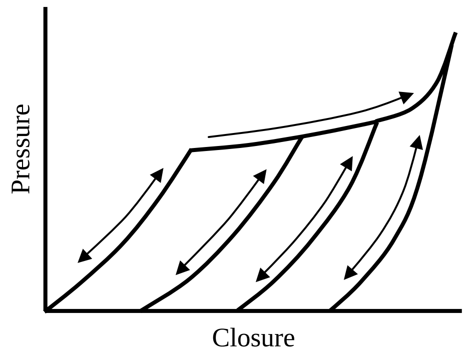
Gasket Materials

Background on Gaskets


Example of Gaskets used in Engines

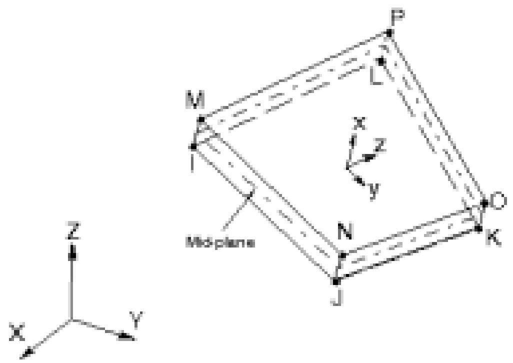
- Gaskets serve two main purposes in many structural assemblies:
  – Provide tight and durable seal between parts
  – Transfer mechanical forces between components
- Characteristics of Gaskets:
  – Multi-layered, metal, elastomer
  – Thin in one direction, but through-thickness behavior is most important
  – Usually negligible in-plane stiffness
  – As a result, can exhibit highly nonlinear loading and unloading behavior with permanent deformations

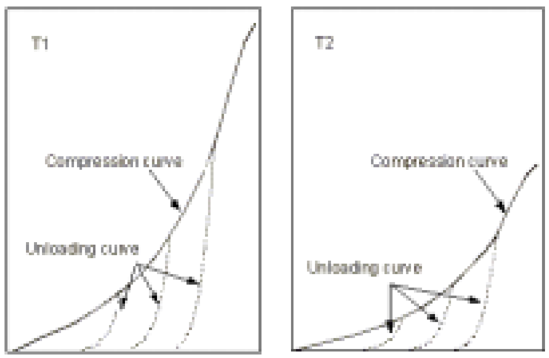
Background on Gasket Behavior



- Because gaskets are often multilayered materials, the overall response is quite nonlinear.
  - Complete gasket behavior is characterized by a pressure vs. mechanical closure relationship
  - Unloading paths can be different, depending on the point at which unloading occurs
  - Permanent deformations can exist in the material, as shown in the curve on right

Gasket Material and Elements





- In 6.1, gasket material and elements have been introduced to model gasket behavior
  - Gasket material provides simplified relationship
    - Pressure vs. closure relationship is input *directly*, rather than needing to model layers in detail
    - This is more computationally efficient, as regular continuum and contact elements are not required
    - Gasket interface elements are designed to have one element thru thickness, so easier modeling.
  - Gasket pressure vs. closure relationship provides response of gasket material
    - Pressure vs. closure relationship can be determined *experimentally* (test data)
    - A separate FE model with continuum elements may be used to calculate curves *analytically*

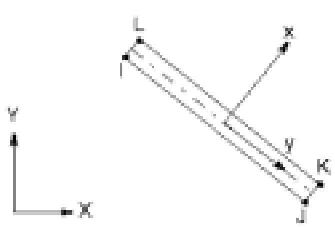
Gasket Material Procedure

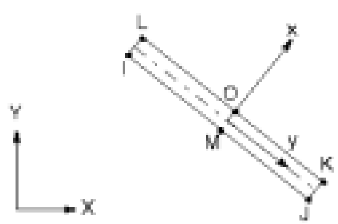
Procedure for Gasket Joint Simulation

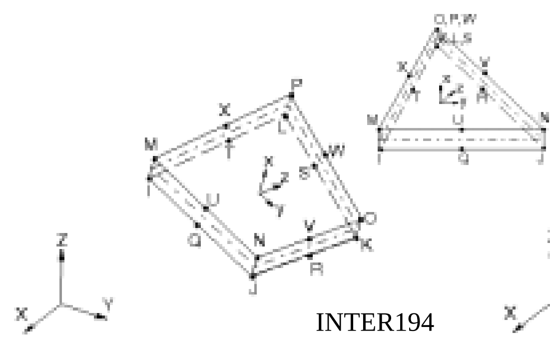
- Besides regular steps associated with any nonlinear analysis in ANSYS, gasket joint simulation requires some additional steps:
  1. Define INTER19x interface elements for use with gasket material.
  2. Define TB,GASKET gasket material parameters, including compression and unloading curve(s).
  3. Generate INTER19x elements, ensuring one element through thickness with correct node numbering.
  4. Apply all other loads/b.c. and solving model.
  5. After solution, postprocess gasket elements separately.

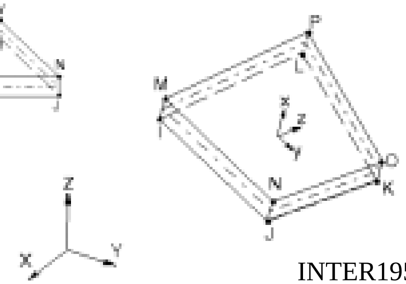
1. Specifying Interface Elements

- The Interface (INTER19x) family of elements has been introduced to model gasket behavior.
  - INTER192 is 4-node linear planar element
  - INTER193 is 6-node quadratic planar element
  - INTER194 is 16-node quadratic solid element
    - Degenerate wedge form allowed
  - INTER195 is 8-node linear solid element


INTER192

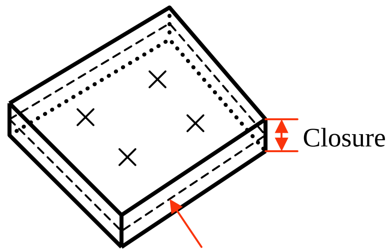

INTER193


INTER194

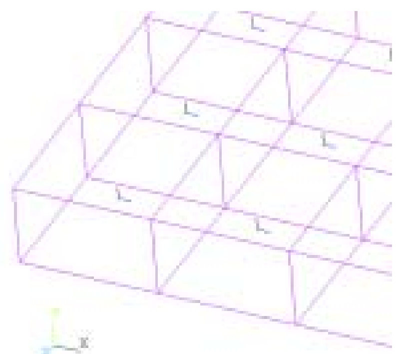

INTER195

Specifying Interface Elements (cont'd)

Sample Interface Element



Integration point locations on midplane shown with "x"



/PSYM,ESYS,1 with /DEV,VECTOR,1 shows element CS, x-axis in thickness direction

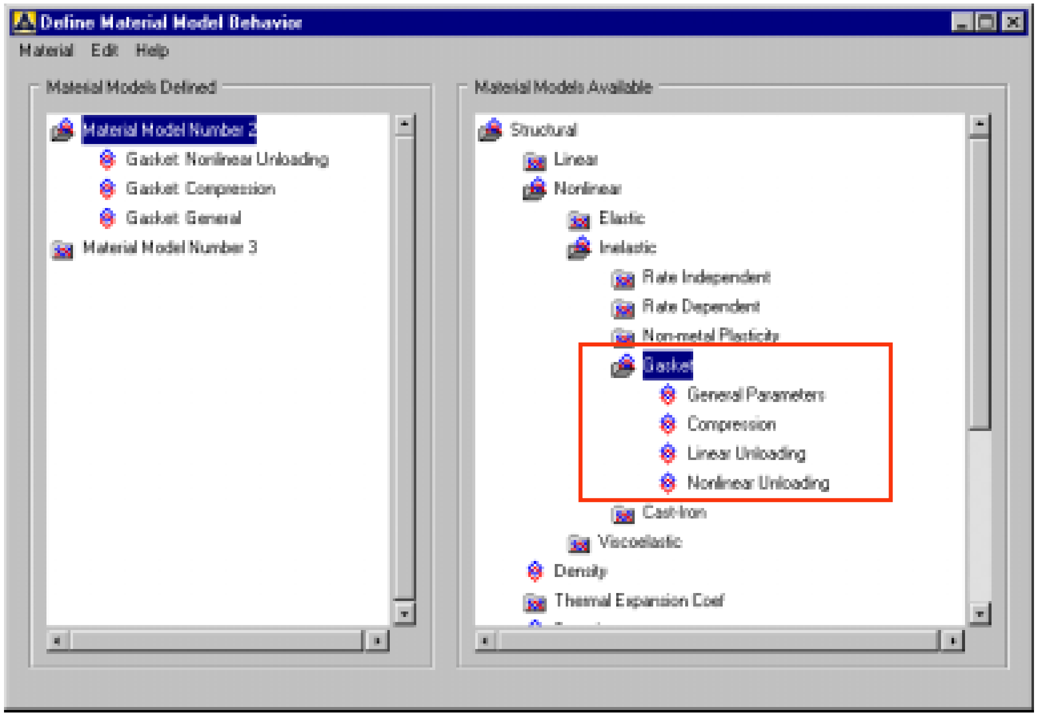
- The interface elements need *closure* value:
  - *Closure* is the relative displacement between top and bottom of gasket. This is required since behavior is defined by pressure vs. closure.
  - Hence, gasket must be only *one element thick.*
  - The *midplane* of the element serves as the location where numerical integration is performed (different from continuum elements)
  - Element coordinate system not affected by ESYS but by node numbering.
    - Node number determines 'top' and 'bottom' of element to calculate closure distance correctly
    - Special meshing considerations apply
    - Use of /PSYM,ESYS,1 can be used to verify element x-axis is oriented correctly.

Specifying Interface Elements (cont'd)

- Specifications of the Interface Elements:
  - Gasket elements require that top and bottom nodes are matching
  - For computational efficiency, it is recommended to connect gasket interface elements with other non-interface elements directly.
  - Higher-order interface elements (INTER193, 194) do not have midplane nodes.
    - No midplane nodes since midplane is calculated by averaging top and bottom nodes only
    - The higher-order elements are currently not compatible with other elements (such as heat-transfer elements) in sequential coupled-field analyses

2. Defining Gasket Material

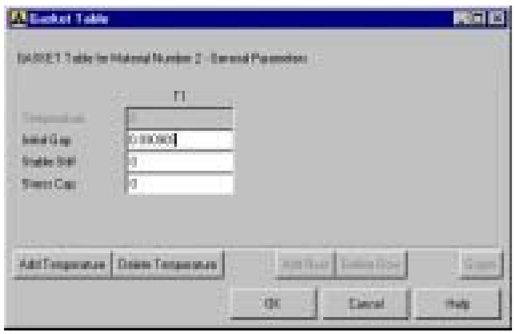
- The gasket material can be specified in the Materials GUI:



Main Menu > Preprocessor > Material Props > Material Models…
Materials GUI > Structural > Nonlinear > Inelastic > Gasket

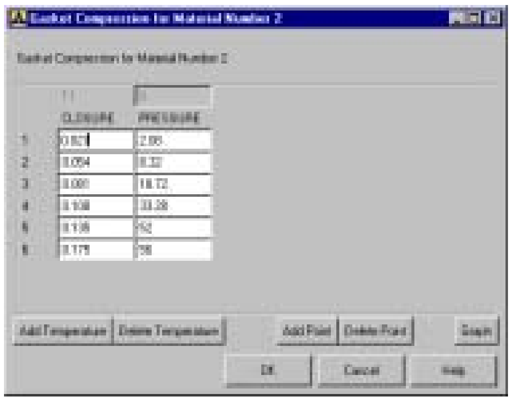
Defining Gasket Material (cont'd)

- *General parameters* can be defined for each gasket material
  - If an initial gap exists, this can be input.
    - Default value is zero (no initial gap).
  - "Stable Stiff" is for numerical stability.
    - The default value is zero.
    - This is required in some cases, for example, if gasket is opened and no stiffness is present (see next point), which may cause numerical difficulty.
  - A stress cap for tension can also be defined.
    - By default, no tensile stiffness (zero) is assumed
    - Tensile stiffness (if allowed by non-zero value) is first slope of compression curve.
  - There is no limit on the number of temperature-dependent sets for gasket parameters.

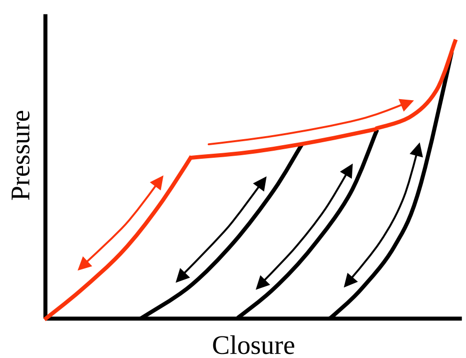



```
TB,GASKET,2,1,,PARA
TBTEMP,0.0
TBDATA,1,1/11,0,0
```

Defining Gasket Material (cont'd)



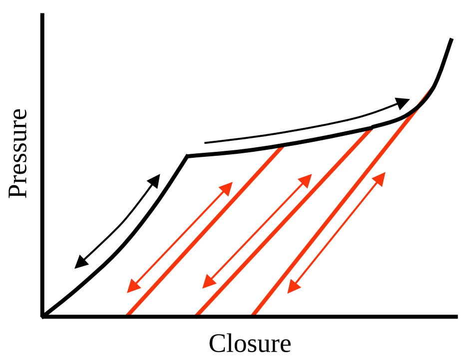

```
TB,GASKET,2,1,6,COMP
TBTEMP,0
TBPT,,0.027,2.08
```



- The *Compression curve* defines loading behavior.
  - Pressure vs. closure (not stress vs. strain) is input to characterize thru-thickness response.
  - *Closure* is the relative displacement between the top and bottom of gasket.
  - In-plane stiffness assumed to be negligible
  - There is no limit on the number of data points or of temperature sets which can be defined

Defining Gasket Material (cont'd)

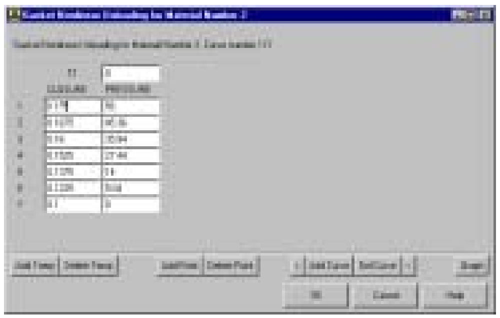

```
TB,GASKET,2,1,5,LUNL
TBTEMP,0
TBPT,,0.1524E-03,2.43E+11
```



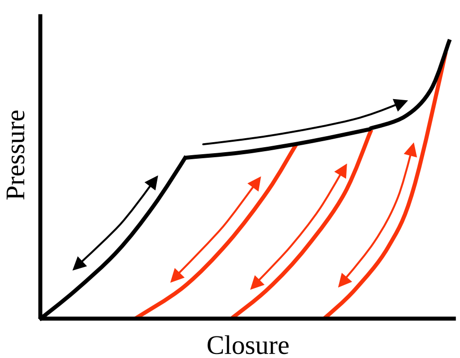
- The *Linear Unloading* option is one way of defining unloading behavior.
  – Provides a simple way of defining unloading behavior by specifying a straight line
  – Each entry consists of closure value at which unloading starts and unloading slope
  – Input more 'points' for each unload slope
  – Inelastic behavior (permanent deformation)
  – There is no limit on the number of unloading slopes, data points, or temperature sets which can be defined.

Defining Gasket Material (cont'd)

- The *Nonlinear Unloading curve* is the other way of defining unloading behavior.
  - Provides a more complex way of defining unloading behavior by specifying a piecewise linear curve
  - Each point consists of a closure and pressure pair. Add more points to define entire curve
  - For permanent deformation, ensure that each curve has a pressure value of zero with a non-zero closure value.
  - Repeat process for each curve desired.
  - There is no limit on the number of data points, unloading curves, or temperature sets which can be defined

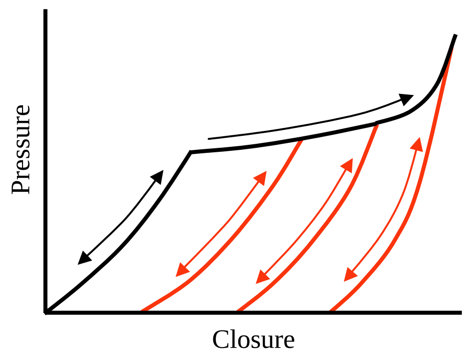


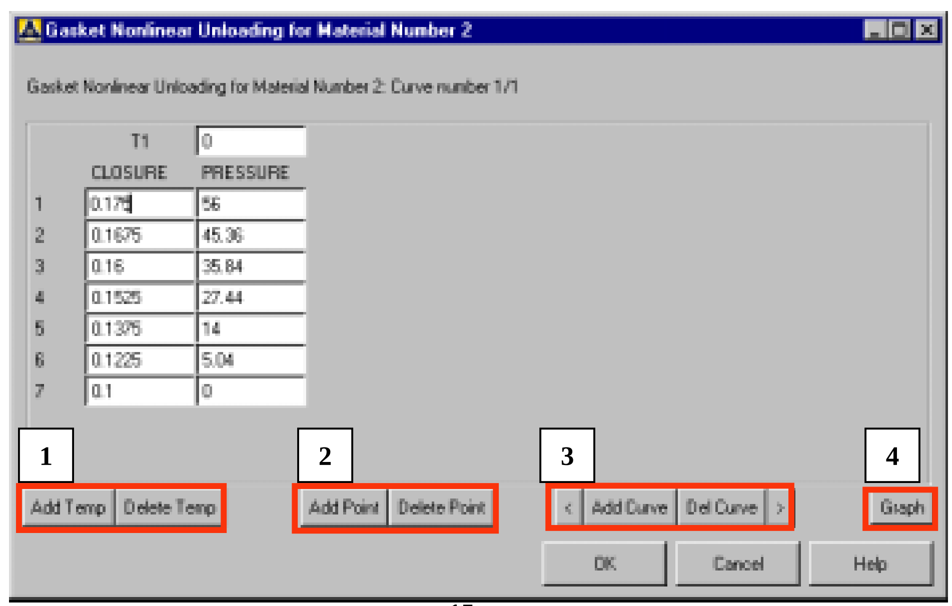
```
TB,GASKET,3,,6,NUNL
TBTEMP,0.0
TBPT,,1.78E-04,1.49E+07
```



Defining Gasket Material (cont'd)

- The *Nonlinear Unloading curve* dialog box has a few features to make input easier.
  1. Ability to add temperature sets
  2. Ability to add/remove points along a given curve
  3. Ability to add/remove/browse through curves
  4. Ability to plot resulting curves





Defining Gasket Material (cont'd)


```
MP,ALPX,1,20e-6
MP,REFT,1,20
```

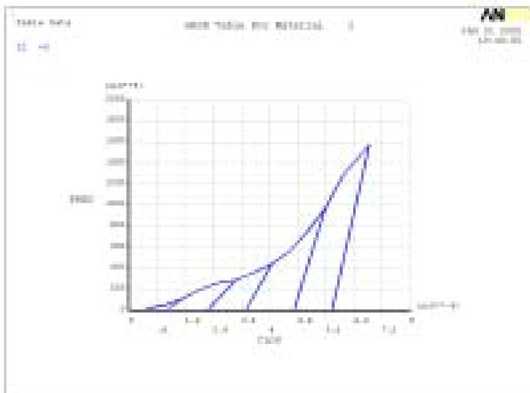
- *Coefficient of Thermal Expansion* can also be defined.
  - Thermal expansion occurs in element x-direction only (through-thickness)

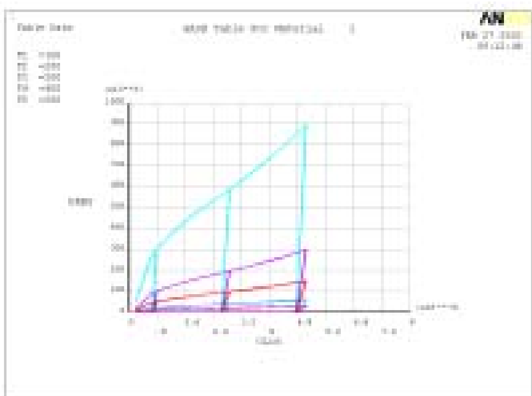
$$d_{th} = \alpha_x \cdot \Delta T \cdot h$$

or

$$GKTH = ALPX \cdot (T - REFT) \cdot Height_{INTER19x}$$

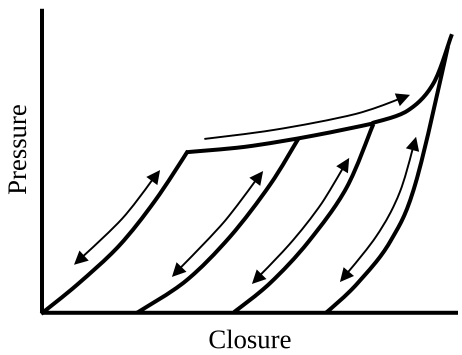
Defining Gasket Material (cont'd)





- After defining data, be sure to plot data to verify correct input
  - Plot compression/unloading curves, including any temperature-dependencies which may be present
  - Ability to plot is in dialog box for compression/unloading curves or via
    - Utility Menu > Plot > Data Tables …
    - TBPLOT,GASKET,matno,tbopt,temp,segn
      - The *matno* option is material number
      - The *tbopt* option is all gasket data, compression, or unloading data only
      - The *temp* option is what temperatures to plot (all or curves associated with specified temperature)
      - The *segn* option is to add segment numbers on the plot.

Defining Gasket Material (cont'd)

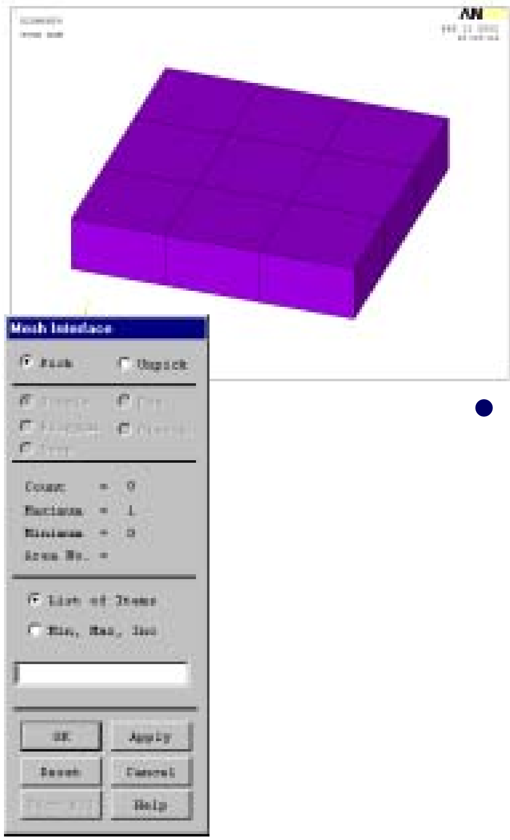


- Assumptions related to gasket material
  - If response is outside of compression curve, slope of last segment is used.
    - For temperatures between defined temperature sets, linear interpolation is used
    - If outside of temperature range, closest temperature data of compression curve will be used.
  - Linear or nonlinear unloading can be defined.
    - If unloading occurs between defined curves, linear interpolation is used
    - If outside of closure range, closest closure values are used for unloading curve.
    - Reloading occurs along unloaded path
  - Response assumed to be rate-independent
    - Rate-dependent effects currently not considered.
    - Cannot combine with other nonlinear material models.

3. Generating Interface Elements

- The INTER19x elements have special considerations for mesh-generation:
  - INTER19x elements require *only* one element through thickness
  - Node numbering is important for INTER19x elements to determine element normal
    - /PSYM,ESYS,1 can be used to verify element normal, with element x-axis pointing in thickness direction
  - Higher-order INTER193,194 do not have nodes on its midplane
- Because of this, the IMESH command has been introduced.
  - User can use IMESH to generate INTER19x
  - If other methods are used, such as VDRAG or EGEN, user must verify above points.

Generating Interface Elements (cont'd)

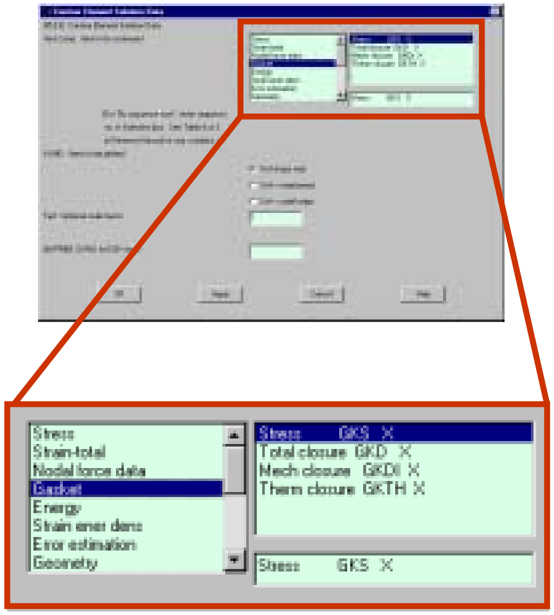


- After defining and activating appropriate INTER19x element types and GASKET materials, issue IMESH to create elements:
  - Main Menu > Preprocessor > Meshing > Mesh > Interface Mesh > 2D/3D Interface +
  - IMESH, *laky, nsla, ntla, kcn, dx, dy, dz, tol*
- Other meshing methods need special considerations
  - VDRAG, EGEN can be used to generate all INTER19x elements
  - VMESH, VSWEEP cannot be used to generate INTER19x elements

4. Solving Model

- Although gasket closure is considered to be inelastic, CUTCONTROL does not currently account for gasket closure for bisection purposes. Hence, the user should ensure that the timestep is small enough to capture path-dependent response
- Use of 17x contact elements with gasket elements are available for situations with non-matching meshes.

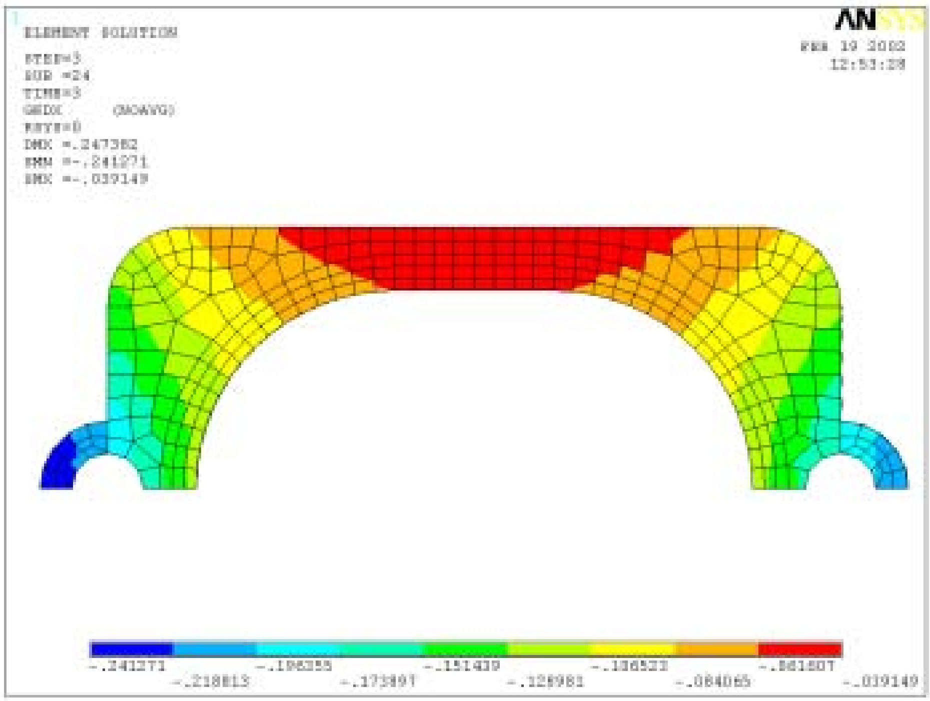
5. Postprocessing Gasket Elements

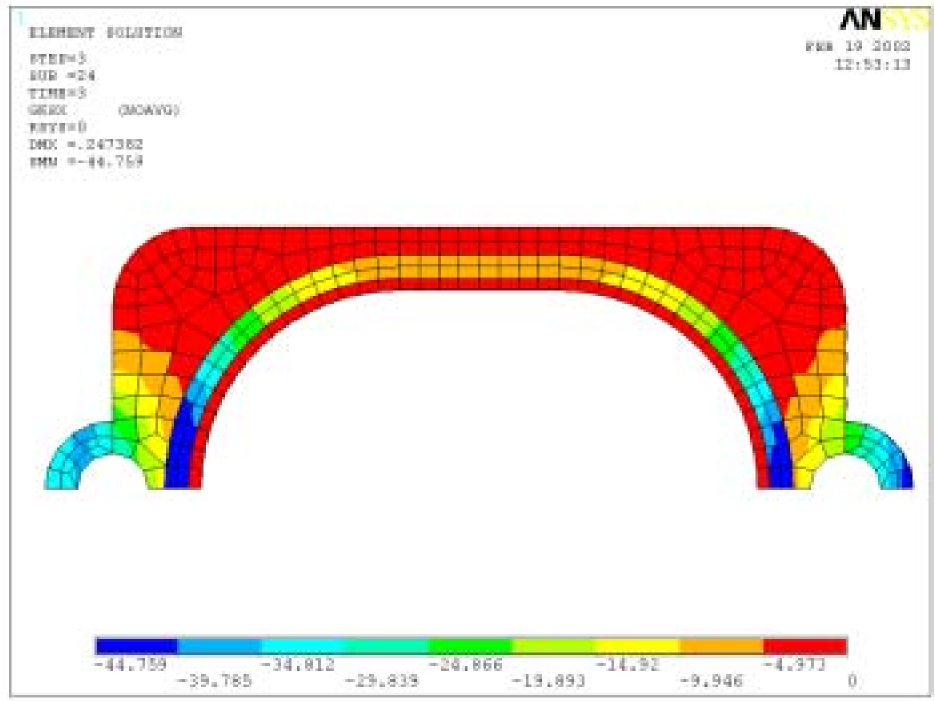


- Gasket output is available as a separate postprocessing item
  - Similar to 17x contact output, gasket output is specific to the interface elements, so a separate gasket output category is available.
  - Gasket stress and closure values are available. Closure is subdivided to mechanical and thermal closure, and 'total closure' is the sum of the two.
  - Users can list or plot element or nodal gasket solution in the General Postprocessor with PLESOL, PLNSOL, PRESOL, PRNSOL.
  - For Time-History Postprocessing, ESOL supports Gasket output.
  - Ability to define a coordinate system for output of gasket pressure and closure

Postprocessing Gasket Elements

- Sample contour plot of gasket total closure (left) and gasket pressure (right) with two materials.



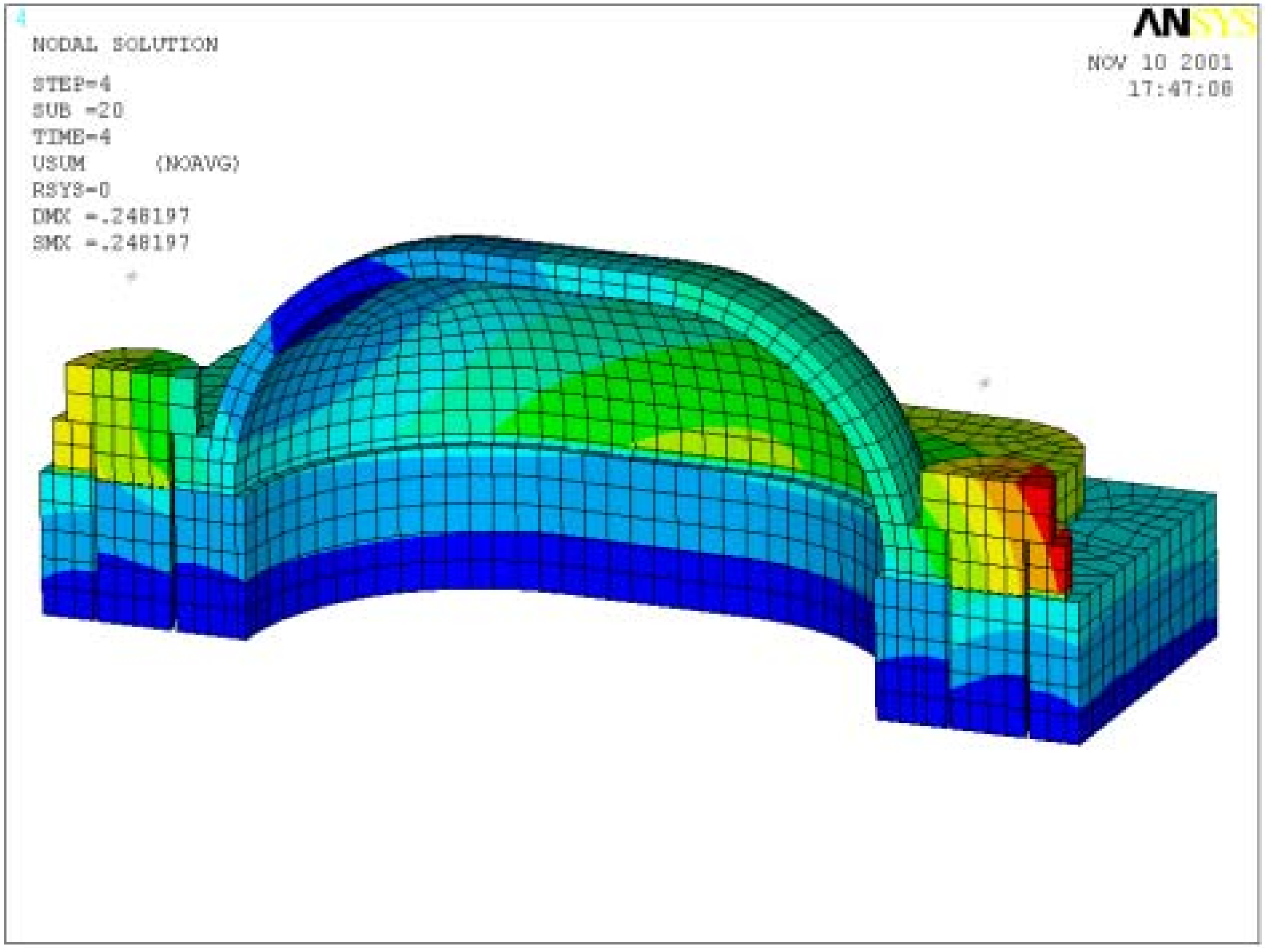


Postprocessing Gasket Elements

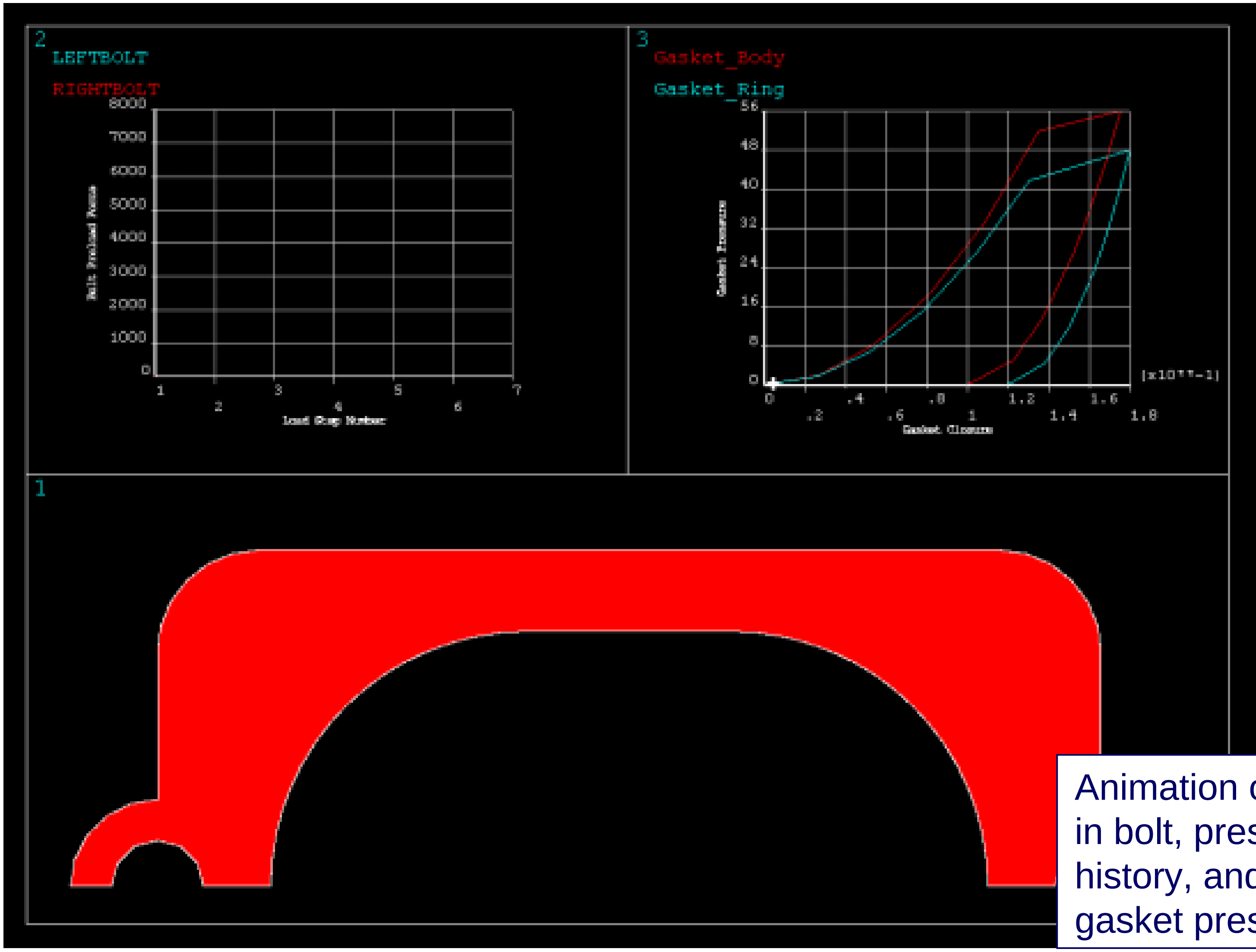
- Some additional points to keep in mind:
  - Gasket mechanical closure (GKDI,X) includes any initial gap, if specified, so user should keep this in mind when postprocessing. If comparing pressure vs. closure relationship directly, user will need to offset results by initial gap value.
  - For general postprocessing, Query of gasket output is not currently available.
  - For time-history postprocessing, ANSOL is not currently supported for Gasket output at 6.1.

Example of Manifold Assembly

- SOLID185 and INTER195 with gasket material and PRETS179:



Example of Manifold Assembly (cont'd)



Animation of reaction forces in bolt, pressure/closure history, and contour of gasket pressure.