCK3D

MODELPARAMETERS

ASKA SUBSTRUCTURES	1
NON LINEAR ELEMENTS	4
RIGID BODIES	0
NODAL POINTS	49
DIFFERENT SPRINGS	1
DIFFERENT SHOCKS	1
PRESCRIBED FREEDOMS	4
SUPPRESSED FREEDOMS	0
NODAL FORCES	0

ASKA SUBSTRUCTURE 1

NODAL POINT NUMBERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41																			

CORRESPONDING ASKA NUMBERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41																			

NON-LINEAR ELEMENT INFORMATION

ELNO	NP 1	NP 2	NP 3	SPRING X	SPRING Y	SPRING Z
1	42	1	44	1	0	0
2	43	1	45	1	0	0
3	46	41	48	1	0	0
4	47	41	49	1	0	0

NODAL POINT COORDINATES

NPNO	COORD X	COORD Y	COORD Z
1	0.0000D+00	0.0000D+00	0.0000D+00
2	0.0000D+00	0.0000D+00	0.0000D+00
3	0.0000D+00	0.0000D+00	0.0000D+00
|	|	|	|
39	0.0000D+00	0.0000D+00	0.0000D+00
40	0.0000D+00	0.0000D+00	0.0000D+00
41	0.1462D+01	0.0000D+00	0.0000D+00
42	0.0000D+00	0.0000D+00	-0.2000D+01
43	0.0000D+00	0.0000D+00	0.2000D+01
44	0.0000D+00	0.2000D+01	-0.2000D+01
45	0.0000D+00	-0.2000D+01	0.2000D+01
46	0.1462D+01	0.0000D+00	-0.2000D+01
47	0.1462D+01	0.0000D+00	0.2000D+01
48	0.1462D+01	0.2000D+01	-0.2000D+01
49	0.1462D+01	-0.2000D+01	0.2000D+01

SPRING INPUT INFORMATION

SPRING	TYPE	NT	XK	XKS	B	CC(I)
			F1	F2	B	CC(I)
			C	FV	D	
1	4	0	0.3900E+09	0.3000E+06	0.7500E-03	

SHOCK INPUT INFORMATION

SHOCK	BETA	YPMAX	B	FRW	T1	T2	XMU
1	0.1000D+01	0.3962D+01	0.3610D+00	0.6667D+01	0.5500D-03	0.2600D-02	0.2000D+00

PRESCRIBED FREEDOMS

NO.	NP	FRD	SHOCK NO
1	42	3	1
2	43	3	1
3	46	3	1
4	47	3	1

INTEGRATION PROCEDURE

FOURTH ORDER RUNGA KUTTA WITH CONSTANT STEPSIZE
TIME AT START OF INTEGRATION 0.000D+00
STEPSIZE 0.200D-04
NUMBER OF STEPS 250

INPUT/OUTPUT PARAMETERS

PRINT OUTPUT EVERY 5 STEPS
ASKA TAPE OUTPUT EVERY 10 STEPS ON FILE(S) 1

DIAGONAL MASS MATRIX ASKA SUBSTRUCTURE 1

EXTERNAL	NODE	FREEDOM	MASS
1	1	3	0.13500D+01
2	2	3	0.27000D+01
3	3	3	0.54500D+01
4	4	3	0.82000D+01
5	5	3	0.82000D+01
6	6	3	0.82000D+01
7	7	3	0.14900D+02
8	8	3	0.21600D+02
9	9	3	0.21600D+02
10	10	3	0.21600D+02
11	11	3	0.21600D+02
12	12	3	0.21600D+02
13	13	3	0.21600D+02
14	14	3	0.21600D+02
15	15	3	0.16050D+02
16	16	3	0.10500D+02
17	17	3	0.10500D+02
18	18	3	0.10500D+02
19	19	3	0.12750D+02
20	20	3	0.15000D+02
21	21	3	0.15000D+02
22	22	3	0.15000D+02
23	23	3	0.12300D+02
24	24	3	0.96500D+01
25	25	3	0.96500D+01
26	26	3	0.96500D+01
27	27	3	0.96500D+01
28	28	3	0.96500D+01
29	29	3	0.96500D+01
30	30	3	0.96500D+01
31	31	3	0.13500D+02
32	32	3	0.17370D+02
33	33	3	0.17370D+02
34	34	3	0.17370D+02
35	35	3	0.13420D+02
36	36	3	0.94500D+01
37	37	3	0.94500D+01
38	38	3	0.94500D+01
39	39	3	0.61900D+01
40	40	3	0.29500D+01
41	41	3	0.14700D+01

ELONGATIONS OF THE NON-LINEAR ELEMENTS (LOCAL DIRECTIONS) AT TIME=0.500D-02

EL.NO.	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	COMPRESSION	COMPRESSION VEL	COMPRESSION	COMPRESSION VEL	COMPRESSION	COMPRESSION VEL
1	-0.60349E-03	-0.42225E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	0.60349E-03	0.42225E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	-0.10415E-02	-0.12163E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
4	0.10415E-02	0.12163E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

FORCES IN THE NON-LINEAR ELEMENTS (LOCAL DIRECTIONS) AT TIME=0.500D-02

EL.NO.	X-DIRECTION			Y-DIRECTION			Z-DIRECTION		
	ELASTIC	DAMPING	TOTAL	ELASTIC	DAMPING	TOTAL	ELASTIC	DAMPING	TOTAL
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
4	0.1137E+06	0.0000E+00	0.1137E+06	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

PRESCRIBED FREEDOMS (GLOBAL DIRECTIONS) AT TIME=0.500D-02

NODE	FREEDOM	SHOCK	DISPLACEMENT	VELOCITY	ACCELERATION
42	3	1	0.31203E-02	0.17305E+00	0.10200E+04
43	3	1	0.31203E-02	0.17305E+00	0.10200E+04
46	3	1	0.31203E-02	0.17305E+00	0.10200E+04
47	3	1	0.31203E-02	0.17305E+00	0.10200E+04

SHOCK RESPONSE (GLOBAL DIRECTIONS) AT TIME=0.500D-02

T R A N S L A T I O N S

NODE	X-DIRECTION			Y-DIRECTION			Z-DIRECTION		
	DISPLACEMENT	VELOCITY	ACCELERATION	DISPLACEMENT	VELOCITY	ACCELERATION	DISPLACEMENT	VELOCITY	ACCELERATION
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3724E-02	0.4396E+01	0.1014E+04
2	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3695E-02	0.3530E+01	-0.8423E+04
3	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3653E-02	0.3508E+01	0.1247E+05
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3652E-02	0.3579E+01	0.7318E+04
5	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3686E-02	0.3266E+01	-0.2546E+04
6	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3671E-02	0.2871E+01	0.1101E+04
7	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3657E-02	0.2311E+01	0.4573E+04
8	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3659E-02	0.1705E+01	-0.2879E+04
9	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3639E-02	0.9790E+00	-0.9282E+04
10	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3575E-02	0.2832E-01	-0.1339E+05
11	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3440E-02	-0.5522E+00	-0.7529E+03
12	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3301E-02	-0.7327E+00	0.5710E+04
13	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3192E-02	-0.3122E+00	0.6340E+04
14	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3080E-02	0.1190E+01	0.5176E+04
15	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3018E-02	0.1462E+01	-0.3724E+04
16	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2942E-02	0.1295E+01	0.9815E+02
17	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2873E-02	0.1319E+01	0.7648E+04
18	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2848E-02	0.1836E+01	0.4777E+04
19	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2848E-02	0.2438E+01	-0.3316E+04
20	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2842E-02	0.2465E+01	-0.3339E+04
21	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2828E-02	0.2228E+01	0.1761E+04
22	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2832E-02	0.1826E+01	0.1825E+02
23	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2846E-02	0.1379E+01	0.1100E+04
24	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2877E-02	0.1332E+01	-0.1472E+03
25	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2917E-02	0.1300E+01	-0.1257E+04
26	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.2957E-02	0.1022E+01	0.2287E+04
27	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3011E-02	0.5884E+00	0.8597E+04
28	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3095E-02	0.1746E+00	0.1142E+05
29	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3215E-02	-0.2343E+00	0.8169E+04
30	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3388E-02	-0.7284E+00	0.2084E+04
31	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3573E-02	-0.9239E+00	-0.3324E+03
32	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3765E-02	-0.2682E+00	-0.1757E+04
33	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.3942E-02	0.6965E+00	-0.1003E+05
34	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4036E-02	0.1382E+01	-0.5543E+04
35	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4104E-02	0.2147E+01	-0.1452E+04
36	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4166E-02	0.2875E+01	-0.4903E+04
37	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4215E-02	0.3271E+01	-0.5459E+04
38	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4187E-02	0.2949E+01	0.1395E+05
39	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4231E-02	0.3482E+01	-0.1152E+05
40	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4218E-02	0.2526E+01	-0.1928E+05
41	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.4162E-02	0.1389E+01	0.1263E+05

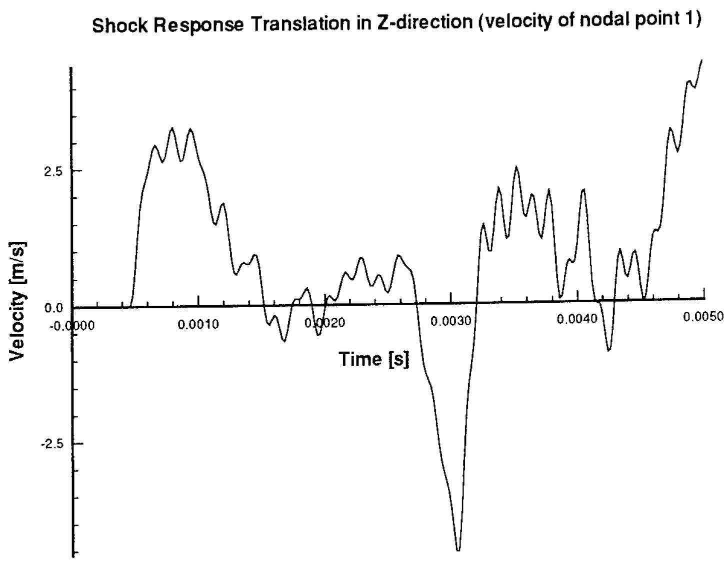

fig. 9.1.2

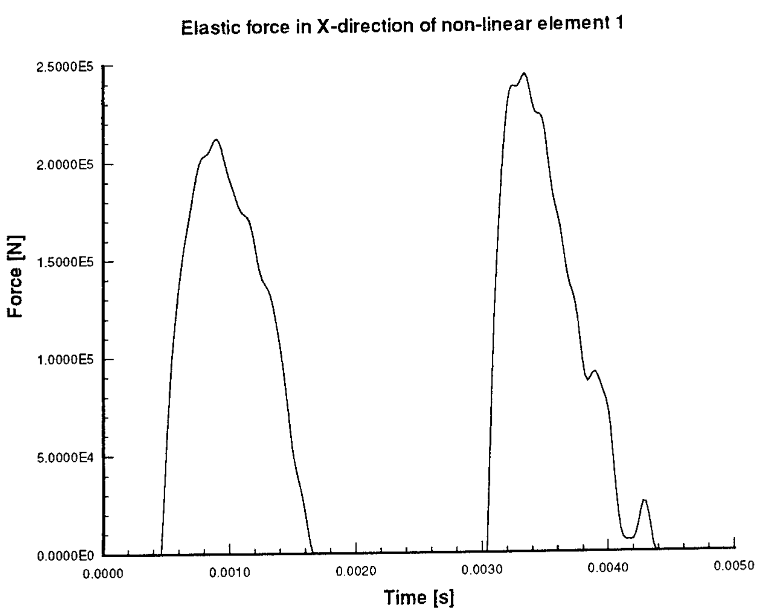

fig. 9.1.3

Input postprocessing program SH3DPOST

```
1                        ! number of non-linear elements
1  1 0 0  1 0 0  1 0 0   ! elem.nr | th c cv | x y z | e d t |

0                        ! number of shock input motions

0                        ! number of shock input forces

1                        ! number of nodal points (translation)
1  0 1 0  0 0 1          ! node nr | d v a | x y z |

0                        ! number of nodal points (rotation)
```

9.2. *Testproblem 2.*

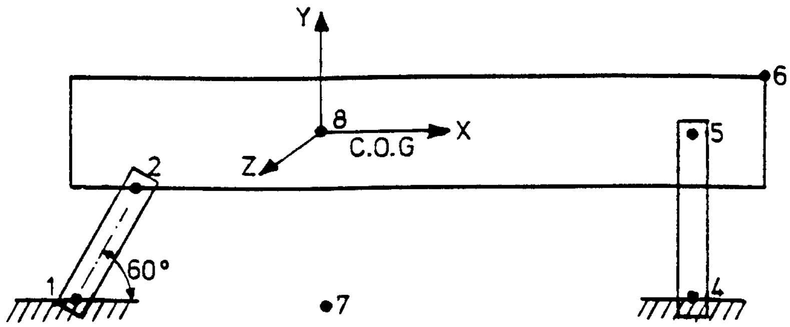

Fig. 9.2.1

A single rigid body is supported by two nonlinear elements. Spring type 3 lies in the direction between nodal points 1 and 2. Spring type 4 is in the direction perpendicular to spring type 3 as well as in the direction between nodal point 4 and 5. There are two analytical naval shock functions with different parameters. The first one applies to the x-direction of both foundations and the second one to the y-direction of both foundations. The printed response results (run 16) have been compared with the results as obtained with another computer program [3] (run 15) which can handle this simple system. No differences in response have been found.

9.3. *Testproblem 3.*

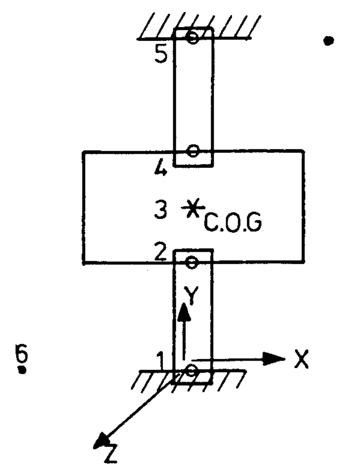

Fig. 9.3.1

A single rigid body is supported by two nonlinear elements. Spring type-2 lies in the direction between the nodal points 1 and 2. Spring type 1 lies in the direction between the nodal points 4 and 5. For spring type -2 six combinations of Δl-b and $\frac{dF}{d(\Delta l - b)}$ have been read in.

A single analytical naval shock function has been defined for the y-direction of the foundations. The printed response results (run 18) have again been compared with the results as obtained with another computer program [3] (run 17). No differences have been found.

9.4. *Testproblem 4.*

This practical problem has been defined and solved a few years ago [14]. It concerns the shock response of a flexible deck of a ship on which is resiliently mounted a common frame with electronic cabinets. Considering the mountings as linear the problem then has been solved completely with the ASKA computer program. The common frame was considered as a rigid body.
The shock response was obtained by first solving the eigen value problem and then adding the response of only the first 20 natural modes (frequency of mode no 20: 464 HZ).
The same structure with the same numerical data has been analyzed with SHOCK3D. The lower part of figure 9.4.1 shows a top view of the port side of the deck (the vertical plane through the centreline of the ship is a plane of symmetry.). The upper part shows a vertical cross section through the deck and the common frame. The deck itself has been considered as an elastic substructure for which mass and stiffness matrices have been obtained with ASKA.
The common frame is considered as a rigid body which is connected by 6 nonlinear elements to the deck. The 7th nonlinear element representing the topsteadies between the cabinets and the bulkhead lies between nodal points 44 and 36 (a foundation). This last point as well as the nodal points 1, 2, 3, 6, 10, 14, 16, 19, 23, 27, 31, 33 and 36 all follow the same prescribed naval shock pulse in the upward vertical direction.

Initially in the ASKA run 19 the rather large number of 56 external degrees of freedom has been chosen in order to avoid the coupling between prescribed and local degrees of freedom. Rather high natural frequencies must have been present in that system, because SHOCK3D run 20, with a stepsize of 0,1 ms, resulted in an unstable solution. Runs 21 and 23 with stepsizes of 0,02 ms and run 22 with a stepsize of 0,004 ms resulted in stable solutions with no mutual response differences.

At that stage it was decided to introduce the possibility of coupling prescribed with local degrees of freedom as described in section 3.4. As a result only 23 external degrees of freedom remained. Page 66 shows the ASKA processors as used in run 24. The SHOCK3D run 26 with a stepsize again of 0,1 ms now produced stable results. The pages 67, 68 and 69 show a copy of the input data for this run.

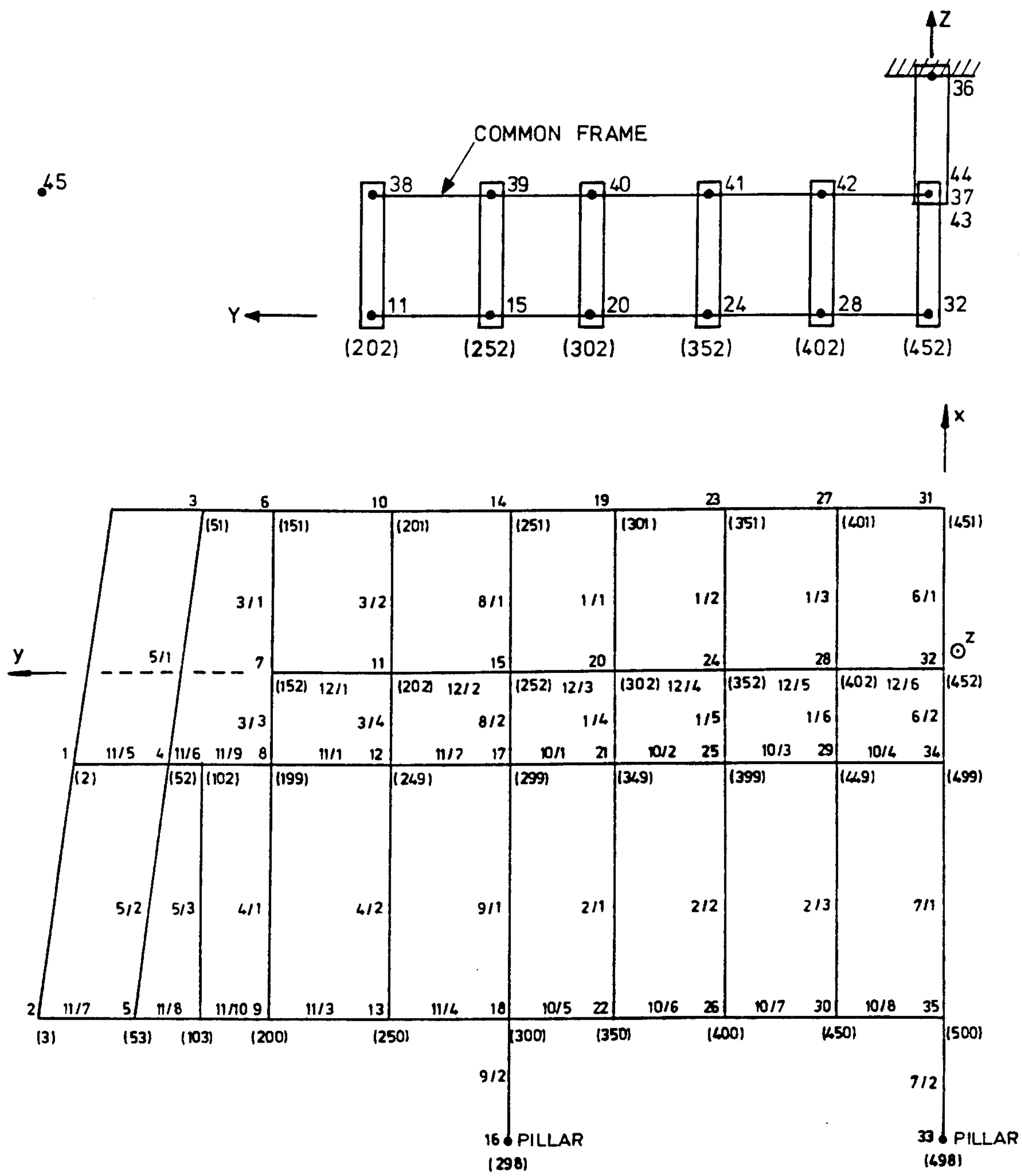

Fig. 9.4.1

11/7 element no. 7 of element group no. 11
9 nodal point no SHOCK3D
(200) nodal point no in ASKA substructure

```
C**** ASKA APC PROGRAM TESTPROBLEM 4 (a)
      CALL START(2,1)
      CALL SET(4HBASE,2)
      CALL SA
      CALL SAVCON(20)
      CALL SAVBUK(20,4HSA  )
      CALL SAVBUK(20,4HSB  )
      CALL INFEL
      CALL INFUNK
      CALL DATIN(0,4HEOF )
      CALL ELCO
      CALL SAVBUK(20,4HELDA)
      CALL TS
      CALL SK
      CALL SAVBUK(20,4HSK  )
      CALL BK
      CALL INFBK
      CALL GPRINT(4HBKCP,1)
      CALL GPRINT(4HBKLP,1)
      CALL SAVBUK(20,4HBKLP)
      CALL SM
      CALL BM
      CALL INFBM
      CALL GPRINT(4HBMCP,1)
      CALL TRIA
      CALL SAVBUK(20,4HBKTR)
      CALL BTLC
      CALL SAVBUK(20,4HBTLC)
      CALL SKM
      CALL GPRINT(4HSKM ,1)
      CALL BT
      CALL CONDM
      CALL GPRINT(4HSMM ,1)
      CALL GPRINT(4HBMLP,1)
      CALL MULTH(4HBT  ,4HBKLP,4HBKCP,-1,2,1)
      CALL GPRINT(4HBKCP,1)
      CALL MULTH(4HBT  ,4HBMLP,4HBMCP,-1,2,1)
      CALL GPRINT(4HBMCP,1)
      REWIND 20
      CALL TNOREG(21)
      CALL TNOREG(99)
      END
```

```
TESTPROBLEM 4 SHOCK3D
*ASKANETS      1    1
      1  23  12    35
*NONLIN        7
*RIGBOD        1
      1   8
*NODPOINTS    45
*SPRINGS       7
*SHOCKS        1
*PRESCRIBE    13
*INTPROC       1
*SOLUTION
500   0.        .0001
*SUPPRESS      1
*END PARAM
*ASKANETS      1   21
  1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
 19  20  21  22  23  24  25  26  27  28  29  30  31  32  33  34  35
  2   3  51  52  53 151 152 199 200 201 202 249 250 251 252 298 299 300
301 302 349 350 351 352 399 400 401 402 449 450 451 452 498 499 500
*NONLIN
 1   11   38   45    1    0    0
 2   15   39   45    2    0    0
 3   40   20   45    3    0    0
 4   24   41   45    4    0    0
 5   28   42   45    5    0    0
 6   32   43   45    6    0    0
 7   36   44   45    7    0    0
*RIGBOD        1
     37   38   39   40   41   42   43   44
  1900.        1.        1.        1.
*COORD        16
11   0.        3.0       0.
15   0.        2.4       0.
20   0.        1.8       0.
24   0.        1.2       0.
28   0.        0.6       0.
32   0.        0.        0.
36   0.        0.         .2
37   0.        0.         .1
38   0.        3.0        .1
39   0.        2.4        .1
```

```
40   0.      1.8     .1
41   0.      1.2     .1
42   0.      0.6     .1
43   0.      0.      .1
44   0.      0.      .1
45   0.      5.      .1
*SPRINGS
1    1    1
0.   0.   0.
553500.
2    1    1
0.   0.   0.
445500.
3    1    1
0.   0.   0.
666000.
4    1    1
0.   0.   0.
740250.
5    1    1
0.   0.   0.
594000.
6    1    1
0.   0.   0.
150750.
7    1    1
0.   0.   0.
612500.
*SHOCKS
1  0.4  9.15  1.0   0.6666   0.0032  0.024   .5
*PRESCRIBE
1     1    3    1
2     2    3    1
3     3    3    1
4     6    3    1
5    10    3    1
6    14    3    1
7    19    3    1
8    23    3    1
9    27    3    1
10   31    3    1
11   16    3    1
```

```
12   33   3   1
13   36   3   1
*OUTPUT
20
*TAPEASKA
4    22
*PLOT
0
*SUPPRESS
1    37   4
*CONTINUE
*END DATA
```

Table 3 shows for some nodal points of interest the displacements, as obtained:

a) first column, run 23, 56 external degrees of freedom.

b) second column, run 26, 23 external degrees of freedom.

c) third column, [14], completely with ASKA.

There are only minor differences between the results of both SHOCK3D runs 23 and 26. There are some differences however with the original results [14] . Such differences are not surprising because the two solution techniques are different. In the original case the responses of only the first 20 natural modes have been added (dynamic condensation) whereas in the present case the equations have been solved numerically. The displacements as obtained with SHOCK3D run 26 at t = 8 ms and at t = 20 ms have been fed back to the ASKA computer program in order to calculate bending moments, shear forces, etc ., in the ship's deck. A copy of the ASKA processors for this run is shown on page 71.

t [ms]	Displacements of nodal points [mm]																				
	11			15			20			24			28			32			RIGID BODY		
	*	**	***																		
2	0,11		-0,15	0,44		0,04	0,21		-0,14	0,20		-0,11	0,19		-0,17	0,45		0,21	0,002		0,001
4	1,59		1,23	1,507		-0,35	1,72		1,12	1,87		1,21	2,04		1,34	2,18		1,29	0,06		0,04
6	4,88		4,75	2,99		-0,17	1,91		0,94	2,88		2,30	3,88		2,91	4,81		3,47	0,34		0,30
8	9,69		9,55	7,26		3,52	4,18		2,85	3,57		2,23	5,33		3,98	6,43		4,78	1,04		0,95
10	16,82	16,85	17,09	15,46	15,41	11,41	12,97	12,98	12,18	10,41	10,45	9,79	8,01	7,76	6,61	7,89	7,61	5,83	2,40	2,33	2,24
20		27,7	27,9		31,08	27,3		35,58	35,0		41,38	41,2		44,83	43,9		45,44	44,0		3,34	3,32
30		24,1	24,2		19,5	14,6		14,03	12,7		9,67	8,73		6,79	5,27		5,43	3,19		11,72	11,71

* run 23; ** run 36; *** [14]

Table 3

```
C**** ASKA APC PROGRAM TESTPROBLEM 4 (b)
C
      CALL START(2,1)
      CALL SET(4HBASE,1)
      CALL SA
      CALL DATIN(0,4HEOF )
      CALL ELCO
      CALL TS
      CALL SK
      CALL BK
      CALL TRIA
      CALL BTLC
      CALL TNOREN(22,1,80,0.008)
      CALL TNOREN(22,2,200,0.020)
      CALL BRLP
      CALL FWSB
      CALL SRLC
      CALL USR
      CALL DATEX(0,4HUSR )
      CALL SP
      CALL ST
      CALL SIGEX(0,0)
      CALL BP
      CALL BRR
      CALL REAK
      CALL DATEX(0,4HREAK)
      STOP
      END
```

9.5. *Testproblem 5.*

This problem concerns the one-dimensional structure as shown in fig. 9.5.1. In fact it is a long spring with a constant stiffness along it's length and equal lumped masses at the nodal points 2 to 8. It is composed from rigid bodies and ASKA substructures interconnected by nonlinear elements having spring type 1 in the main direction (constant stiffness). Spring type 2 transmitting only compression forces and having a zero clearance b, lies between nodal points 1 and 2.
The ASKA substructures are being built from flange elements.

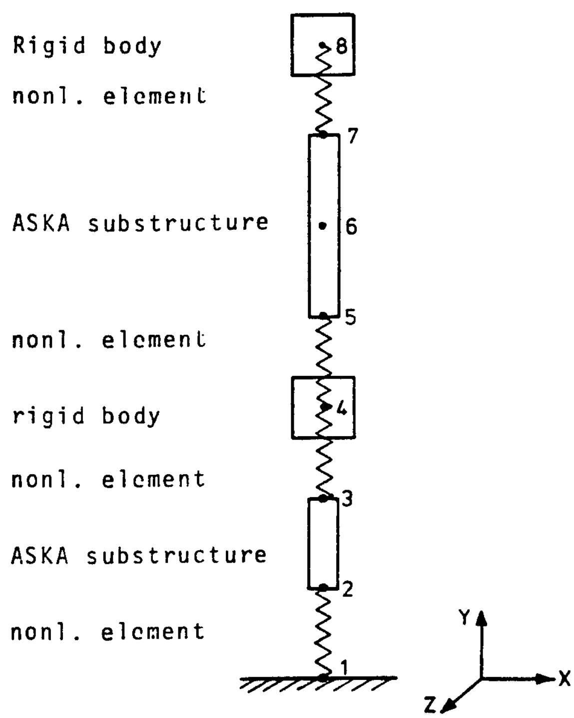

Fig. 9.5.1

The initial conditions are such that at t = 0 the displacements of the nodal points 2 to 8 are zero and the velocities of these nodal points are 5 m/s in the -y-direction. The motion of the foundation has been suppressed. So in fact the calculation starts at the moment the free falling structure touches the foundation. The next two pages show the ASKA processors and the input data for SHOCK3D. Some of the results of run no. 30 are shown graphically in fig. 9.5.2. For this structure no comparable calculations were available. The results however seem to be quite reliable.

```
C**** ASKA APC PROGRAM TESTPROBLEM 5
      CALL START(1,1)
      DO 10 I=1,2
      CALL SET(4HBASE,2)
      CALL SA
      CALL INFEL
      CALL INFUNK
      CALL DATIN(0,4HEOF )
      CALL ELCO
      CALL SK
      CALL BK
      CALL INFBK
      CALL GPRINT(4HBKLL,1)
      CALL TNOREG(20)
      CALL TNOREG(99)
   10 CONTINUE
      END
```

```
TESTPROBLEM 5 SHOCK3D
*ASKANETS       2    0
       1    2   0    2
       2    3   0    3
*NONLIN         4
*RIGBOD         2
       1    1
       2    1
*SPRINGS        2
*PRESCRIBE      1
*NODPOINTS      9
*INTPROC        1
*SOLUTION
 38     0.         .001
*END PARAM
*NONLIN
 1     1     2     9     1     0     0
 2     3     4     9     2     0     0
 3     4     5     9     2     0     0
 4     7     8     9     2     0     0
*COORD          9
 1    0.         0.0        0.
 2    0.         0.1        0.
 3    0.         0.2        0.
 4    0.         0.3        0.
 5    0.         0.4        0.
 6    0.         0.5        0.
```

```
 7    0.          0.6         0.
 8    0.          0.7         0.
 9    1.          0.0         0.
*PRESCRIBE
1      1     2     0
*ASKANETS       1    20
 2  3
 2  1
*ASKANETS       2    20
 5  6  7
 3  2  1
*SPRINGS
1     2     1
0.    0.    0.
2.E6
2     1     1
0.    0.    0.
2.E6
*RIGBOD         1
      4
    10.         1.          1.         1.
*RIGBOD         2
      8
    10.         1.          1.         1.
*OUTPUT
2
*PLOT
1  2
*CONTINUE
*MASS           1     2
2  2   10.
3  2   10.
*MASS           2     3
5  2   10.
6  2   10.
7  2   10.
*INITIAL        0     7
2  2  -5.0
3  2  -5.0
4  2  -5.0
5  2  -5.0
6  2  -5.0
7  2  -5.0
8  2  -5.0
*END DATA
```

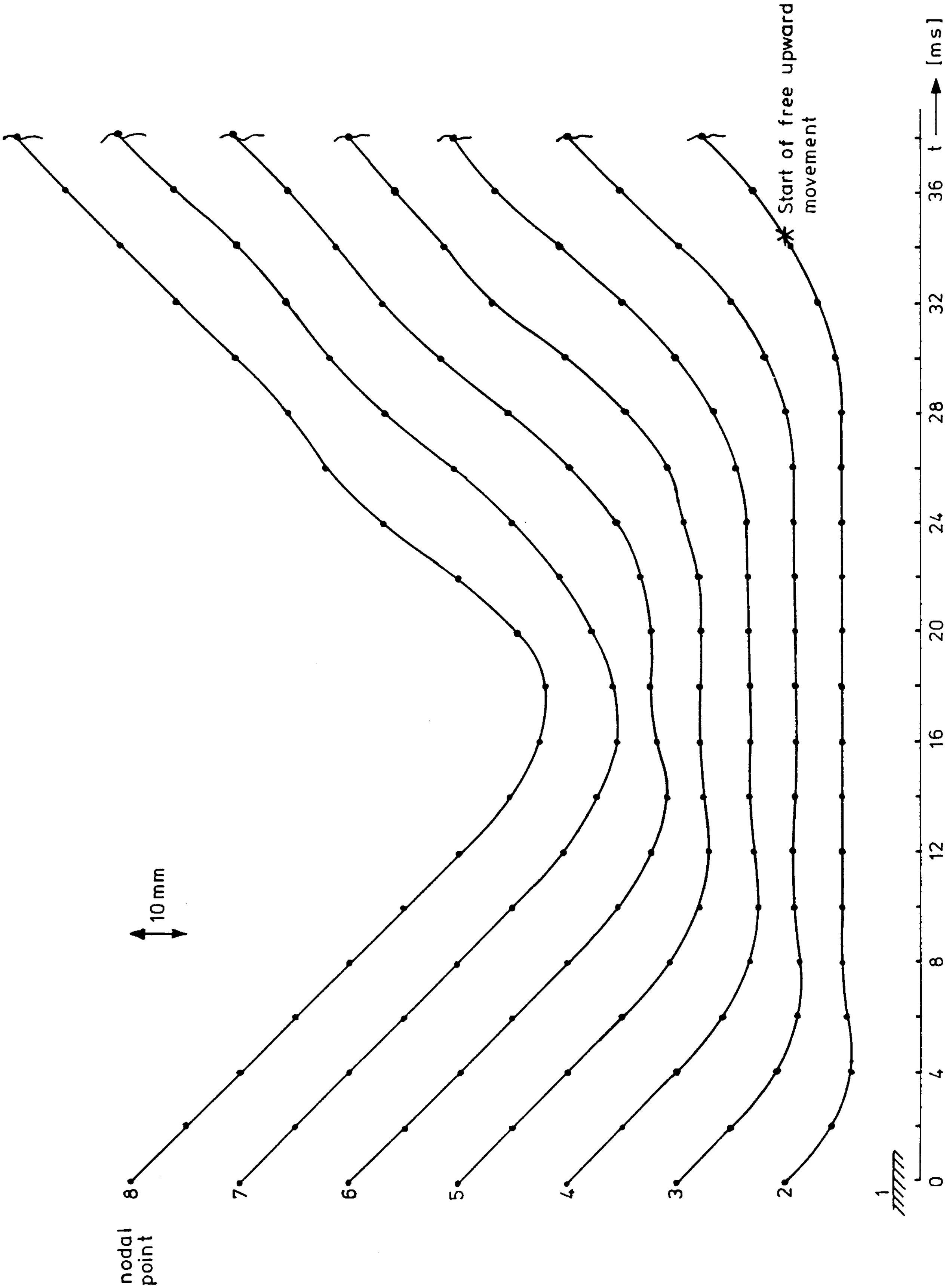

Fig. 9.5.2. Nodal point displacements as a function of time.

9.6. *Testproblem 6.*

The structure is the same as in testproblem 3, but for the upper nonlinear element which has now been deleted. First of all testproblem 3 was run once more, now with print output every 0,2 ms. This run (no 31) resulted a.o. in acceleration values for the motion of the foundation (nodal point 1) and in values for the force transmitted by the upper nonlinear element. Both these tabulated signals have been used as input for testproblem no 6. The acceleration signal has been divided into two sections. The next two pages show all input data for run no 32. The response showed a good agreement with that of run no 31.

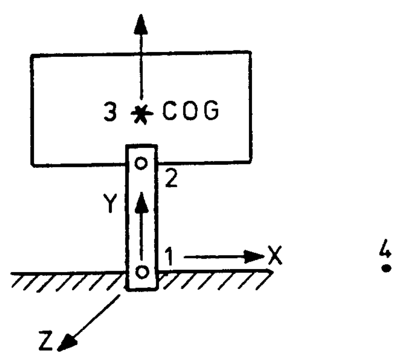

Fig. 9.6.1

```
TESTPROBLEM 6 SHOCK3D
*RIGBOD        1
1    2
*NONLIN        1
*SPRINGS       1
*NODPOINTS     4
*PRESCRIBE     1
*NODFORCE      1
*SIGNALS       1    1
*INTPROC       1
*SOLUTION
37   .0        .0002
*END PARAM
*RIGBOD
3    2
10000.         1.        1.         10.
*NONLIN
1    1    2    4    1    0    0
*SPRINGS
1   -2    6
5000.               10000.                    .002
0.              .6046E8       .0024       .6711E8
 .0048          .8041E8       .0072       .13301E9
 .0096          .24184E9      .0120       .68319E9
*COORD         4
1   0.          0.          0.
2   0.          10.         0.
3   0.          10.75       0.
4  10.          0.          0.
*PRESCRIBE
1    1    2    -1
*NODFORCE
1    3    2    -1
```

```
*SIGNALS      1     2     3
20   .0        .0002  10.0
    .0      16.54    32.651    47.917    61.942   74.362   84.857   93.154
  99.038   102.36   103.03    101.02     96.408   89.295   79.868   68.374
  55.108    40.415   24.676     8.2968
10  .0038      .0004   1.0
  82.968   -26.894  -60.339   -91.004  -118.88  -144.0   -166.37  -186.06
-203.12   -217.63
*SIGNALS      1     1     0
38   .0        .0002  10.0
    .0      2.2224  11.21      30.51     63.67   114.1    184.7    278.0
 395.9     539.1    707.8     900.9     1116.    1352.    1603.    1865.
2135.0    2407.0   2676.     2938.     3191.    3440.    3687.    3930.
4170.     4406.    4639.     4866.     5089.    5307.    5520.    5726.
5927.     6121.    6309.     6490.     6663.    6829.
*OUTPUT
1
*CONTINUE
*END DATA
```

9.7. *Testproblem 7.*

Testproblem 7 was recently added to the existing range of testproblems to see if the spring with Coulomb damping (type 5 and -5) behaved well.

It is a simple single degree of freedom system as shown in fig. 9.7.1 with two nonlinear elements in parallel between the nodal points 1 and 2. Spring type -5 is in the main direction of nonlinear element 2.
Next page shows a copy of the input data whereas the load deflection curve of the nonlinear element is in fig. 9.7.2. The velocity both of the input and of the mass is as shown in fig. 9.7.3.

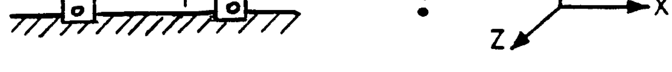

Fig. 9.7.1

```
TESTPROBLEM 7  SHOCK3D  (Coulomb damping)
*RIGBOD        1
1    2
*NONLIN        2
*SPRINGS       2
*NODPOINTS     4
*PRESCRIBE     1
*SHOCKS        1
*SUPPRESS      5
*SOLUTION
1000    0.0    0.0001
*INTPROC       1
*END PARAM
*RIGBOD        1
3   2
1000.0  1.0  1.0  1.0
*NONLIN
1  1  2  4  1  0  0
2  1  2  4  2  0  0
*SPRINGS
1  1  1
0.0  0.0
5.0E6
2  -5  2
1.0E4  -2.0E4  0.01
0.0  2.0E6  0.03  8.0E6
*COORD         4
1  0.0  0.0  0.0
2  0.0  1.0   0.0
3  0.0  2.0  0.0
4  1.0  0.0  0.0
*PRESCRIBE
1  1  2  1
*SHOCKS
1  0.6  4.95  1.0  1.3  0.0083  0.035  0.2
*SUPPRESS
1  3  1
2  3  3
3  3  4
4  3  5
5  3  6
*OUTPUT
20
*PLOT
1
*CONTINUE
*END DATA
```

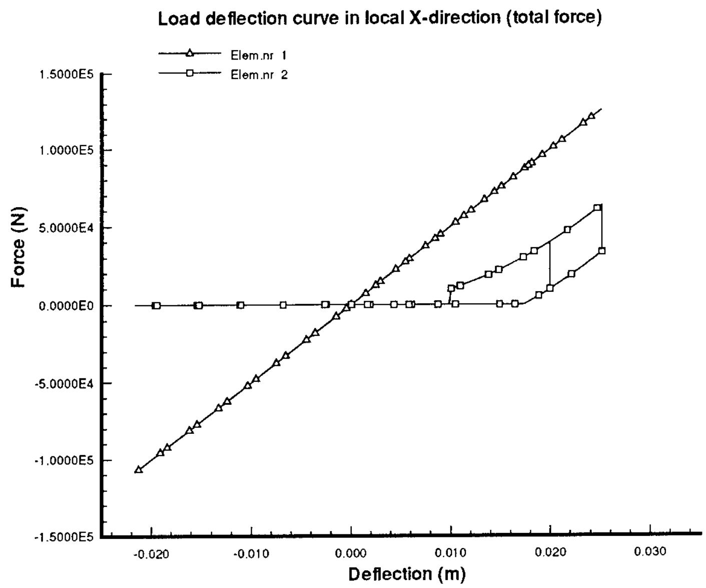

Figure 9.7.2

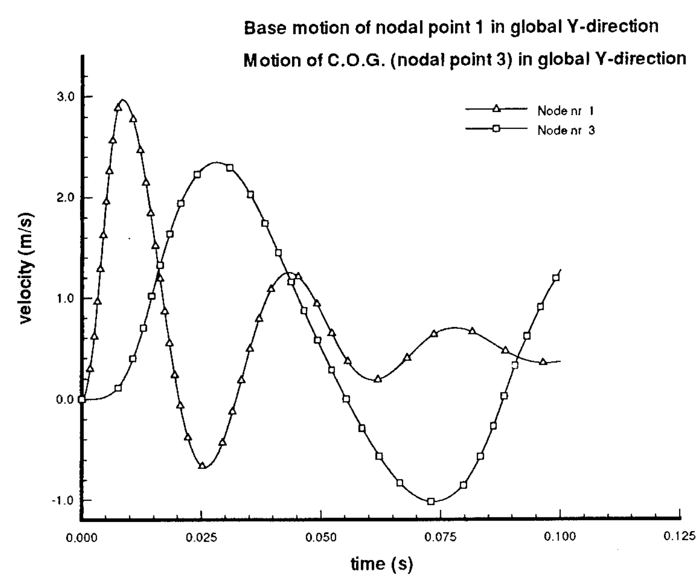

Figure 9.7.3

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APPENDIX A : List of subroutines.

No.	Name	Function
1.	SHOCK3D	Main program
2.	BLOCK DATA	Commonblock initialisation
3.	ASKAIN	Read ASKA tape-output
4.	BOOKIN	Read an ASKA book
5.	COEFAF	Calculate right hand side of the system of equations
6.	DATEX	Generate model information on the print output
7.	DATIN1	Read parameterlines
8.	DATIN2	Read model data lines
9.	DATOUT	General output steering routine
10.	DATOU1	Output of diagonal mass matrix on the printer
11.	DATOU2	Output of elongations and elongation velocities of the non-linear elements on the printer.
12.	DATOU3	Output of element forces on the printer
13.	DATOU4	Output of prescribed motions on the printer
14.	DATOU5	Output of prescribed forces on the printer
15.	DATOU6	Output of shock response on the printer
16.	DATOU7	Generate plottape
17.	DATOU8	Generate ASKA-post processing tape
18.	DATOU9	Generate Restart tape
19.	DGELG	Solution of a general system of equation (Gaussian elimination)
20.	DPDMI	Diagonal matrix inversion
21.	DPDMSM	Diagonal matrix-symmetric matrix product
22.	DPDMVP	Diagonal Matrix-vector product
23.	DPMVM	Matrix-vector product
24.	DPSMCF	Choleski decomposition
25.	DPSMI	Symmetric matrix inversion
26.	DPSMVP	Symmetric matrix-vector product
27.	DPSVMA	Scalar-vector multiplication
28.	DPTMVM	Transpose matrix-vector product
29.	DPVA	Addition of two vectors
30.	DPVC	Copying one vector in another
31.	DPVOP3	Calculation of a vector outproduct (dimension 3)
32.	DPVS	Subtraction of two vectors
33.	DPVSMA	Adding or multiplying a vector component to or with a scalar

34.	DPVZI	Initialise a vector with zeroes
35.	FORFUN	User subroutine to input prescribed forces with aid of analytical functions
36.	GETBOD	Calculate response of freedoms belonging to rigid bodies out of the response of the centre of gravity of that rigid body.
37.	GETFRD	Select response of a single node out of the total response vector
38.	HEAD	Generate first two pages of printer output
39.	HEADER	Main driver routine of the program
40.	INTERP	Linear interpolation of an equidistant signal
41.	ITPS	Determination of an element in a packed symmetric-matrix
42.	LINES	Count number of lines on current page and if necessary call for new page
43.	LOCASK	Determine overall freedom numbers for nodes belonging to ASKA-structures
44.	LOCBOD	Determine overall freedom numbers for nodes belonging to rigid bodies
45.	LOCVEC	Determination of nodal location vector
46.	MATRIN	Read mass-, stiffness- and/or initial conditions inputlines
47.	MEMORY	Enlarge memory or check dimension of blank common.
48.	NONLIN	Calculation of system right hand side due to forces in the non-linear elements
49.	NUL	Initialise a vector with zeroes
50.	PAGE	Give a new page on print output and print page heading
51.	PREASK	Calculation of system right hand side due to prescribed motion of freedoms belonging to an ASKA structure
52.	PRECAL	Perform some calculation before the integration is started
53.	PRESCR	Calculation of the prescribed displacements, velocities and accelerations
54.	PRFORC	Calculation of the system right handside due to prescribed forces
55.	PUTASK	Put response of ASKA structure in array for plottape and/or for print output
56.	PUTBOD	Put response of rigid bodies in array for plottape and/or print output

57.	PUTFOR	Put prescribed forces in array for plottape and/or print output
58.	PUTFRD	Substitute a small right hand side in the system righthand side
59.	PUTNEL	Put non-linear element information in array for plottape and/or for print output.
60.	PUTNOD	Put nodal point information in array for plottape and/or for print output
61.	PUTPRE	Put prescribed motions in array for plottape and/or for print output
62.	QUIT	Stop program execution and give an error message.
63.	READIN	Read a vector from tape
64.	RESTAR	Read restart tape
65.	RIGBOD	Calculate small right hand side due to forces acting on a rigid body
66.	RUKUCS	Fourth order Runga-Kutta integration of a system of first order differential equations
67.	SECORDEINT	Second order integration of a system of first order differential equations.
68.	SCHOCK	Calculation of prescribed displacements, velocity and acceleration if given by a sinusoidal shock function accordig BV43
69.	SHOCK	Calculation of prescribed displacements, velocity and acceleration if given by the naval shock function
70.	SIGDIF	Differentiation of a tabulated signal
71.	SIGINT	Integration of a tabulated signal
72.	SIGNAL	Selection of a vector out of an array
73.	SOLUTI	Solution of the system of equations
74.	SPRING	Calculation of the spring forces
75.	SUBSTI	Substitution of a submatrix in a matrix
76.	SUPRES	Suppression of some degrees of freedom of rigid bodies
77.	TRACE	Generate a matrix on the printer (mainly for testing purposes)
78.	TRANSF	Calculation of the transformation matrices of the non-linear elements
79.	VEERCO	Calculation of the constants C_j of spring types -1 and -2

APPENDIX B : Usage of the PC-version of the program SHOCK3D.

Elucidation to the usage of SHOCK3D (PC-version)

The program SHOCK3D developed for the usage on a mainframe computer has been modified to a version suitable for the usage on a personal computer (PC) type 486 (4Mb memory) under DOS-operating system.
This PC version of SHOCK3D will only work on models wich do not include flexible bodies.
When no plot output is requested there are no limitations with respect to the number of non-linear elements, the number of nodal points, the number of different shocks and the number of timesteps as compared with the mainframe version of SHOCK3D.

The input format for SHOCK3D is exactly as described in section 6.1 of this manual.
The ASCII-inputfile can be made with any common PC-editor.

The name of the file is prescribed and will be as follows : **SH3D_INP.nnn**, whereas **nnn** stands for a combination of 3 figures and/or characters in order to identify the current problem.

The output of SHOCK3D will be written to a file named: **SH3D_OUT.nnn**
In addition, when plot output is requested, the following output files will be generated :
ELEM_OUT.nnn (containing time-history of non-linear-elements),
PRFR_OUT.nnn (containing time-history of prescribed motions),
PRFO_OUT.nnn (containing time-history of prescribed forces),
SHRT_OUT.nnn (containing time-history of shockresponse translation),
SHRS_OUT.nnn (containing time-history of shockresponse rotation).

Whereas **nnn** stands for the above mentioned testproblem identification.

The program will be started by typing **SHOCK3D** followed by <Enter>.
Then the user will be asked for the problem identification number **nnn**.

Elucidation to the usage of SH3DPOST (PC-version)

The program SH3DPOST developed for the postprocessing of the results of SHOCK3D on a mainframe computer has been modified to a version suitable for the usage on a PC.
The program SH3DPOST will generate ASCII-files, wich allow the making of graphics with the aid of a common PC-spreadsheet program.
When plot output is requested the following limitations with respect to the number of non-linear elements, the number of nodal points, the number of different shocks and the number of timesteps as compared with the mainframe version of SHOCK3D has to be taken in account.

Maximum number of non-linear elements	35	(instead of 100 on mainframe)
Maximum number of different shocks	10	(instead of 30 on mainframe)
Maximum number of nodal points	35	(instead of 100 on mainframe)
Maximum number of timesteps	350	(instead of 3000 on mainframe)

The format of the control file for SH3DPOST is exactly as described in section 7.3 of this manual.
The ASCII-control file can be made with any common PC-editor.

The name of the file is prescribed and will be as follows : **POST_INP.nnn**, whereas **nnn** stands for a combination of 3 figures and/or characters in order to identify the current problem.

The default output will be written to the following files :
ELEM_DAT.nnn (containing time-history of non-linear-elements),
PRFR_DAT.nnn (containing time-history of prescribed motions),
PRFO_DAT.nnn (containing time-history of prescribed forces),
SHRT_DAT.nnn (containing time-history of shockresponse translation),
SHRS_DAT.nnn (containing time-history of shockresponse rotation).

Whereas **nnn** stands for the above mentioned testproblem identification.
With these ASCII-files graphical output can be achieved by means of a common PC-spreadsheet program.

The program will be started by typing **SH3DPOST** followed by <Enter>.
Then the user will be asked for the problem identification number **nnn**.

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15. ABSTRACT (MAXIMUM 200 WORDS, 1044 BYTES)

The program SHOCK3D deals with the shock response of a 3D structure, being composed from elastic parts, rigid bodies and non-linear mountings. Shock loading is in the form of prescribed shock motions as they are defined by several Navies in Equipment Shock Specifications (UNDEX shock) or in the form of prescribed forces. Mass- and stiffness matrices for the elastic parts are assembled within a separate f.e.m. program. A transient response analysis leads to time histories which can be plotted. Test problems have been added. A pc version may be used in case there is no need to include elastic parts.

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