

**\*INTERFACE\_COMPENSATION\_NEW\_{OPTION}**

Available options include:

<BLANK>

ACCELERATOR

MULTI\_STEPS

LOCAL\_SMOOTH

PART\_CHANGE

Purpose: These features are developed to compensate springback in stamping tools. The capabilities of the features include: (1) to calculate the deviation of the part from its intended design of the stamped part, and automatically compensate the tool to minimize the deviation; (2) to map the existing trimming curve to the modified tool; and (3) to automatically detect the undercut problem.

This compensation algorithm is a nonlinear iterative method. If one iteration is not enough to bring down the part deviation caused by to springback to less than the acceptable tolerance, it is always advised to use more iterations. Usually, it is found that 2~4 iterations are needed for most of the cases. In addition, this method provides a scale factor, which allows the user to decide the ratio of shape deviation the part is compensated.

The option **ACCELERATOR** speeds up the convergence rate in reducing the part deviation to design tolerance thus reducing the number of iterations. This option also allows for a much simpler user interface.

The option **MULTI\_STEPS** allows for tooling compensation of the next die process, based on target blank shape, compensated blank shape for the next step, and current tools. This feature is useful in line die process/tooling compensation.

The option **LOCAL\_SMOOTH** features smoothing of a tool's local area mesh, which could become distorted because of either bad or coarse mesh of the original tool surface, or in areas where tooling pairs (for example, flanging post and flanging steel) does not maintain a constant gap, or after a few compensation iterations.

The option **PART\_CHANGE** allows for updating of the final compensated tool using the changed part or formed blank shape, thus eliminating the need for going through a new compensation iteration loop. This option is used together with **\*INCLUDE\_COMPENSATION\_UPDATED\_BLANK\_SHAPE**, and **\*INCLUDE\_COMPENSATION\_UPDATED\_RIGID\_TOOL**.

Limitation of the current methods involves deficiency in eliminating the undercut problem.

# \*INTERFACE

# \*INTERFACE\_COMPENSATION\_NEW

All required input files must be included by using various options in the keyword: \*INCLUDE\_COMPENSATION\_{*OPTION*}. The option LOCAL\_SMOOTH also needs to use a keyword \*SET\_NODE\_LIST\_SMOOTH.

Card 1 for keyword options <BLANK>, MULTI-STEPS, and LOCAL\_SMOOTH:

Card 1	1	2	3	4	5	6	7	8
Variable	METHOD	SL	SF	ELREF	PSIDm	UNDCT	ANGLE	NLINEAR
Type	I	F	F	I	F	F	F	I
Default	6	5.0	0.75	1	none	none	0.0	1

Card 1 for keyword option ACCELERATOR:

Card 1	1	2	3	4	5	6	7	8
Variable	ISTEPS	TOLX	TOLY	TOLZ	OPTION			
Type	I	F	F	F	I			
Default	0	0.5	0.5	0.5	1			

Card 1 for keyword option PART\_CHANGE:

Card 1	1	2	3	4	5	6	7	8
Variable	MAXGAP							
Type	F							
Default	none							

## VARIABLE

## DESCRIPTION

METHOD

There are several extrapolation methods for the addendum and binder outside of trim lines, see **Remarks**.

<b>VARIABLE</b>	<b>DESCRIPTION</b>
SL	<p>The smooth level parameter controls the smoothness of the modified surfaces. A large value makes the surface smoother. The commonly used value is between 5 and 10. If springback is large, the transition region is expected to be large. However, by using a smaller value of SL, the region of transition can be reduced.</p>
SF	<p>Shape compensation scale factor. The value scales the springback amount of the blank and the scaled amount is used to compensate the tooling.</p> <p>GT.0: compensate in the opposite direction of the springback;</p> <p>LT.0: compensate in the punch moving direction (for undercut).</p> <p>This scale factor scales how much of the shape deviation is compensated. For example, if 10 mm of springback is predicted, and the scale factor is chosen as 0.75, then the compensation in the opposite direction will only be 7.5 mm.</p> <p>Experiences show that the best scale factor for reaching a converged solution (within part tolerance) is case dependent. In some cases, a scale factor range of 0.5~0.75 is best; while in others, larger values prevail. Sometimes, the best value can be larger than 1.1. It is noted that within an automatic compensation loop, this factor does not need to be varied.</p> <p>Since it is impossible to choose the best value for each application, it is suggested that for a new application, the initial trial is 0.75. If the springback cannot be effectively compensated (diverge), the factor can be moved upward or downward to obtain a converged solution, or more iterations must be used with the initial trial value to compensate the remaining shape deviation.</p> <p>For channel type of part with twisting mode of springback, the scale factor is more important. It was found that a small change of the tool shape might change the twisting mode. If this occurs, using a small value (&lt;0.5) is suggested.</p>
ELREF	<p>Element refinement option:</p> <p>EQ.1: special element refinement is used with the tool elements (default);</p> <p>EQ.2: special element refinement is turned off.</p>

<b>VARIABLE</b>	<b>DESCRIPTION</b>
PSIDm	<p>Define the part set ID for master parts. It is important to properly choose the parts for the master side. Usually, only one side (master side) of the tool will be chosen as the master side, and the modification of the other side (slave side) depends solely on the change in the master side. This allows the two sides to be coupled and a constant (tool) gap between the two sides is maintained. If both sides are chosen as master side, the gap between the two sides might change and the gap might become inhomogeneous.</p> <p>The choice of master side will have an effect on the final result for method 7 for three-piece draw. At this time, when the punch and binder are chosen as the master side, the binder region will not be changed. Otherwise, when the die is chosen as master side the binder will be changed, since the changes extend to the edges of the master tool.</p>
UNDCCT	<p>Tool undercut treatment option:</p> <p>EQ.0: no check (default);</p> <p>EQ.1: check and fix undercut.</p>
ANGLE	<p>An angle defining the undercut.</p>
NLINEAR	<p>Activate nonlinear extrapolation.</p>
ISTEPS	<p>Steps in accelerated compensation procedure, see <b>Remarks</b>.</p>
TOLX	<p>Part deviation tolerance between current blank and target blank shape in global X-direction.</p>
TOLY	<p>Part deviation tolerance between current blank and target blank shape in global Y-direction.</p>
TOLZ	<p>Part deviation tolerance between current blank and target blank shape in global Z-direction.</p>
OPTION	<p>Compensation acceleration method. Currently only method 1 is available.</p>
MAXGAP	<p>Maximum gap between the original part and changed part.</p>

### **Compensation Methods Overview:**

After trimming, only a limited part of the tool has direct relationship with the springback of the blank part. The modification of the rigid tool outside the trimming curve has to rely on extrapolation. However, extrapolating is an unstable process, as it tends to generate non-smooth surfaces. To

resolve this problem, seven smoothing algorithms have been proposed. The frequently used methods are methods 7, 8 and -8. The others are used occasionally.

**Method 7:** If the punch is chosen as the master side, the binder will not be changed. The only change occurring involves inside punch opening. Under this option, the smoothing factor has little effect. The smoothness of the modified tool depends on the magnitude of the springback and the size of the addendum region.

*Advantages:* The binder will not be changed.

*Disadvantages:* The change will be limited inside the addendum region, and the modified surface may not be smooth if the springback magnitude is large and the transition is small. This is a non-linear method, and the iterative method is used.

**Method 6:** The smoothness and the transition region of the modified surface will depend on the springback magnitude and the smoothing factor. If the springback magnitude is large, the transition region will be increased automatically. On the other hand, the transition region will be smaller if the springback magnitude is small. At the same time, a larger smoothing factor will result in a smaller transition region.

*Advantages:* The smoothness of the modified surfaces can be controlled. This is a non-linear method and the iterative method is used.

*Disadvantages:* It is impossible to limit the transition region, and the binder surface (therefore, draw beads) could change if the springback is large.

**Method 3:** Similar to Method 6, however, it is a linear method and no iteration is necessary. The other options may be removed in the future; therefore they will not be discussed.

**Method 8:** This is an improvement over Method 6, and can account for addendum and binder changes. Usually the upper tooling including addendum and binder (in an air draw) are included in the PSIDm definition.

**Method -8:** This method is a modification of Method 8, and is used for trim die nesting (from the drawn panel shape).

**Method to Prevent Undercut:** When the draw wall is steep, it is very possible that undercut will occur. Since undercut is not accepted in real world die manufacturing, it is necessary to prevent it from happening.

The compensation code can automatically detect undercut and issue a warning message. In addition, it will save all the element information into a file called *blankundercut.tmp* so that the user can easily identify which elements may be problematic.

If the undercut is only limited to a few elements, it is possible to fix the problem manually. The code provides one more option to handle undercut problem, i.e. to compensate the springback only

in the punch moving direction (by using a negative scale factor). Although it is known that this method is not the best method to handle undercut problems, better solutions are being studied.

## Iterative springback compensation:

Shown in Figure 0-1 is a flow chart for the iterative springback compensation for a typical stamping process. The first stamping process simulation is done following gravity→forming→trimming→springback (ITERATION 0). The stamping process simulation is set up using eZ-Setup (<http://ftp.lstc.com/anonymous/outgoing/lsprepost/4.0/metalforming/>). With the use of parameterized automatic tool/blank positioning feature, the process simulation is fully automated (no user intervention required). Based on the calculated springback amount, tooling geometry is compensated through a compensation run. The stamping process simulation is conducted again, automatically, based on the new compensated tooling, followed by a second tooling compensation (ITERATION 1). Similarly, ITERATIONs 2, 3, 4 are done. The iteration process is repeated until blank springback shape conforms to tooling designed intent (target), or until it reaches 4 iterations (typically required to achieve part tolerance). With a few DOS or linux commands and batch commands, this iterative loop can be completed automatically. The commands also allow for use of different precisions (double or single) of LS-DYNA versions.

The task of tracking the files involved in the iterative process can be daunting, especially in the advanced stage of the iterations. Figure 0-2 provides the file structures typically used in the process.

In a complete keyword input example below for a tool springback compensation, the keyword file *blank0.k* includes node and element information of the blank shape before springback (after forming and trimming) with adaptive constraints (if exist). The keyword file *spb.k* includes node and element information of the blank after springback, with adaptive constraints (if exist). Files *blank0.k* and *spb.k* may be based on the original die design (ITER0), or based on the n<sup>th</sup> iteration (ITERn) on an intermediate compensated die design. The keyword file *reference0.k* is the blank shape before springback in the ITER0. This file is the same as *blank0.k* and should not change from iteration to iteration. The file *reference1.k* is the same as *blank0.k* for the ITER0. For ITER1 *reference1.k* should be assigned as a file name called *disp.tmp* generated from the compensation run in the ITER0, so on and so forth. The file *tools.k* is the mesh information of all stamping tools and all tools must be in home position. Compensated tools will be in a file named *rigid.new* and the original constant gap is maintained among the tools. In the baseline run of the ITER0, a keyword file called *geocur.trm*, generated during a LS-DYNA trimming simulation based on trimming curve input (usually in IGES format), is used for keyword \*INCLUDE\_COMPENSATION\_TRIM\_CURVE. In the compensation run of the ITER1, *geocur.trm* is used to generate new trim curves called *geotrm.new*, which conforms to the current compensated tools; and this new mapped trim curves are used for the ensuing ITER2, so on and so forth. The file *geotrm.new* is also a keyword file defined by \*DEFINE\_CURVE\_TRIM\_3D. In this example of a three-piece air draw, upper die cavity (including binder) has a part ID 2, which is included in the part set ID 1 and is used for variable PSIDm. Method 8 will compensate all the tools included in file *tools.k* based on compensated shape for the upper cavity.

\*KEYWORD

\$---+-----1-----+-----2-----+-----3-----+-----4-----+-----5-----+-----6-----+-----7-----+---

## \*INTERFACE\_COMPENSATION\_NEW

## \*INTERFACE

```
*INTERFACE_COMPENSATION_NEW
$  METHOD      SL      SF      ELREF      PSIDm      UNDRCT      ANGLE  NLINEAR
    8      10.000      1.000      0          1          0          0.0      1
*INCLUDE_COMPENSATION_BLANK_BEFORE_SPRINGBACK
blank0.k
*INCLUDE_COMPENSATION_BLANK_AFTER_SPRINGBACK
spbk.k
*INCLUDE_COMPENSATION_DESIRED_BLANK_SHAPE
reference0.k
*INCLUDE_COMPENSATION_COMPENSATED_SHAPE
reference1.k
*INCLUDE_COMPENSATION_CURRENT_TOOLS
tools.k
*INCLUDE_COMPENSATION_TRIM_CURVE
geocur.trm
*SET_PART_LIST
$  PSID
    1
$  PID
    2
$-----1-----2-----3-----4-----5-----6-----7-----
*END
```

In an example shown in Figure **0-3**, the NUMISHEET'05 cross member is compensated based on the flow chart. A total of two iterations reduced springback amount from 13mm to less than 1.7 mm. Further iterations will reduce the part deviation down to a specific design target. Typically, four iterations are needed.

### Iterative compensation applied during die construction:

The blank shape after springback can be obtained from the actual shape of the springback panel, if available. For example, in hard tool construction, the trimmed panel can be scanned using white light technology and the panel shape can be output as STL format. The STL format can be easily converted to LS-DYNA keyword format and the trimmed panel can then be used as a rigid tool onto which baseline (ITER0) trimmed panel (deformable) can be “pushed” using element normal pressure, and using \*CONTROL\_IMPLICIT\_FORMING type 1. In this scenario, the adaptive refinement is turned off to maintain the one-to-one correspondence of the elements and nodes information. An advantage of this method is that the springback shape used for compensation will be exactly the same as the actual panel springback, therefore the best tooling compensation result is expected. An example of such is shown in Figures **0-4** and **0-5**.

### Compensation of localized regions:

Compensation of a localized tooling region is possible, with the keyword \*INCLUDE\_COMPENSATION\_CURVE, by simply adding the following lines into the above example inputs:

```
*INCLUDE_COMPENSATION_CURVE
curves.k
```

The file *curves.k* defines the two enclosed “begin” and “end” curves using \*DEFINE\_CURVE\_COMPENSATION\_CONSTRAINT\_BEGIN/END. More explanations can be found in the

corresponding keyword manual pages. In an example shown in Figure 0-6, the NUMISHEET'05 decklid inner is being compensated locally in the horizontal area above the backlite. Tangency of the compensated tool is maintained at the 'End Curve' as shown in the section A-A. Also shown in Figure 0-7 includes color contours of part-separation distance between compensated panel and the target design intent. Part tolerance is achieved in two iterations.

### Accelerated springback compensation (ASC):

The option ACCELERATOR can be used in conjunction with \*INCLUDE\_COMPENSATION, with options ORIGINAL\_DYNAIN and SPRINGBACK\_INPUT to compensate springback with a faster convergence rate and a simplified user interface. In some cases, this feature has shown promising potential. In a complete example inputs provided below, included are the necessary keywords, which use a springback input file *spbk.dyn*, and a trimmed panel, with file name *case20trimmed.dynain* (including all stress and strain tensors and adaptive constraints). The variable ISTEPS was increased from 0 to 3, representing 3 compensation iterations. ISTEPS=0 represents the baseline springback simulation (ITER0); while ISTEPS=1, 2, 3 represent the compensation iterations. This feature requires the user to change only one variable (ISTEPS), and then submit the same input file to continue the next iteration. Many scratch files (do not delete), including a file named *accltmp.tmp*, will be generated and updated in the same running directory and is used for each ISTEPS run. A file, *compensation.info*, generated and updated after each ISTEPS run, contains iteration information, maximum deviations in X, Y, and Z directions. When the maximum deviation is reached within the tolerances specified with TOLX, TOLY, and TOLZ, a message appears in the file proclaiming the compensation iterations has converged, along with a message of instructions for the next step. Essentially, a file *spbk.new* will be generated in the same directory and needs to be used for \*INCLUDE\_COMPENSATION\_BLANK\_AFTER\_SPRINGBACK, and the scale factor for the tool compensation must be set to one. After the compensation, a verification run may be needed.

```
*KEYWORD
*INTERFACE_COMPENSATION_NEW_ACCELERATOR
$  ISTEPS      TOLX      TOLY      TOLZ      OPTION
   3         0.20      0.20      0.2         1
*INCLUDE_COMPENSATION_ORIGINAL_DYNAIN
./case20trimmed.dynain
*INCLUDE_COMPENSATION_SPRINGBACK_INPUT
./spbk.dyn
*END
```

Currently, mesh coarsening and checking are not supported in the accelerated mode. Also, inclusion of *dynain* file from the previous die process in the *spbk.dyn* is not necessary.

An example of such is shown for a simple channel type of draw (one-half model) in Figure 0-8, which converged in three iterations; while four iterations were needed for the non-accelerated compensation.

**Line die compensation:**

The option MULTI\_STEPS can be used together with \*INCLUDE\_COMPENSATION\_COMPENSATED\_SHAPE\_NEXT\_STEP to enable compensation of tools for the next die process. In a complete input file example below, in addition to the target blank shape (*reference0.tmp*) and current tool (*rigid.tmp*) from the 1<sup>st</sup> die process step, the file *disp.tmp* comes from the compensation in the 2<sup>nd</sup> die process step. For example, a flanging die compensation can be a 2<sup>nd</sup> die process step, preceded by a redraw die process as the 1<sup>st</sup> die process step.

```
*KEYWORD
*INTERFACE_COMPENSATION_NEW_MULTI_STEPS
$---+-----1-----+-----2-----+-----3-----+-----4-----+-----5-----+-----6-----+-----7-----+-----8
$  METHOD          SL          SF          ELREF          PSID          UNDRCT          ANGLE          NLINEAR
      8          6.000          1.00          1          1          0          0          1
*INCLUDE_COMPENSATION_DESIRED_BLANK_SHAPE
reference0.tmp
*INCLUDE_COMPENSATION_COMPENSATED_SHAPE_NEXT_STEP
disp.tmp
*INCLUDE_COMPENSATION_CURRENT_TOOLS
rigid.tmp
*SET_PART_LIST
$  PSID
      1
$  PID
      2
*END
```

**Compensation of trim dies (trim die nesting):**

Trim die can be compensated using the drawn panel springback shape when Method is set to a value of -8. In a complete keyword input deck below, further referring to Figure **0-9**, draw panel (*state1.k*) is taken as the blank before springback, and, draw panel springback shape (*state2.k*) is taken as the blank after springback. Tool shape for the draw process (*drawtool.k*) is used as the current tool. After the simulation, LS-DYNA will create a compensated tool named *rigid.new*, which can be used for the trim die shape.

```
*KEYWORD
$---+-----1-----+-----2-----+-----3-----+-----4-----+-----5-----+-----6-----+-----7-----+-----8
*INTERFACE_COMPENSATION_NEW
$  METHOD          SL          SF          ELREF          PSID          UNDRCT          ANGLE          NLINEAR
      -8          10.000          1.000          2          1          0          0.0          1
*INCLUDE_COMPENSATION_BLANK_BEFORE_SPRINGBACK
state1.k
*INCLUDE_COMPENSATION_BLANK_AFTER_SPRINGBACK
state2.k
*INCLUDE_COMPENSATION_DESIRED_BLANK_SHAPE
ref0.tmp
*INCLUDE_COMPENSATION_COMPENSATED_SHAPE
ref1.tmp
*INCLUDE_COMPENSATION_CURRENT_TOOLS
drawtool.k
*INCLUDE_COMPENSATION_TRIM_CURVE
originaltrim.k
*SET_PART_LIST
$  PSID
      1
```

# \*INTERFACE

# \*INTERFACE\_COMPENSATION\_NEW

```
$      PID
      3
$---+---1---+---2---+---3---+---4---+---5---+---6---+---7---+---8
*END
```

## Local smoothing of tooling mesh:

The option LOCAL\_SMOOTH can be used, along with a few more keywords, to smooth and restore the distorted tooling mesh after iterative compensation. In a keyword input example below, the keyword \*INCLUDE\_COMPENSATION\_ORIGINAL\_RIGID\_TOOL includes an original tool, 'rigid.tmp', which has a good and smooth mesh. The keyword \*INCLUDE\_COMPENSATION\_NEW\_RIGID\_TOOL includes a compensated tool, 'rigidnew.bad', which could have distorted meshes arising from the reasons listed in the 'Purpose' section of this keyword. The last keyword \*SET\_NODE\_LIST\_SMOOTH defines in the distorted mesh a node set in and surrounding a distorted local area. Each node set defines a region needed smoothing. The node set should not include any boundary nodes of the tooling parts, otherwise position of the tooling may be altered undesirably. Smoothed tooling is stored in a file called 'rigid.new'. It is noted method 7 is to be used, the variable ELREF to be set to a value of 2, and PSID left as undefined.

```
*KEYWORD
*INTERFACE_COMPENSATION_NEW_LOCAL_SMOOTH
$  METHOD      SL      SF      ELREF      PSID      UNDRCT      ANGLE      NLINEAR
      7      10.000      1.000      2
*INCLUDE_COMPENSATION_ORIGINAL_RIGID_TOOL
rigid.tmp
*INCLUDE_COMPENSATION_NEW_RIGID_TOOL
rigidnew.bad
*SET_NODE_LIST_SMOOTH
  1
  61057      61058      61059      61060      61061      61062      61063      61064
...
*SET_NODE_LIST_SMOOTH
  2
  56141      56142      56143      56144      56145      56146      56147      56148
...
*END
```

In an example shown in Figures **0-10** and **0-11**, smoothing of the local mesh is performed in the draw bead area of the NUMISHEET 2005 cross member. This is the case where die gap is not maintained throughout the tooling surface, typically happens in the draw bead regions where male beads usually only have lower bending radii (missing upper radii) and female beads have only upper bending radii (missing lower radii). Two node sets are defined for local areas of left and right female draw beads (Figure **0-12**), which needed smoothing. Smoothed results show original distorted meshes on the lower beads corner areas are corrected and is satisfactory, Figure **0-13**.

In another example, a corner of a flanging die on a fender outer is being smoothed. The mesh becomes distorted after a few compensation iterations, as shown in Figure **0-14**. In Figure **0-15**, the result of local smoothing is shown, and the improvement is remarkable.

**Compensation with symmetric boundary condition:**

A keyword example is provided in the manual pages related to \*INCLUDE\_COMPENSATION\_{OPTION}.

**Global compensation using the original tool mesh:**

For some tool mesh, compensated die surfaces become somewhat distorted. The keyword option \*INCLUDE\_COMPENSATION\_ORIGINAL\_TOOL is created to allow the compensation code to use the original tool mesh (starting in the second compensation) to extrapolate the addendum and binder in the compensated tooling surfaces. This minimizes the accumulative error, compared with using the last compensated tooling mesh, and therefore is a preferred method. A complete keyword example is listed below, as part ID 3 (included in part set ID 1) is being compensated after ITERATION #3 (ITER3), using method #8, with a scale factor of 0.5. The ‘dynain’ files of ITER3 trimming and springback are taken as ‘before’ and ‘after’ sheet blank shapes, respectively. ‘Desired’ blank shape is from ITER0 trimmed ‘dynain’ file, which never changes. ‘Compensated shape’ is taken from the ‘disp.tmp’ file of the last compensation run. ‘Current tool’ is also from last compensation. The ‘original tool’, is taken from the tool mesh in ITER0. Updated trim curves ‘geotrm.new’ are taken from mapped trim lines of last compensation. It is noted that, in an automatically compensation-loop runs, as shown in the path of the input files, input files ‘disp.tmp’, ‘rigid.new’, and ‘geotrm.new’, taken from the default file names of the previous compensation, should not be in the same directory as the current compensation run, as these files will be overwritten.

```
*KEYWORD
$---+-----1-----+-----2-----+-----3-----+-----4-----+-----5-----+-----6-----+-----7-----+-----8
*INTERFACE_COMPENSATION_NEW
$  METHOD      SL      SF      ELREF      PSID      UNDRCT      ANGLE      NLINEAR
      8      10.000      0.500      2      1      1      0.0      1
*INCLUDE_COMPENSATION_BLANK_BEFORE_SPRINGBACK
../7_iter3.dir/2_trim.dir/dynain
*INCLUDE_COMPENSATION_BLANK_AFTER_SPRINGBACK
../7_iter3.dir/3_spbk.dir/dynain
*INCLUDE_COMPENSATION_DESIRED_BLANK_SHAPE
../1_iter0.dir/2_trim.dir/dynain
*INCLUDE_COMPENSATION_COMPENSATED_SHAPE
../6_compensation.dir/disp.tmp
*INCLUDE_COMPENSATION_CURRENT_TOOLS
../6_compensation.dir/rigid.new
*INCLUDE_COMPENSATION_ORIGINAL_TOOLS
../1_iter0.dir/sim_forming_mesh.k
*INCLUDE_COMPENSATION_TRIM_CURVE
../6_compensation.dir/geotrm.new
*SET_PART_LIST
$  PSID
      1
$  PID
      3
$---+-----1-----+-----2-----+-----3-----+-----4-----+-----5-----+-----6-----+-----7-----+-----8
*END
```

**Updating compensated tool with small amount of part shape change:**

Often times a part will have some small amount of shape change as a result of a product change. If the amount of shape change does not significantly alter the springback results, the compensated tools can be updated with the part mesh (inside the trim lines) or formed blank shape without going through another iterative compensation loop. This is accomplished using the option `PART_CHANGE`. Within the specified `MAXGAP`, compensated tool shape can be updated. It is noted that geometry features such as sharp corners and transition with no fillet are not permissible. A complete keyword example is provided below, where a maximum gap of 5mm is specified between the original shape and modified product shape. The updated part file name is 'updatepart.tmp' and output file for the new rigid tool is 'newrigid.k'.

```
*KEYWORD
*INTERFACE_COMPENSATION_NEW_PART_CHANGE
$   MAXGAP
    5.0
*INCLUDE_COMPENSATION_DESIRED_BLANK_SHAPE
../1_iter0.dir/2_trim.dir/dynain
*INCLUDE_COMPENSATION_COMPENSATED_SHAPE
../6_compensation.dir/disp.tmp
*INCLUDE_COMPENSATION_CURRENT_TOOLS
../6_compensation.dir/rigid.new
*INCLUDE_COMPENSATION_UPDATED_BLANK_SHAPE
./updatedpart.tmp
*INCLUDE_COMPENSATION_UPDATED_RIGID_TOOL
$ file name to output the new rigid tools
./newrigid.k
*END
```

**Reference:**

The manual pages related to `*INCLUDE_COMPENSATION_{OPTION}` can be further referenced for details.

**Revision Information:**

This keyword requires double precision executable. The option of `ACCELERATOR` is available starting in Revision 61264. The option of `MULTI_STEPS` is available starting in Revision 61406. The option of `LOCAL_SMOOTH` is available starting in Revision 73850. The keyword option `*INCLUDE_COMPENSATION_ORIGINAL_TOOL` is available starting in Revision 82701. The keyword option `PART_CHANGE` is available starting in Revision 82698.

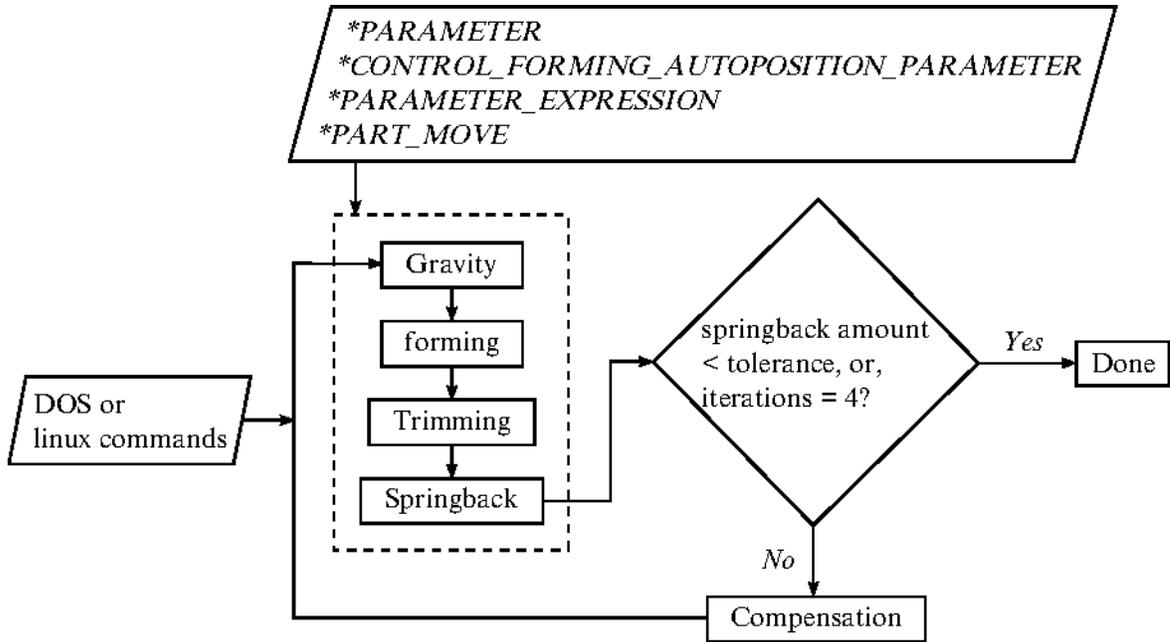
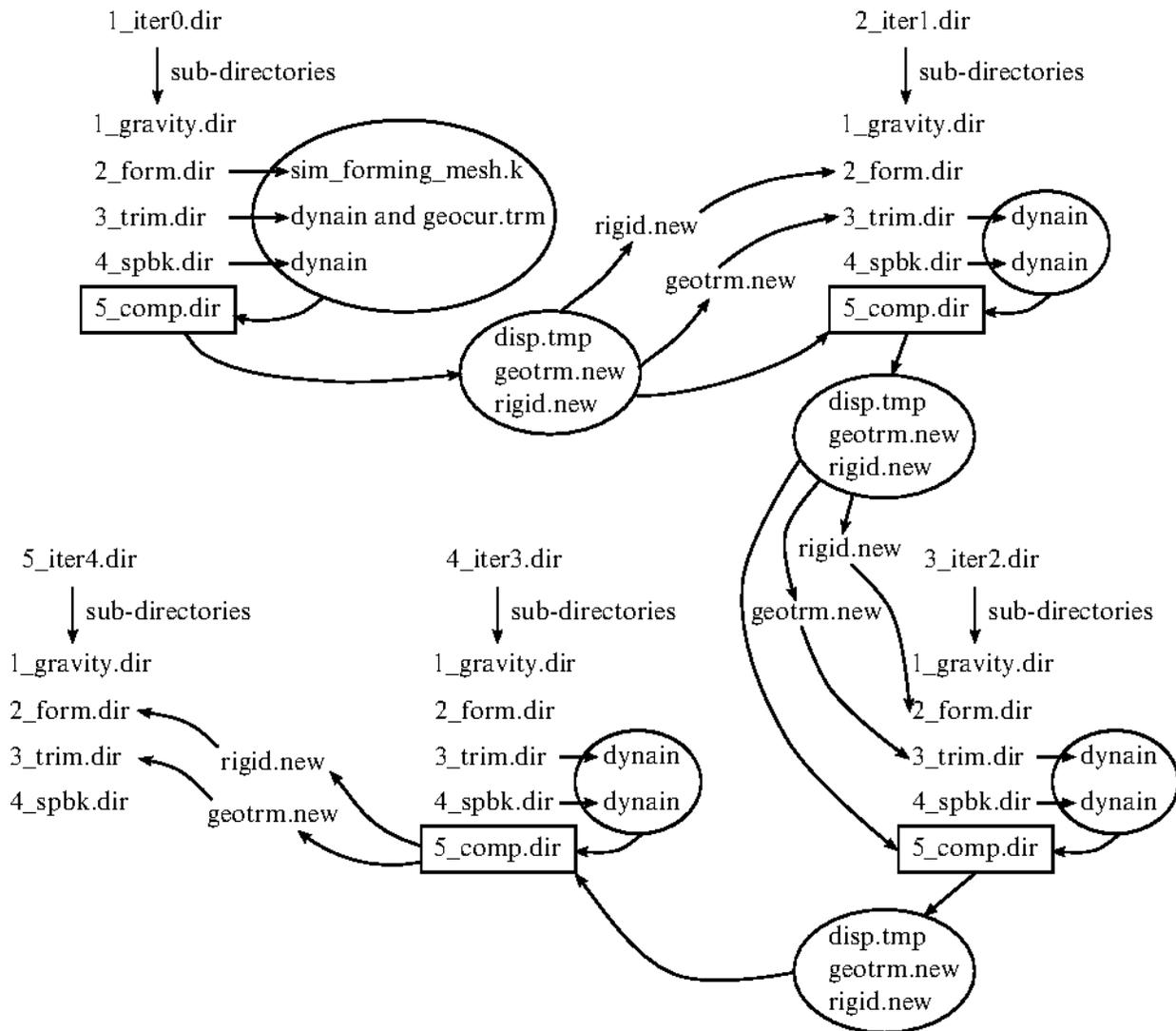
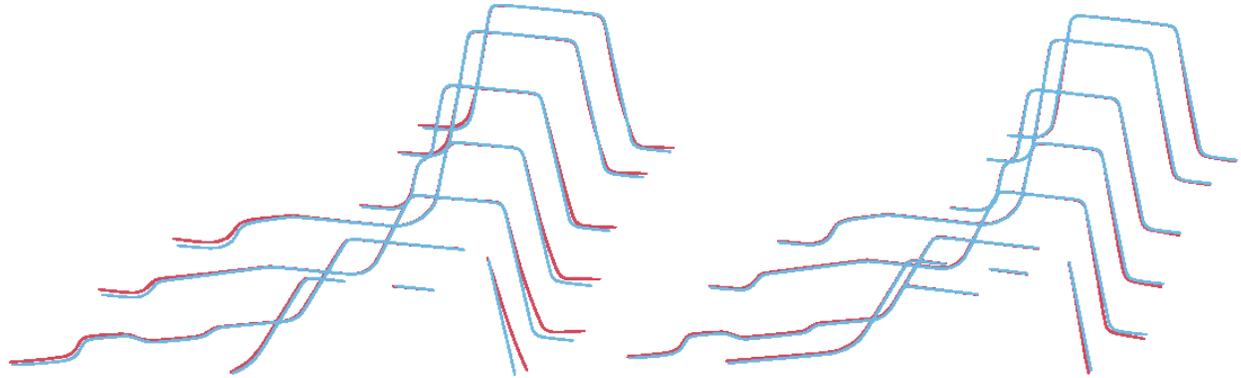


Figure 0-1. Iterative compensation flow chart

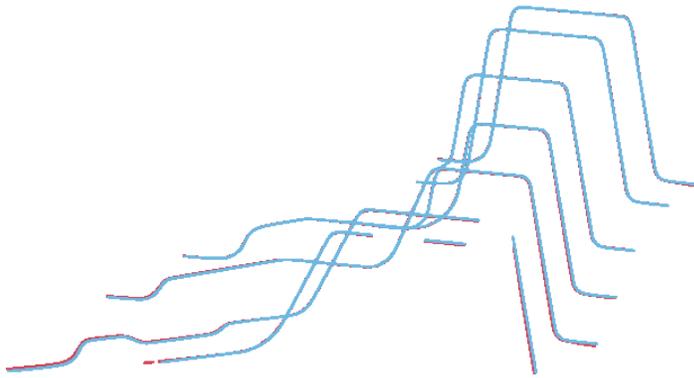


**Figure 0-2.** File structure for compensation

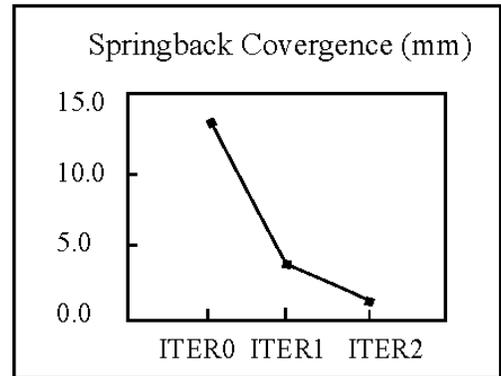


- ITERATION 0
- Max. springback 13mm on flanges

- ITERATION 1
- Springback reduced to < 3.5mm

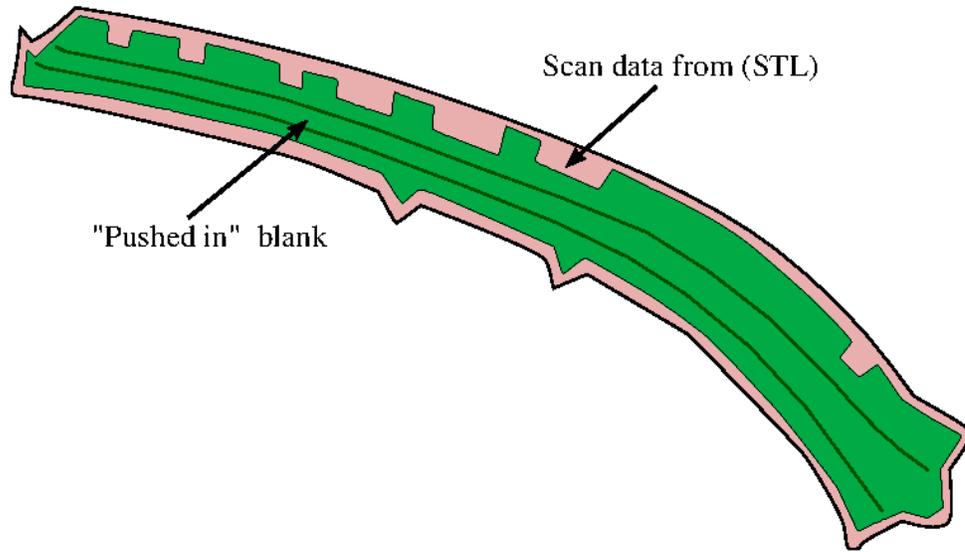


- ITERATION 2
- Springback reduced to < 1.7mm

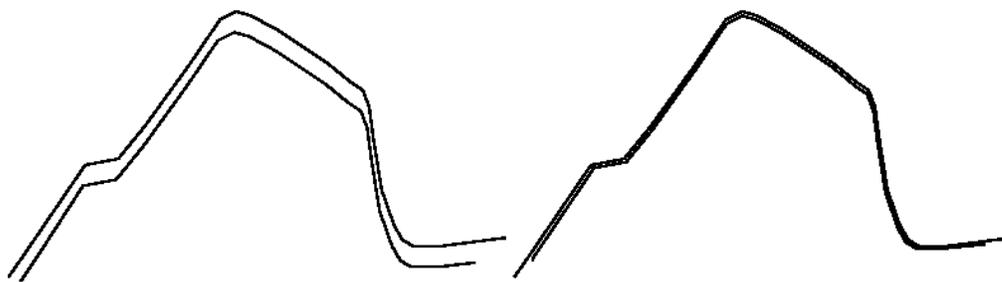


- Compensation convergence history

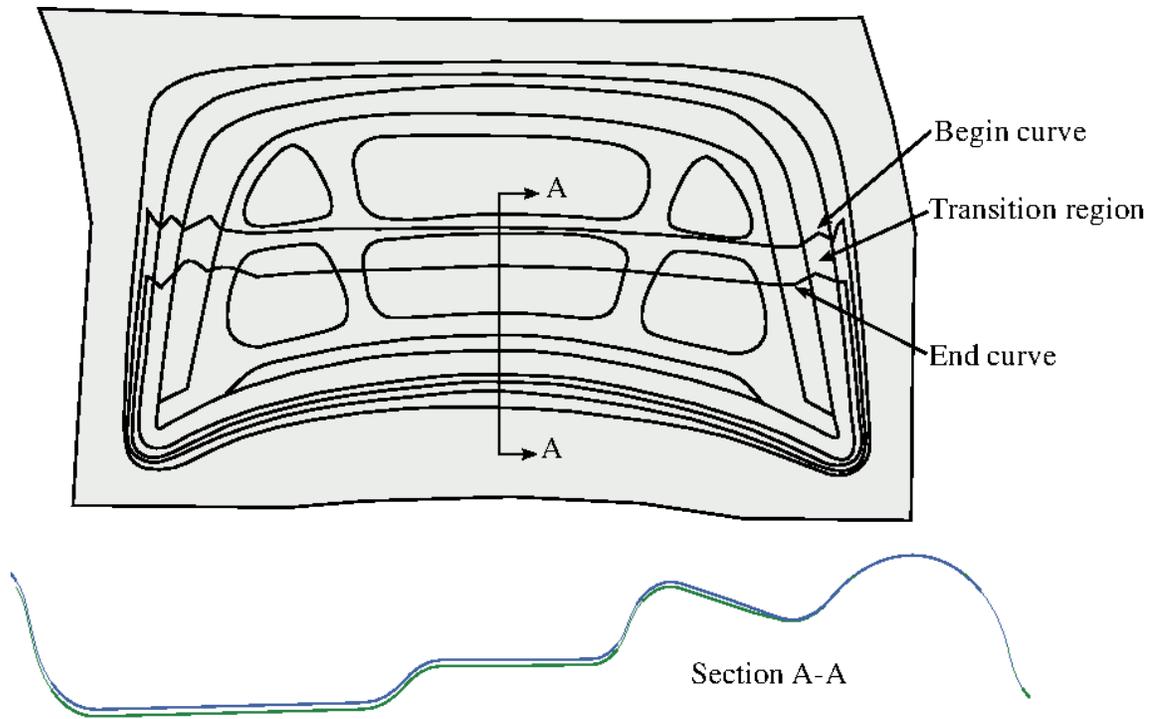
**Figure 0-3.** Iterative springback compensation on NUMISHEET'05 Xnbr(red – springback, blue – design intent)



**Figure 0-4.** A trimmed panel “pushed” onto the scan data (rigid body).



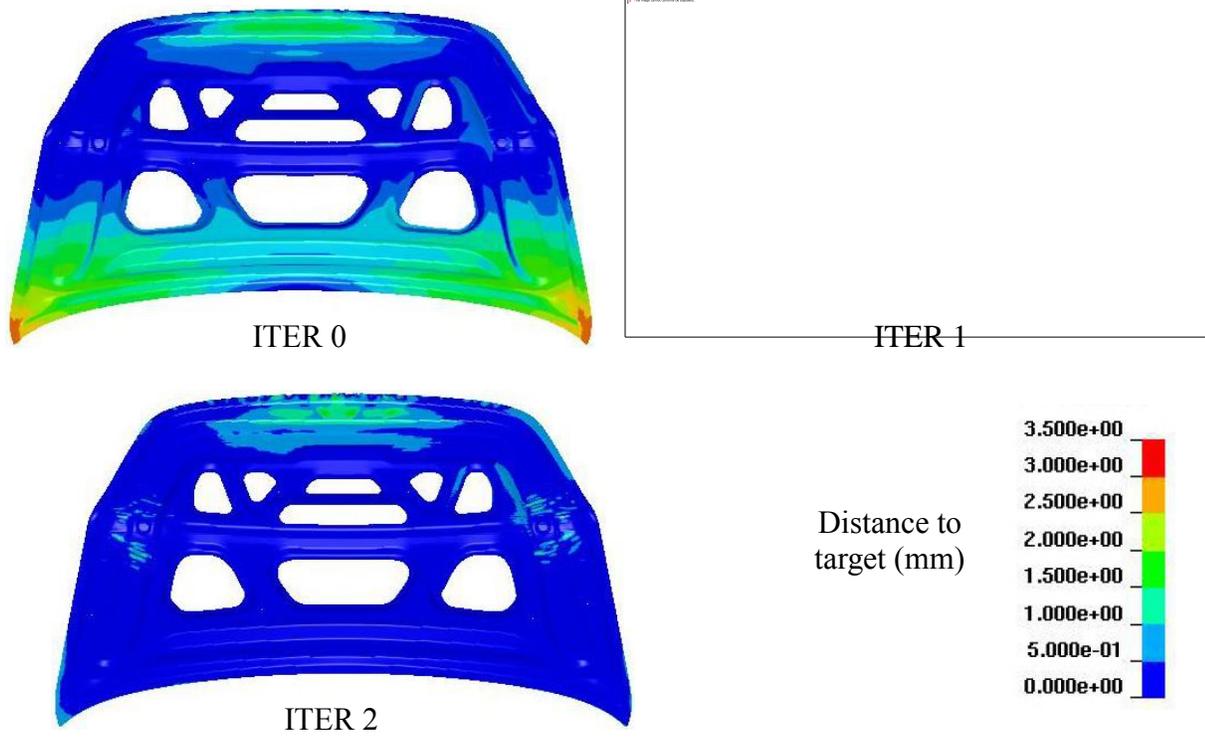
**Figure 0-5.** Section showing the “push” results – before and after.



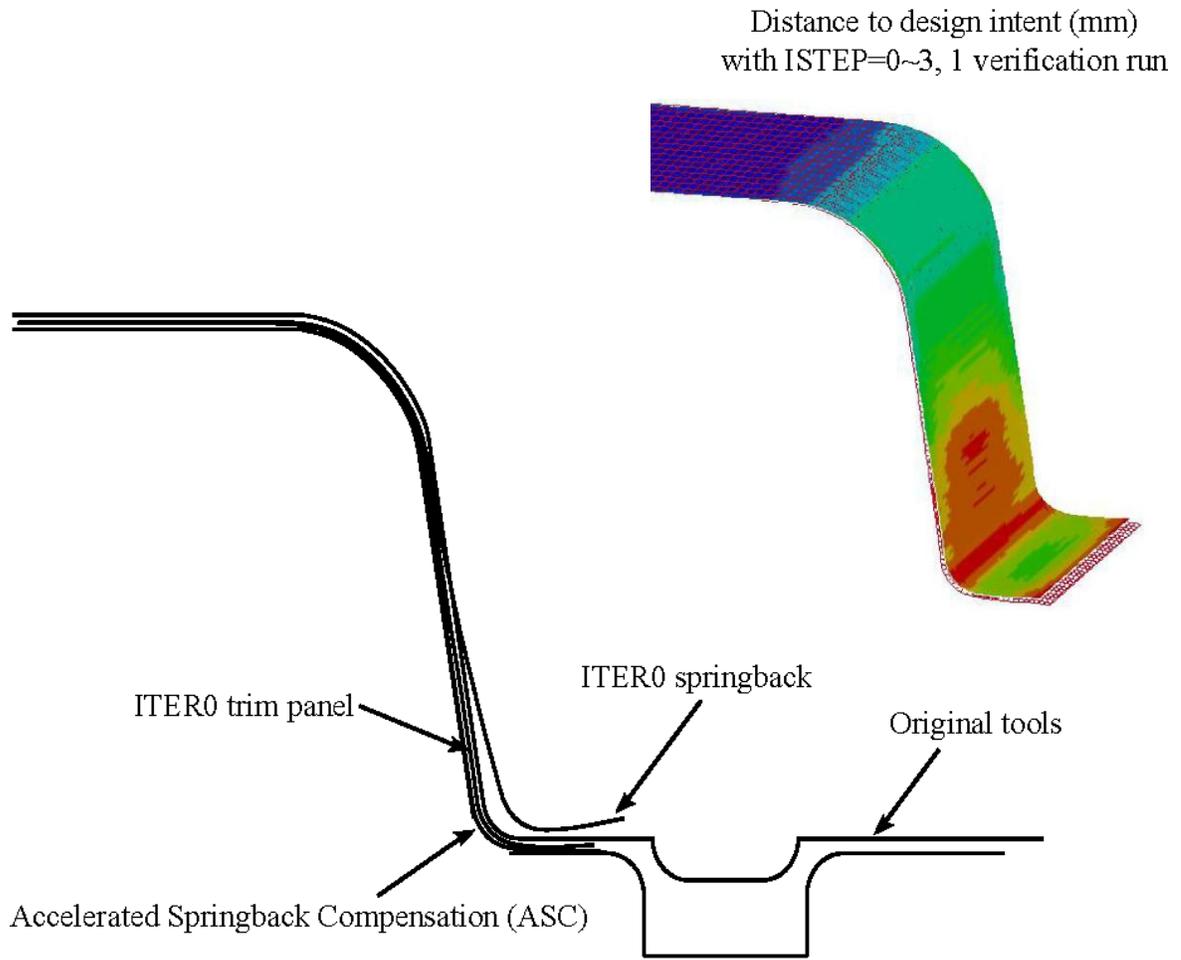
**Figure 0-6.** Two curves defining a localized area of a decklid inner.

# \*INTERFACE

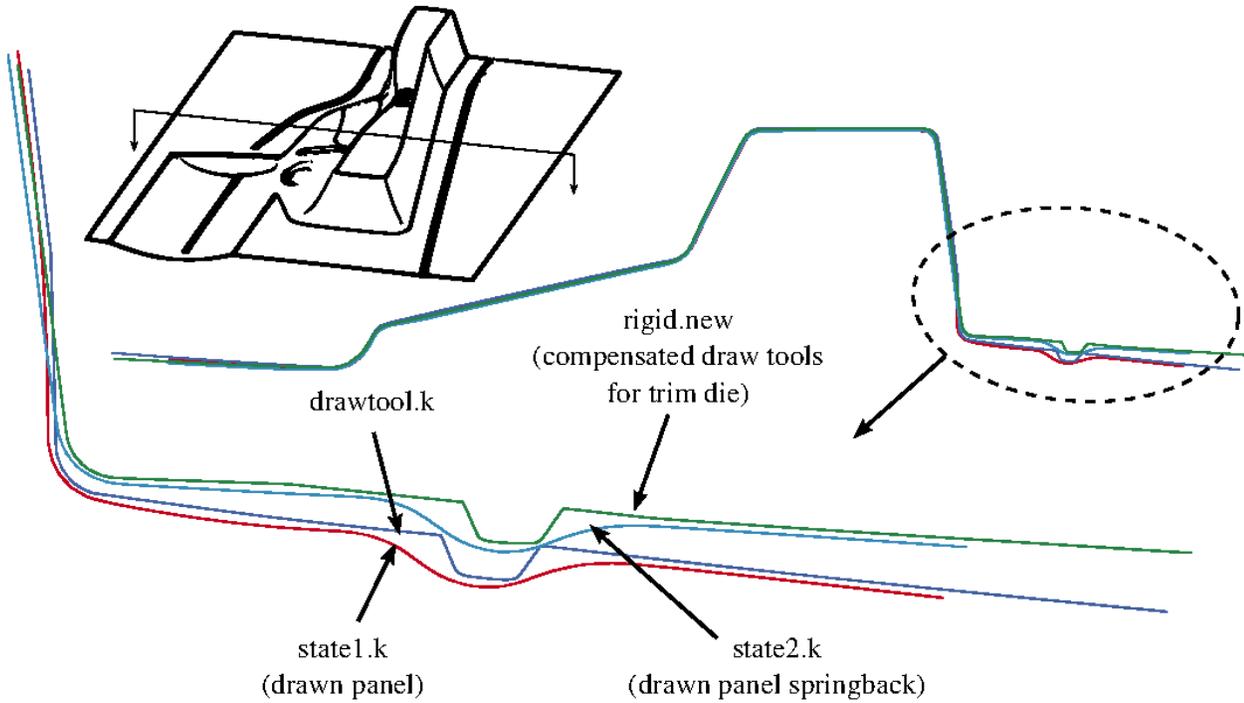
# \*INTERFACE\_COMPENSATION\_NEW



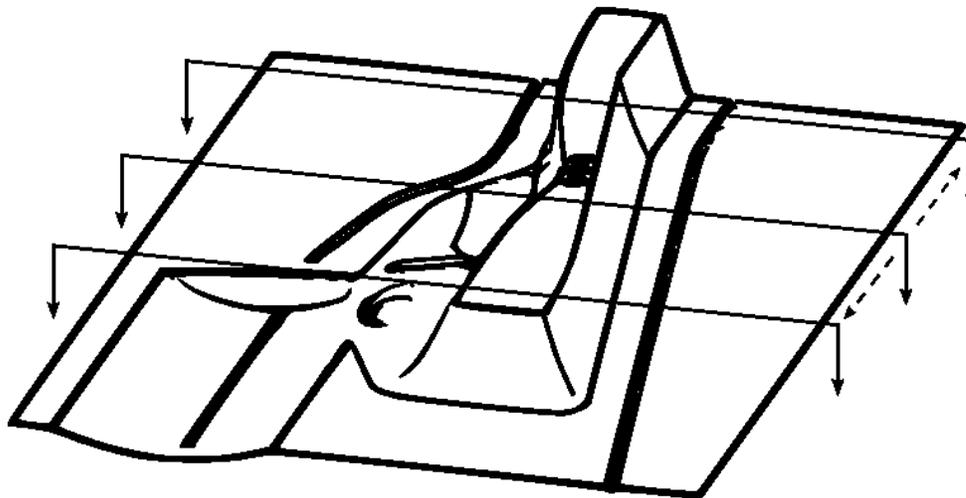
**Figure.0-7** Iterative compensation for a localized region.



**Figure 0-8.** Accerated Springback Compensation.



**Figure 0-9.** Trim die compensation with drawn panel springback shape.



**Figure 0-10.** The NUMISHEET 2005 cross member.

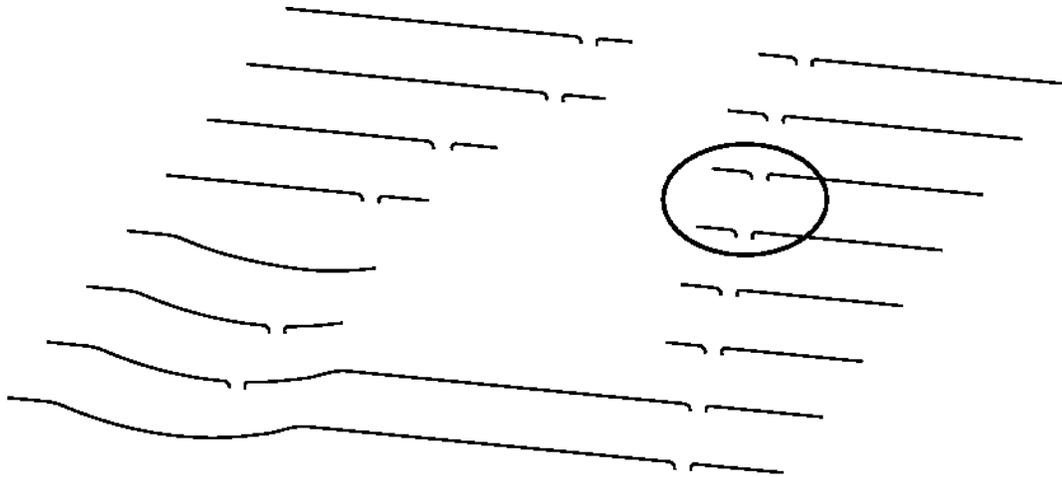


Figure 0-11. Multiple sections cut on the lower binder.

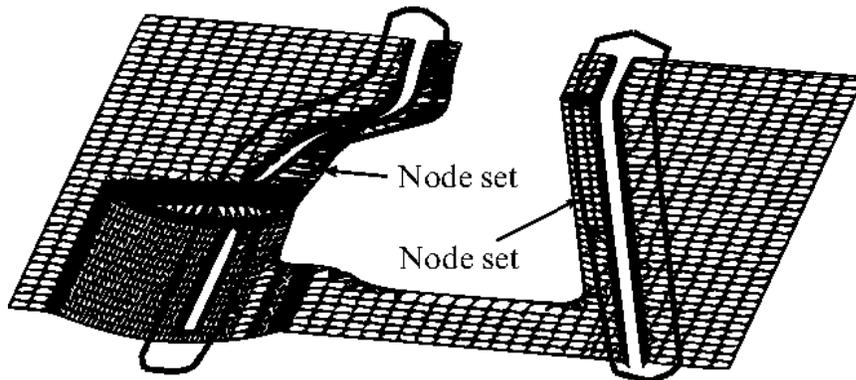


Figure 0-12. Two node sets defined for left and right draw beads.

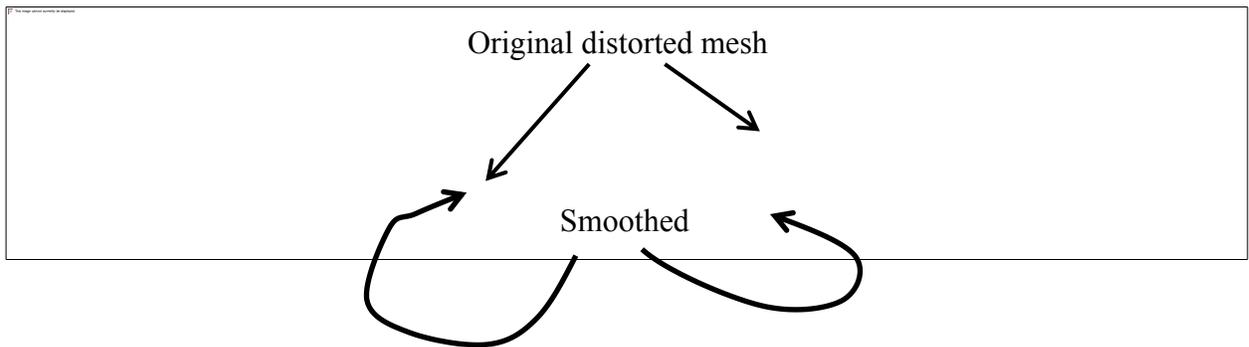
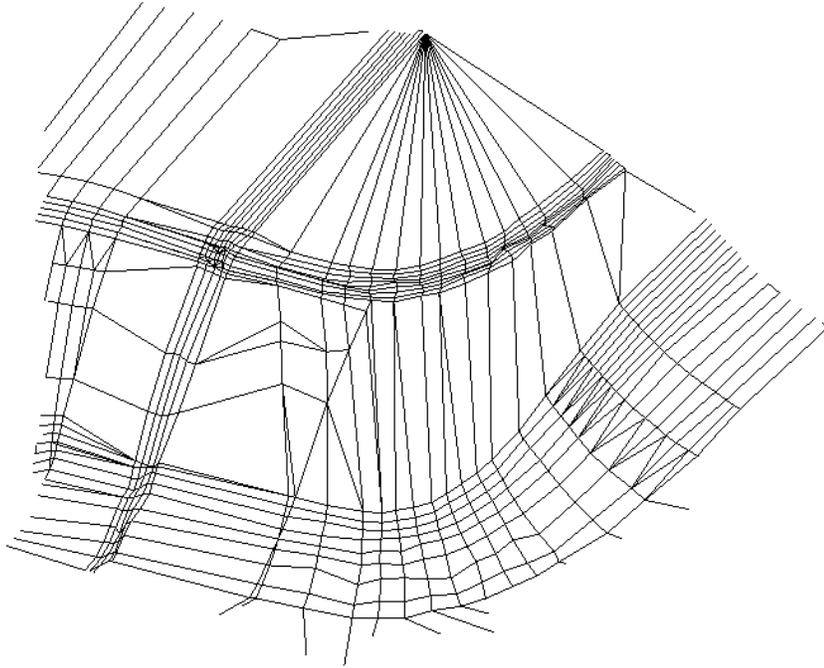
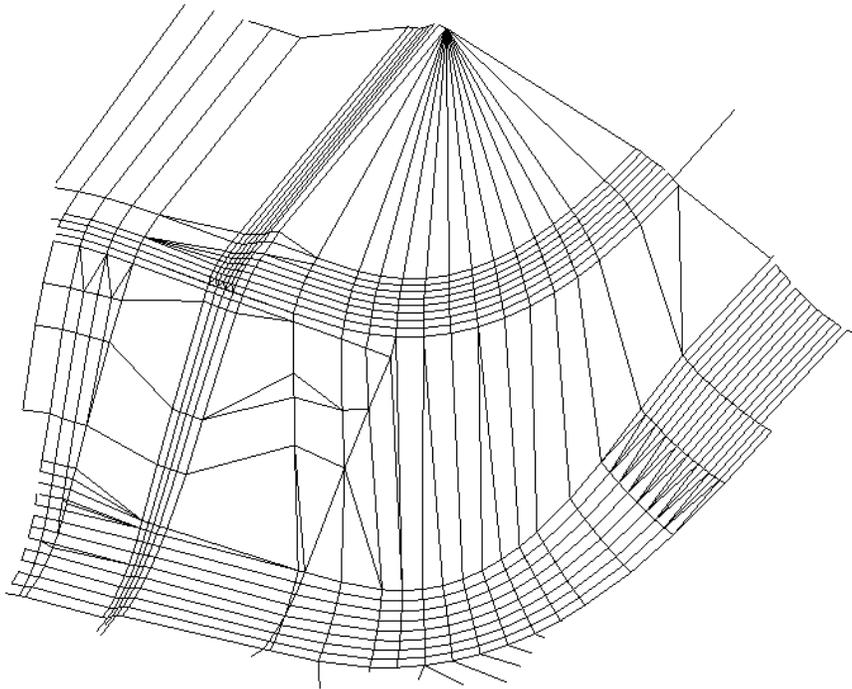


Figure 0-13. Comparison between original and smoothed tooling mesh.



**Figure 0-14.** Original distorted tooling mesh.



**Figure 0-15.** Smoothed tooling mesh.

**\*INTERFACE\_COMPENSATION\_NEW**

**\*INTERFACE**

---