

***CONTROL_IMPLICIT_FORMING**

Purpose: This keyword is used to perform implicit static analysis, especially for metal forming processes, such as gravity loading, binder closing, flanging, and stamping subassembly simulation. A systematic study had been conducted to identify the key factors affecting implicit convergence, and the preferred values are automatically set with this keyword. In addition to forming application, this keyword can also be used in other applications, such as dummy loading and roof crush, etc.

Card	1	2	3	4	5	6	7	8
Variable	IOPTION	NSMIN	NSMAX	BIRTH	DEATH	PENCHK		
Type	I	I	I	F	F	F		
Default	1	none	2	0.0	1.e+20	0.0		

VARIABLE**DESCRIPTION**

IOPTION

Solution type:

EQ.1: Gravity loading simulation, see remarks below.

EQ.2: Binder closing and flanging simulation, see remarks below.

NSMIN

Minimum number of implicit steps for IOPTION=2.

NSMAX

Maximum number of implicit steps for IOPTION=2.

BIRTH

Birth time to activate this feature.

DEATH

Death time.

PENCHK

Relative allowed penetration with respect to the part thickness in contact for IOPTION=2.

General remarks:

This keyword provides a simplified interface for implicit static analysis. If no other implicit cards are used, the stiffness matrix is reformed for every iteration. Convergence tolerances (DCTOL, ECTOL, etc.) are automatically set and not recommended to be changed. In almost all cases, only two additional implicit control cards (*CONTROL_IMPLICIT_GENERAL, and AUTO) may be needed to control the stepping size. Step size control is handled with the variables *DT0*, *DTMIN* and *DTMAX*. As always, the variable *IGAP* should be set to "2" in *CONTACT_FORMING... cards for a more realistic contact simulation in forming. The contact type *CONTACT_FORMING_SURFACE_TO_SURFACE is recommended to be used with implicit analysis. Although a smaller penalty stiffness scale factor *SLSFAC* produces a certain amount of contact penetration but achieves

a faster simulation time, and therefore is recommended for gravity and closing (in case of no physical beads) simulation. Subsequent forming process is likely to follow and contact conditions will be reestablished there. In simulation other than gravity and closing, a tighter, default *SLSFAC* (0.1) should be used.

It is recommended that the fully integrated element type 16 is to be used for all implicit calculation. For solids, type “-2” is recommended. Executable with double precision is to be used for all implicit calculation. Models with over 100,000 deformable elements are more efficient to be simulated with MPP for faster turnaround time.

Gravity loading example:

An example of the implicit gravity is provided below, where a blank is loaded with gravity into a toggle die. A total of five steps are used, controlled by the variable *DT0*. The results are shown in Figure 0-1. If this binder closing is done with explicit dynamics, efforts need to be made to reduce the inertia effects on the blank since contact with the upper binder only happens along the periphery and a large middle portion of the blank is not driven or supported by anything. With implicit static method, there is no inertia effect at all on the blank during the closing, and no tool speed, time step size, etc. to be concerned about.

The implicit gravity application for both air and toggle draw process is available through *LS-PrePost 4.0* in *Metal Forming Application / eZ Setup* (<http://ftp.lstc.com/anonymous/outgoing/lsprepost/4.0/metalfforming/>).

```
*KEYWORD
*PARAMETER
...
*CONTROL_TERMINATION
1.0
$---+---1---+---2---+---3---+---4---+---5---+---6---+---7---+---8
*CONTROL_IMPLICIT_FORMING
$ IOPTION
1
*CONTROL_IMPLICIT_GENERAL
$ IMFLAG DT0
1 0.2
*CONTROL_CONTACT
$ SLSFAC RWPNAL ISLCHK SHLTHK PENOPT THKCHG ORIEN
0.03 0.0 2 1 4 0 4
$ USRSTR USRFAC NSBCS INTERM XPENE SSTHK ECDT TIEDPRJ
0 0 10 0 1.0 0
*PART
Blank
&blkpid &blksec &blkmid
*SECTION_SHELL
$ SID ELFORM SHRF NIP PROPT QR/IRID ICOMP SETYP
&blksec 16 0.833 7 1.0
$ T1 T2 T3 T4 NLOC
&bthick,&bthick,&bthick,&bthick
*CONTACT_FORMING_SURFACE_TO_SURFACE
$ SSID MSID SSTYP MSTYP SBOXID MBOXID SPR MPR
&blkssid &lpunsid 2 2 1 1
$ FS FD DC VC VDC PENCHK BT DT
0.12 0.0 0.0 0.0 20.0 0 0.0 1E+20
$ SFS SFM SST MST SFST SFMT FSF VSF
```

*CONTROL_IMPLICIT_FORMING

*CONTROL

```
      1.0      1.0      0.0      &mstp
$      SOFT      SOFSCL      LCIDAB      MAXPAR      PENTOL      DEPTH      BSORT      FRCFRQ
      0
$      PENMAX      THKOPT      SHLTHK      SNLOG      ISYM      I2D3D      SLDTHK      SLDSTF
      1
$      IGAP      IGNORE      DPRFAC      DTSTIF      FLANGL
      2
...
*LOAD_BODY_Z
90994
*DEFINE_CURVE_TITLE
Body Force on blank
90994
0.0,9810.0
10.0,9810.0
*LOAD_BODY_PARTS
&blksid
*END
```

Binder closing example:

An example of binder closing and its progression is shown in Figures **0-2**, **0-3**, **0-4**, and **0-5**, using the NUMISHEET'05 deck lid inner, where a blank is being closed in a toggle die (modified). An adaptive level of three was used in the closing process. Gravity is and should be always applied at the same time, regardless if a prior gravity loading simulation is performed or not, as listed at the end of the input deck. The presence of the gravity helps the blank establish an initial contact with the tool, thus improving the convergence rate. The upper binder is moved down by a closing distance (defined by a parameter &bindmv) using a displacement boundary condition (VAD=2), with a simple linearly increased triangle-shaped load curve. The variable *DT0* is set at 0.01, determined by the expected total deformation. The solver will automatically adjust based on the initial contact condition. The maximum step size is controlled by the variable *DTMAX*, and this value needs to be sufficiently small (<0.02) to avoid missing contact, but yet not too small causing a long running time. In some cases, this variable can be set larger, but the current value works for most cases.

```
*KEYWORD
*PARAMETER
...
*CONTROL_TERMINATION
1.0
*CONTROL_IMPLICIT_FORMING
$ IOPTION      NSMIN      NSMAX
      2      2      100
*CONTROL_IMPLICIT_GENERAL
$ IMFLAG      DT0
      1      0.01
*CONTROL_IMPLICIT_AUTO
$ IAUTO      ITEOPT      ITEWIN      DTMIN      DTMAX
      0      0      0      0.01      0.03
*CONTROL_ADAPTIVE
...
*CONTROL_CONTACT
$ SLSFAC      RWPNAL      ISLCHK      SHLTHK      PENOPT      THKCHG      ORIEN
      0.03      0.0      2      1      4      0      4
$ USRSTR      USRFAC      NSBCS      INTERM      XPENE      SSTHK      ECDT      TIEDPRJ
      0      0      10      0      1.0      0
$---+---1---+---2---+---3---+---4---+---5---+---6---+---7---+---8
...
*PART
```

*CONTROL

*CONTROL_IMPLICIT_FORMING

```
Blank
$      PID      SECID      MID      EOSID      HGID      GRAV      ADOPT      TMID
      &blkpid    &blksec    &blkmid
*SECTION_SHELL
$      SID      ELFORM      SHRF      NIP      PROPT      QR/IRID      ICOMP      SETYP
&blksec      16      0.833      7      1.0
$      T1      T2      T3      T4      NLOC
&bthick,&bthick,&bthick,&bthick
...
*CONTACT_FORMING_SURFACE_TO_SURFACE
$      SSID      MSID      SSTYP      MSTYP      SBOXID      MBOXID      SPR      MPR
      &blksid    &lpunsid    2      2
$      FS      FD      DC      VC      VDC      PENCHK      BT      DT
      0.12      0.0      0.0      0.0      20.0      0      0.0      1E+20
$      SFS      SFM      SST      MST      SFST      SFMT      FSF      VSF
      1.0      1.0      0.0      &mstp
$      SOFT      SOFSCL      LCIDAB      MAXPAR      PENTOL      DEPTH      BSORT      FRCFRQ
      0
$      PENMAX      THKOPT      SHLTHK      SNLOG      ISYM      I2D3D      SLDTHK      SLDSTF
      1
$      IGAP      IGNORE      DPRFAC      DTSTIF      FLANGL
      2
*CONTACT_...
$---+---1---+---2---+---3---+---4---+---5---+---6---+---7---+---8
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$      typeID      DOF      VAD      LCID      SF      VID      DEATH      BIRTH
&bindpid      3      2      3      -1.0      0
*DEFINE_CURVE
3
0.0,0.0
1.0,&bindmv
$---+---1---+---2---+---3---+---4---+---5---+---6---+---7---+---8
$ Activate gravity on blank:
*LOAD_BODY_Z
90994
*DEFINE_CURVE_TITLE
Body Force on blank
90994
0.0,9810.0
10.0,9810.0
*LOAD_BODY_PARTS
&blksid
*END
```

Binder closing with real beads example:

Binder closing with real beads can also be done with implicit static, and with adaptive mesh. An example is shown in Figure **0-6**, where a hood outer is being closed implicitly. It is noted a small buckle can be seen near the draw bead region along the fender line. These kind of small forming effects can be more accurately detected with implicit static method.

The implicit static closing can now be set up in *LS-PrePost v4.0 Metal Forming Application/eZ Setup* (<http://ftp.lstc.com/anonymous/outgoing/lsprepost/4.0/metalforming/>).

Flanging example:

An example of flanging simulation using this feature is shown in Figures **0-7**, **0-8** and **0-9**, with NUMISHEET'02 fender outer, where flanging is conducted along the hood line. A partial input is

provided below, where *DTMAX* is controlled by a load curve for contact and speed. The use of *DTMAX* with a load curve is an exception to the rule, where most of the time this is not needed. Smaller step sizes are better in some cases than larger step sizes, which may take longer to converge resulting from cutbacks in step sizes. Gravity, pad closing and flanging were set to 10%, 10% and 80% of the total step size, respectively. Pad travels a distance of '&padtrav' starting at 0.1, when it is to be automatically moved to close the gap with the blank due to gravity loading (*CONTACT_AUTO_MOVE), and finishing at 0.2 and held in that position until the end. Flanging steel travels a distance of '&flgtrav' starting at 0.2 and completing at 1.0. A detailed section view of the simulation follows in Figure 0-10.

```

*KEYWORD
*PARAMETER ...
*CONTROL_TERMINATION
1.0
*CONTROL_IMPLICIT_FORMING
$ IOPTION      NSMIN      NSMAX
   2           2         200
*CONTROL_IMPLICIT_GENERAL
   1         0.100
*CONTROL_IMPLICIT_AUTO
$   IAUTO      ITEOPT      ITEWIN      DTMIN      DTMAX
   0           0           0         0.005     -9980
*DEFINE_CURVE
9980
0.0,0.1
0.1,0.1
0.2,0.1
0.7,0.005
1.0,0.005
*CONTROL_ADAPTIVE...
*CONTROL_CONTACT...
*PART...
*SECTION_SHELL...
*CONTACT_...
*CONTACT_FORMING_SURFACE_TO_SURFACE_ID_MPP
2
0,200,,3,2,1.005
$   SSID      MSID      SSTYP      MSTYP      SBOXID      MBOXID      SPR      MPR
   &blkssid   &padsid      2         2
$   FS        FD         DC         VC         VDC         PENCHK      BT         DT
   0.12      0.0        0.0        0.0        20.0        0           0.0       1E+20
$   SFS       SFM        SST         MST         SFST        SFMT        FSF        VSF
   1.0       1.0        0.0        &mstp
$   SOFT      SOFSCL     LCIDAB     MAXPAR     PENTOL     DEPTH      BSORT     FRCFRQ
   0
$   PENMAX    THKOPT     SHLTHK     SNLOG      ISYM       I2D3D     SLDTHK    SLDSTF
   1
$   IGAP      IGNORE     DPRFAC     DTSTIF     FLANGL
   2
*BOUNDARY_PRESCRIBED_MOTION_RIGID
$   typeID    DOF        VAD         LCID        SF         VID        DEATH     BIRTH
   &padpid     3          2           3          -1.0       0
   &flgpid     3          2           4          -1.0       0
*DEFINE_CURVE
3
0.0,0.0
0.1,0.0
0.2,&padtrav
1.0,&padtrav
*DEFINE_CURVE
4
0.0,0.0

```

```

0.2,0.0
1.0,&flgtrav
$ Activate gravity on blank:
*LOAD_BODY_PARTS
&blksid
*LOAD_BODY_Z
90994
*DEFINE_CURVE_TITLE
Body Force on blank
90994
0.0,9810.0
10.0,9810.0
*CONTACT_AUTO_MOVE
$      ID      ContID      VID      LCID      ATIME
      -1      2      89      3      0.1
*END

```

Flanging simulation using IOPTION of 1:

IOPTOIN 1 can also be used for closing and flanging simulation, or other applications that go through large plastic strains or deformation. This is used when an equal step size throughout the simulation is desired, and is done by specifying the equal step size in the variable *DT0* in ***CONTROL_IMPLICIT_GENERAL**, as shown in the following keywords (other cards similar and not included), where *DT0* of 0.014 is chosen. Such an application is shown in Figures **0-11** and **0-12****Error! Reference source not found.**

```

*CONTROL_TERMINATION
1.0
*CONTROL_IMPLICIT_FORMING
$ IOPTION
  1
*CONTROL_IMPLICIT_GENERAL
$ IMFLAG      DT0
  1      0.014

```

Switching between implicit dynamic and implicit static for gravity loading:

For sheet blank gravity loading, it is now possible to start the simulation using implicit dynamic method, switching to implicit static method at a user defined time until completion. This feature is activated by setting the variable TDYDTH in ***CONTROL_IMPLICIT_DYNAMICS** and was recently (Rev. 81400) linked together with ***CONTROL_IMPLICIT_FORMING**. In a partial keyword example below, death time for the implicit dynamic is set at 0.55 second. The test model shown in Figure **0-13** (left) results in a gravity loaded blank shape in Figure **0-13** (right). Without the switching, the blank will look like as shown in Figure **0-14**. The gravity loaded blank shape is more reasonable with the switching. A check on the energy history reveals that the kinetic energy dissipated completely at 0.60 second, Figure **0-15**.

```

*CONTROL_TERMINATION
1.0
*CONTROL_IMPLICIT_FORMING
$ IOPTION      NSMIN      NSMAX      BIRTH      DEATH      PENCHK
  1
*CONTROL_IMPLICIT_DYNAMICS
$ IMASS      GAMMA      BETA      TDYBIR      TDYDTH      TDYBUR      IRATE
  1      0.600      0.380      0.55

```

Revision information:

This implicit capability is available in R5.0 and later releases. Multi-step gravity loading simulation is recommended in Revision 64802 and later releases, and it is frequently used together with the blank pre-bending feature (*CONTROL_FORMING_PRE_BENDING) in Revision 66094 and later releases. The switching feature between implicit dynamic and implicit static is available in Revision 81400 and later releases. Another related keyword also includes *CONTACT_AUTO_MOVE, where an empty distance between the tool and blank can be automatically eliminated in a combined gravity and closing simulation in implicit static. This keyword is also available in LS-PrePost4.0 eZSetup for metal forming application.

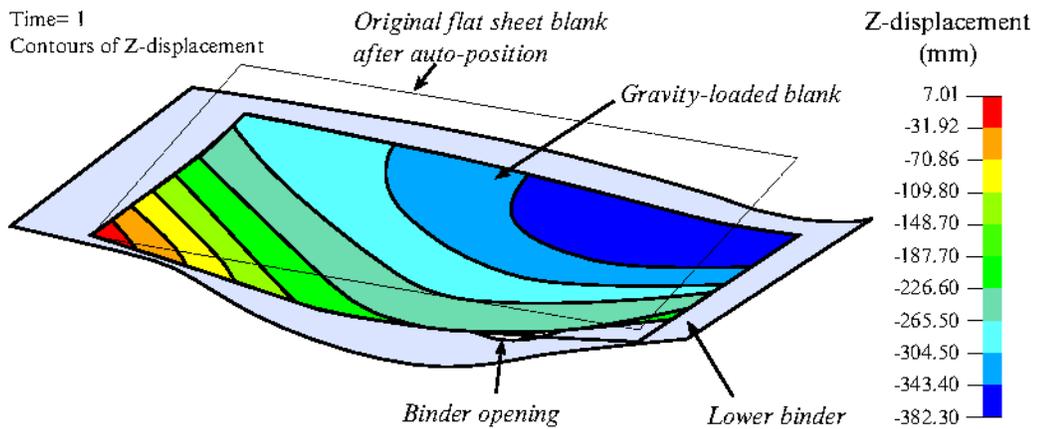


Figure 0-1. Gravity loading on a box side outer toggle die (courtesy of Autodie, LLC).

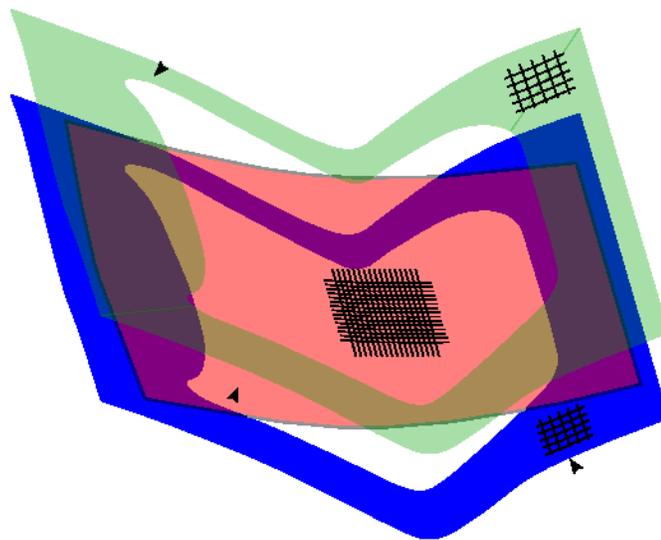


Figure 0-2. Initial auto-positioning (NUMISHEET2005 decklid inner).

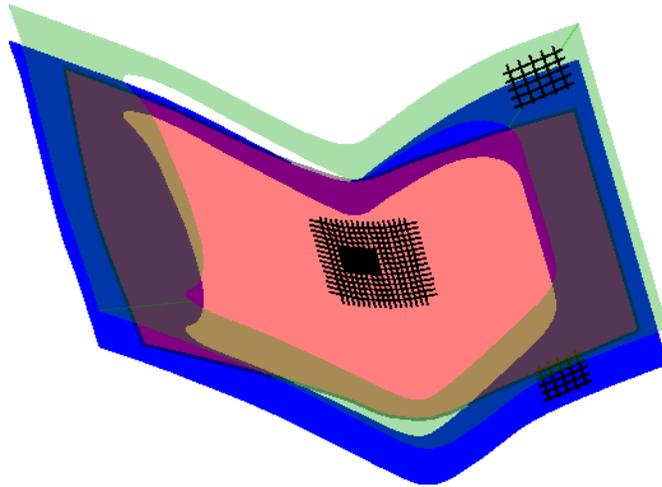


Figure 0-3. At 50% upper travel.

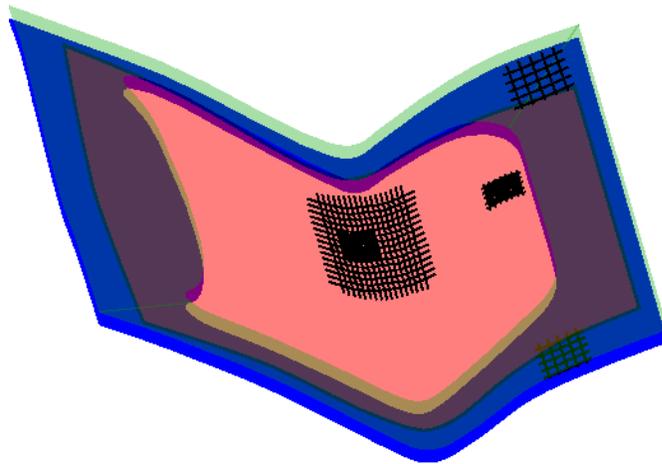


Figure 0-4. At 80% upper travel.

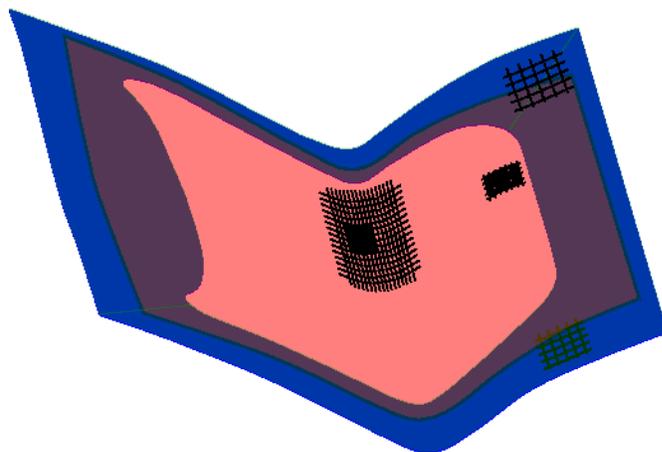


Figure 0-5. Upper travels to home.

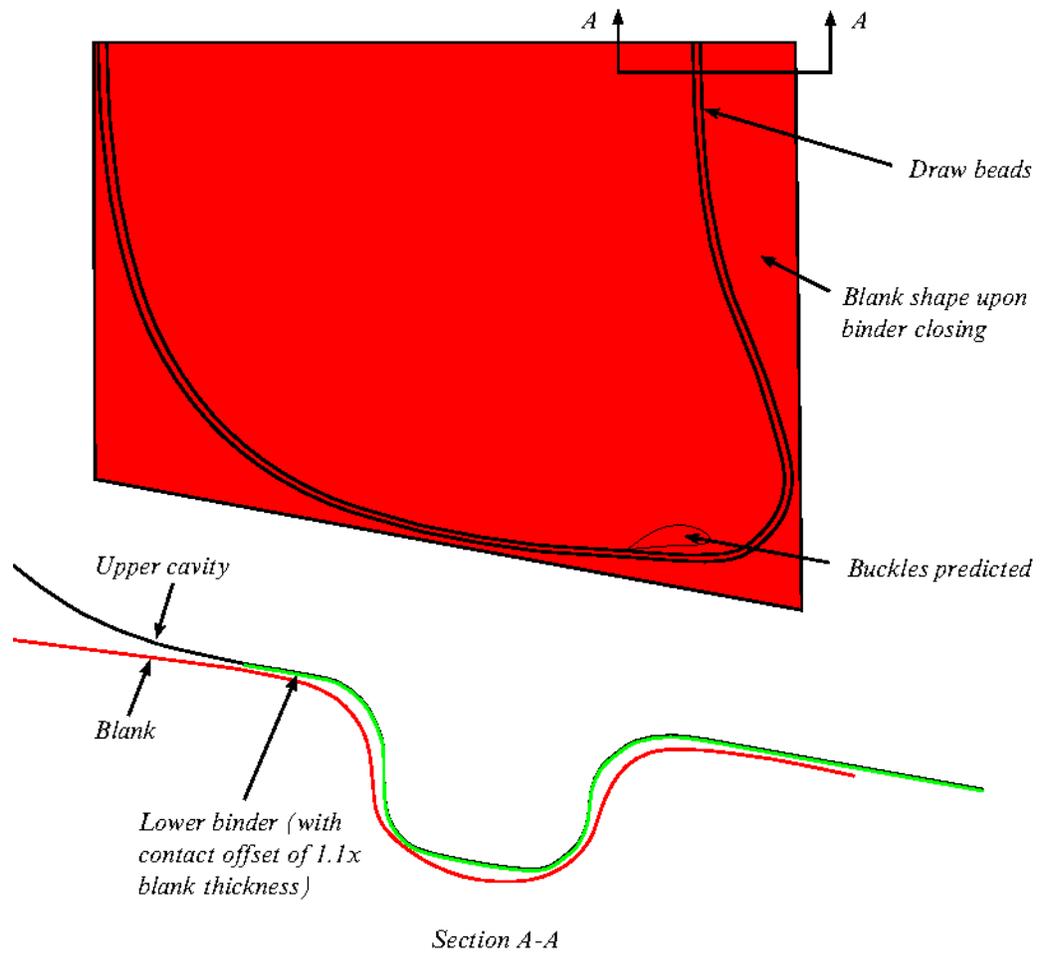


Figure 0-6. Binder closing with beads on a hood outer.

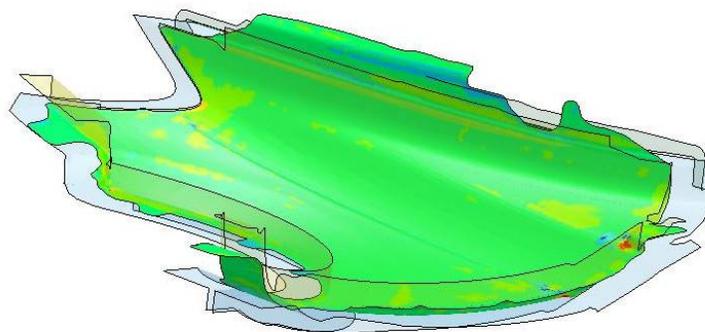


Figure 0-7. Mean stress at pad closing.

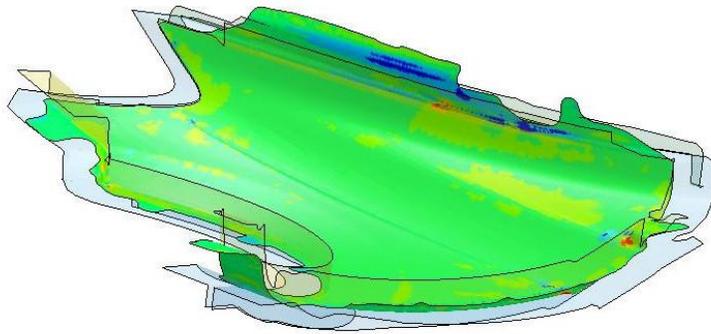


Figure 0-8. Mean stress at 40% Travel.

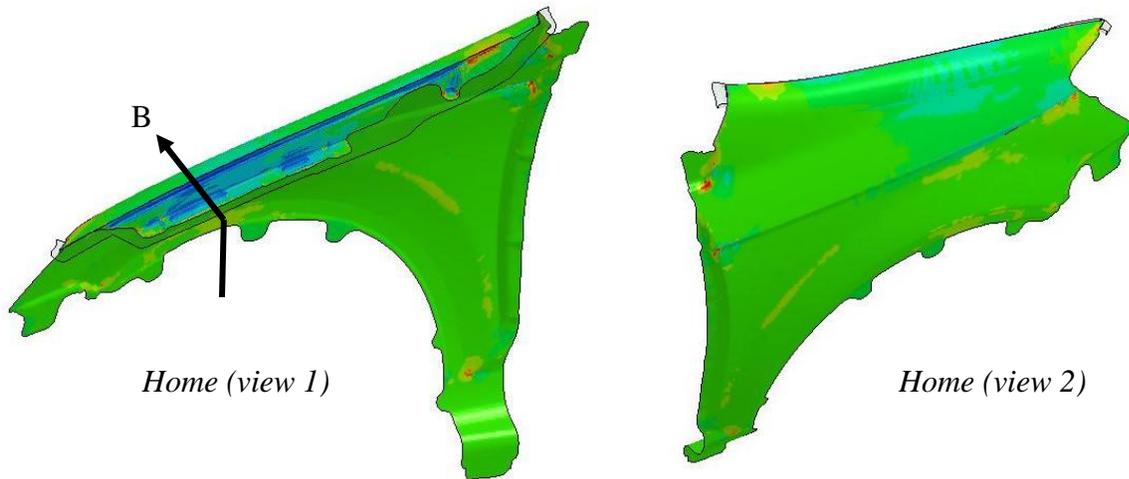


Figure 0-9. Mean stress at flanging home (compression/surface lows in red).

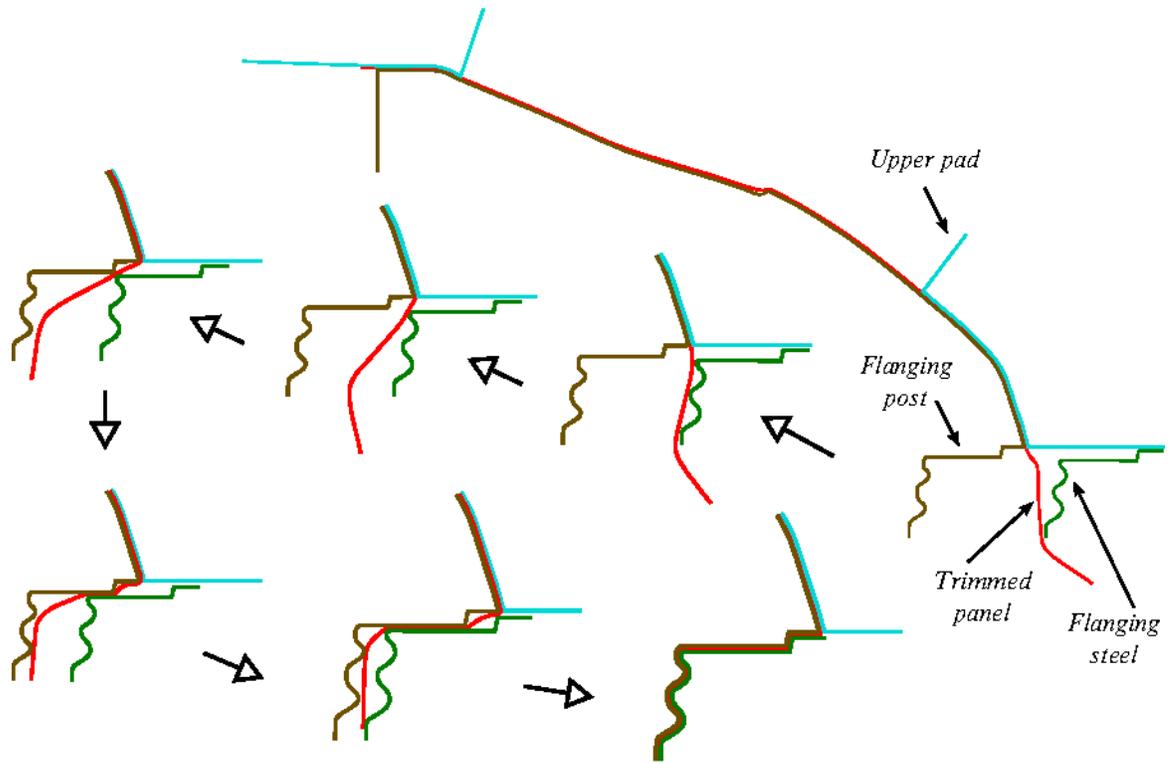


Figure 0-10. Flanging progression along section B (flanging post stationary).

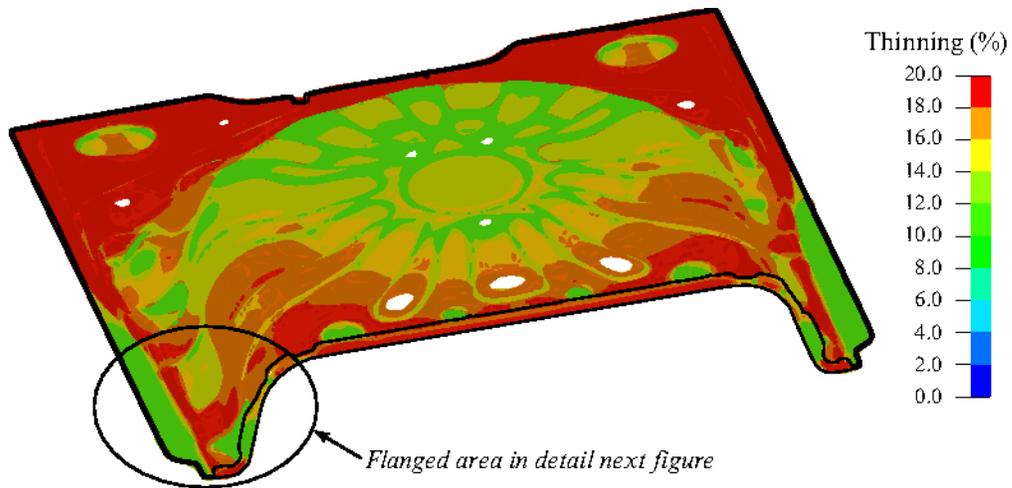


Figure 0-11. Flanging simulation of a rear floor pan using IOPTION 1 (Courtesy of Chrysler, LLC).

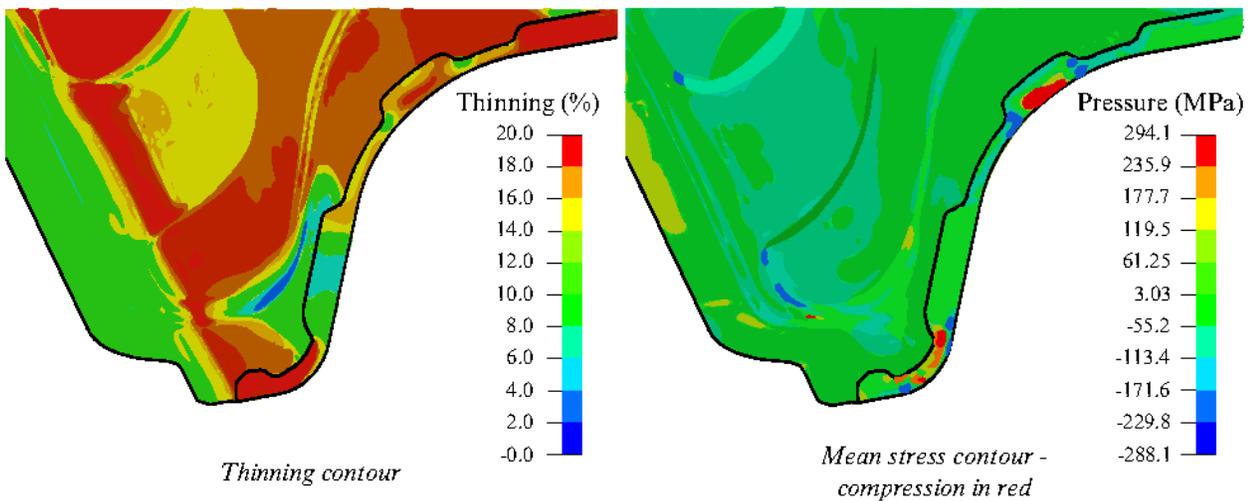


Figure 0-12. Localized view of the last figure.

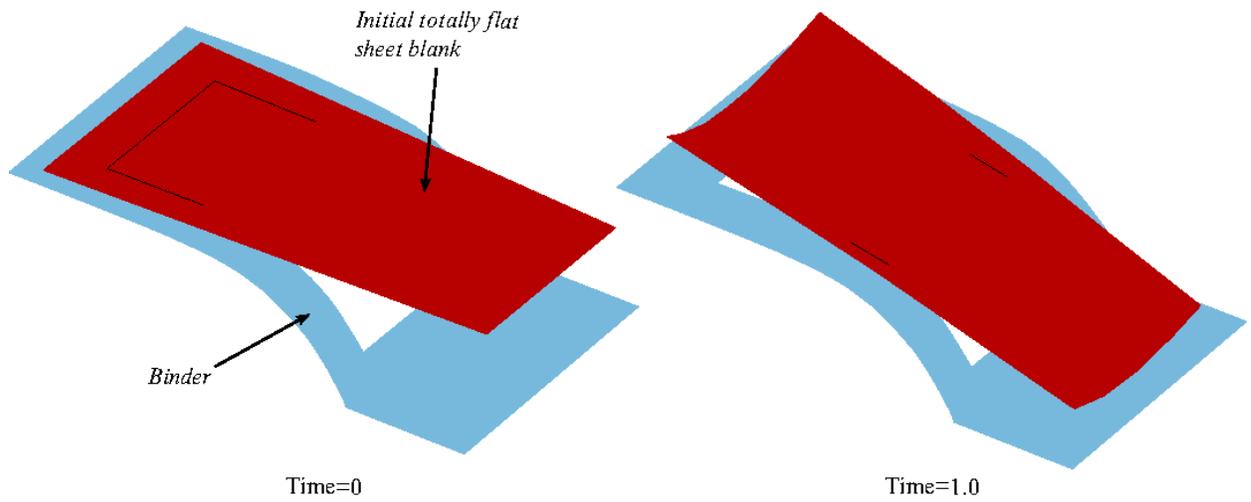


Figure 0-13. Test model (left) and gravity loaded blank (right) with switching from implicit dynamic to implicit static.

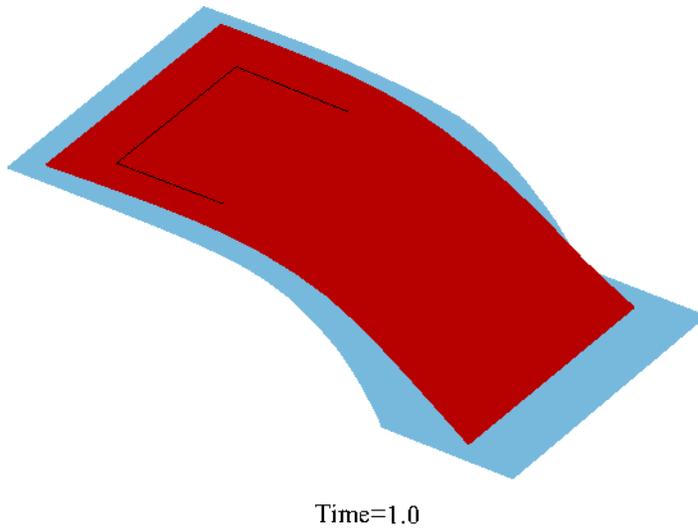


Figure 0-14. Gravity loaded blank without the “switching”.

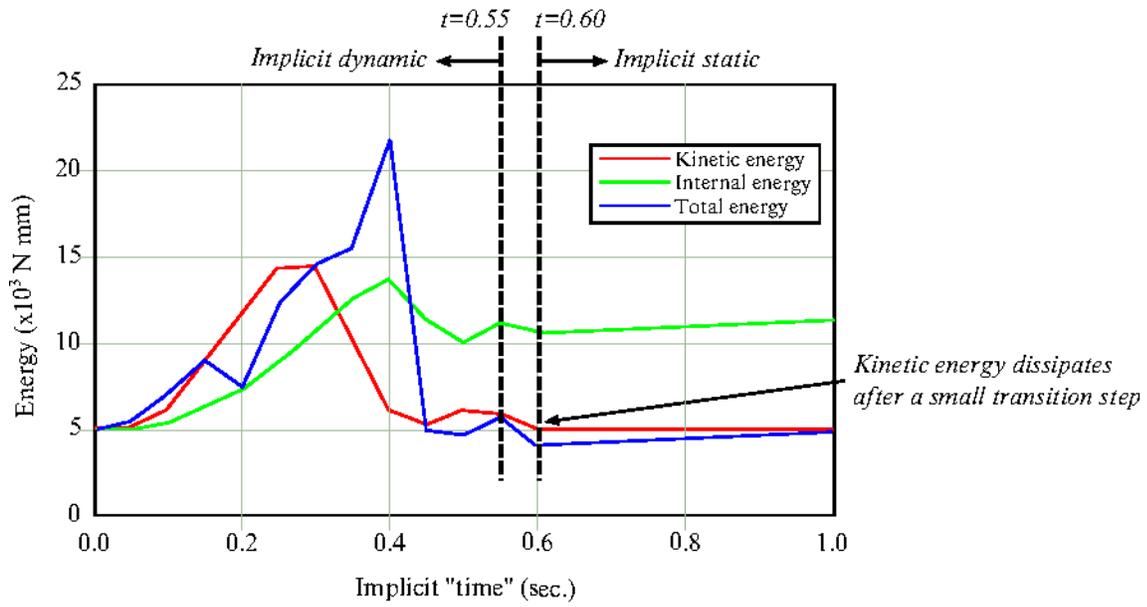


Figure 0-15. Switching between implicit dynamic and implicit static.

