MSC SOFTWARE
SIMULATING REALITY

Special Interest Group

Integrated Structural Analysis

VPD Conference

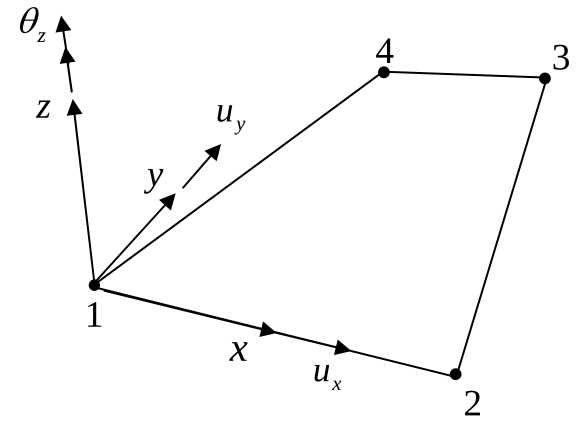
Huntington Beach
October 20, 2004

Proposed Subjects

- Shell and Connector Modeling
  - New defaults SNORM=20. and K6ROT= 100.
  - QUADR
  - Connector modeling techniques
- Dynamics
  - RESVEC
  - MODESELECT
  - Enforced motion
- Global-Local Analysis

Problems with Membrane Rotations in Shells

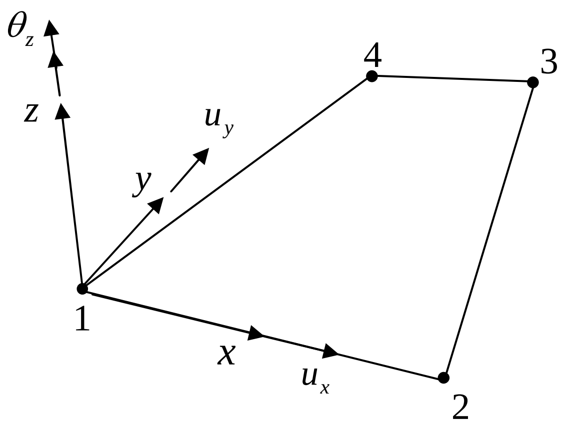
- Mindlin shells have no stiffness in the membrane rotation θ_z normal to the shell plane
- The rank deficiency can be automatically removed, for example using AUTOSPC in MSC.Nastran
- The membrane rotation may be loaded either by accident or intentionally, for example, through stiffeners, spot welds, rigid elements, concentrated masses, etc.
- False load transfers or spurious modes may occur



MSC SOFTWARE SIMULATING REALITY

How to Avoid Problems with Membrane Rotations

- Force the user to clean up the model so that membrane rotations are not loaded
- Make the element more robust
  - Introduce a penalty stiffness for the membrane rotations
  - Introduce a real stiffness in membrane rotations , a shell element with 6 dof per node



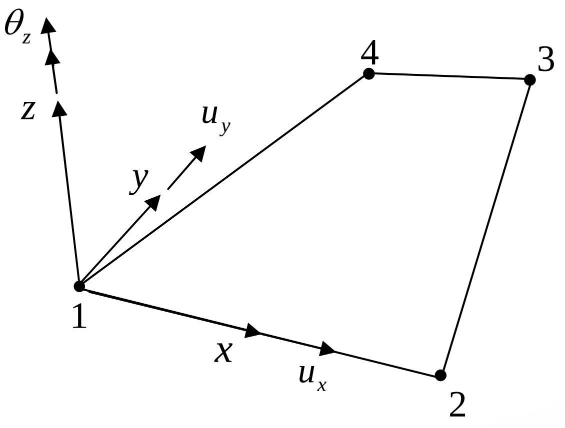
Penalty Stiffness for Membrane Rotations in QUAD4

A penalty term is added to the energy functional

$$\Pi_p = 10^{-6}\ \mathrm{K6ROT}\ \frac{1}{2} G \int_A (\Theta_z - \Omega_z)^2 t\, dA$$

with

$$\Omega_z = \frac{1}{2}\left(\frac{\partial u_y}{\partial x} - \frac{\partial u_x}{\partial y}\right)$$



Defaults:

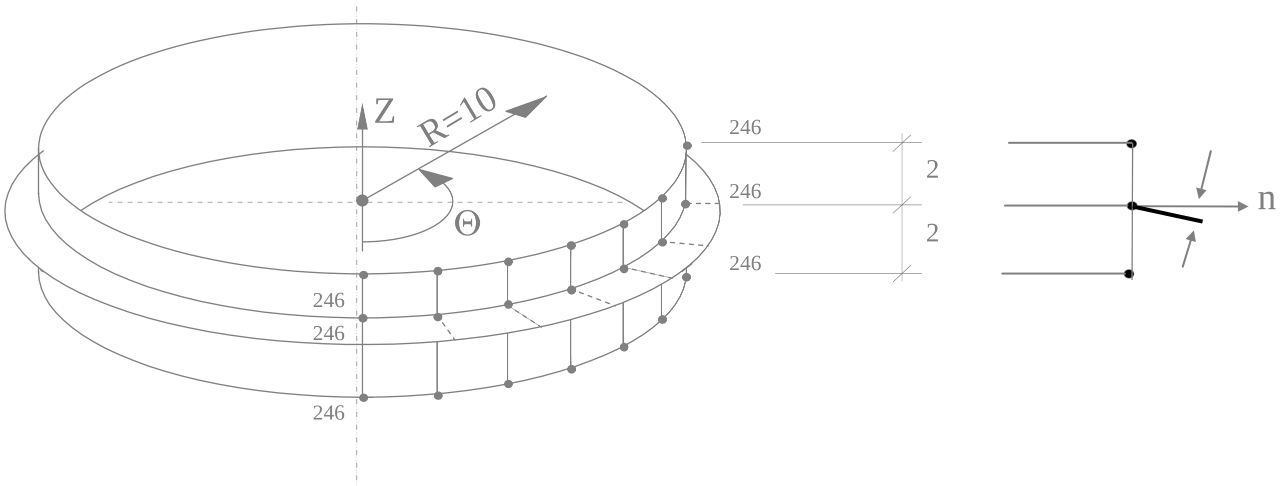
K6ROT= 100. Default since V2004

SNORM= 20. Shell normals are default since V2001

Effect of K6ROT – Ring with Stiffener

- **Unintentional loading of the drilling degree-of-freedom occurs in some cases, for example, in stiffened shells modeled with beams and offsets.**

Cylindrical Ring with Stiffener



Ring Modeled with CQUAD4
Stiffener modeled with CBARS and offset
No I2 specified on PBAR
Offset direction and normal direction differ slightly

MSC SOFTWARE
SIMULATING REALITY

Effect of K6ROT – Ring with Stiffener (cont.)

Normal Modes of Cylindrical Ring with Offset

K6ROT	SNORM	Offset Disturbance	Comments
0.	20.	$\varepsilon \leq 1.8E-4$	1 rigid body mode No spurious modes AUTOSPC catches singularity 2nd mode 9.667
0.	20.	$\varepsilon \geq 1.9E-4$	1 rigid body mode 5 spurious modes 7th mode 9.734
100.	20.	$\varepsilon \geq 1.9E-4$	1 rigid body mode No spurious modes 2nd mode 9.655

With PARAM, K6ROT, 100., we always get 6 rigid body modes for a free system, here we get only 1 rigid body mode due to symmetry conditions

Effect of K6ROT

Special Remark for Plane Stress Problems

- For plane stress problems (membrane only), it is common practice to constrain the 6th dof , SPC 3456 if plane stress is in the x-y plane
- No problem if K6ROT=0.
- The structure is grounded if the 6th dof is constrained and K6ROT=100.
- Do not constrain 6 if K6ROT= 100. or set K6ROT=0. for plane stress problems

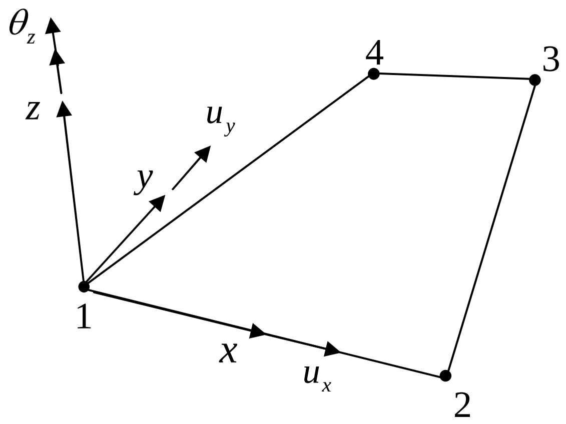
QUADR with 6 Degrees of Freedom per Node

The membrane displacements and the membrane rotations are coupled with quadratic shape functions, for example, the displacement at the midpoint of edge 1-2 is

$$\boldsymbol{u}_m = \frac{1}{2}(\boldsymbol{u}_1 + \boldsymbol{u}_2) + \frac{1}{8} l_1 (\Theta_{z2} - \Theta_{z1}) \boldsymbol{n}_1$$

The following term is added to the energy functional

$$\Pi_\Theta = \frac{1}{2} G \int_A (\Theta_z - \Omega_z)^2 t \, dA$$

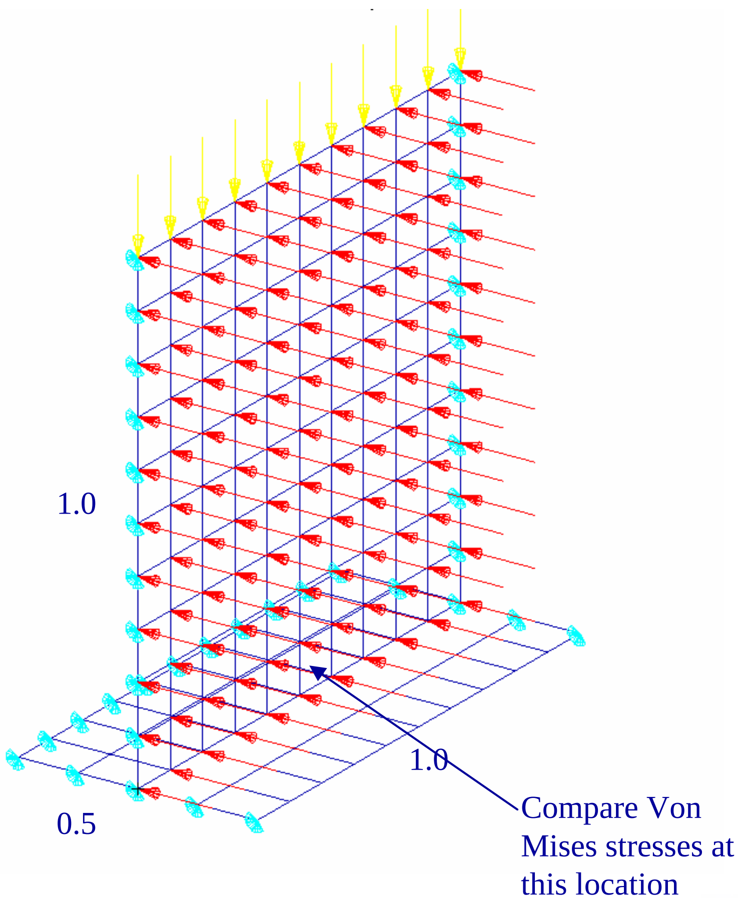


Default:

SNORM= 20. Shell normals are default since V2001

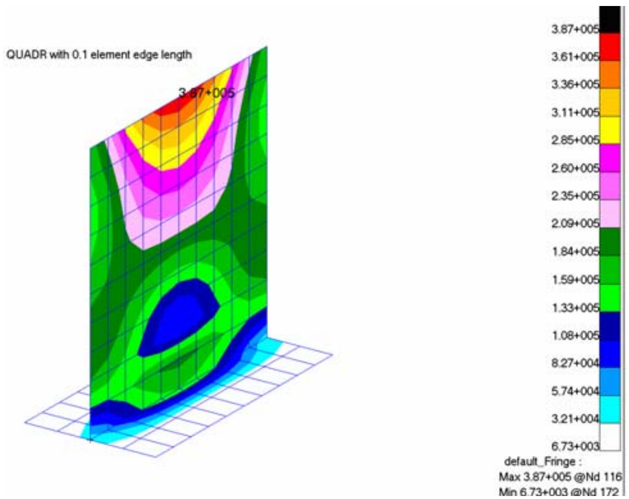
QUADR Study

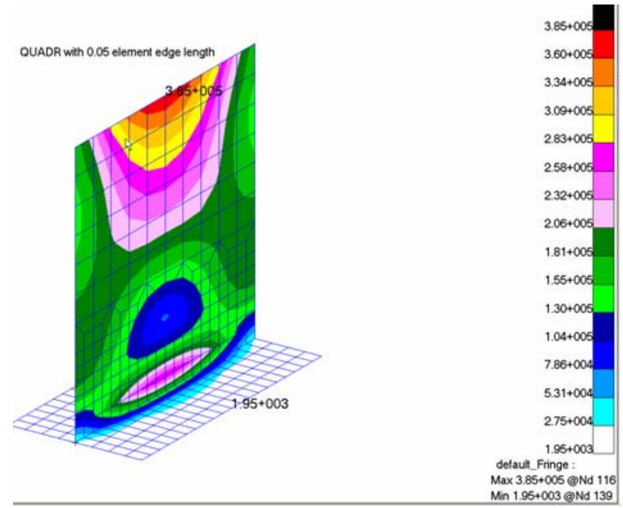
- The QUADR has shown to yield consistent quality results for both a fine and coarse mesh
- The T-Section shown on the right is used for illustration
  - Simply supported around the edges
  - Pressure loading on vertical face and top
  - QUAD4 with 4 different mesh density
  - QUADR with 4 different mesh density

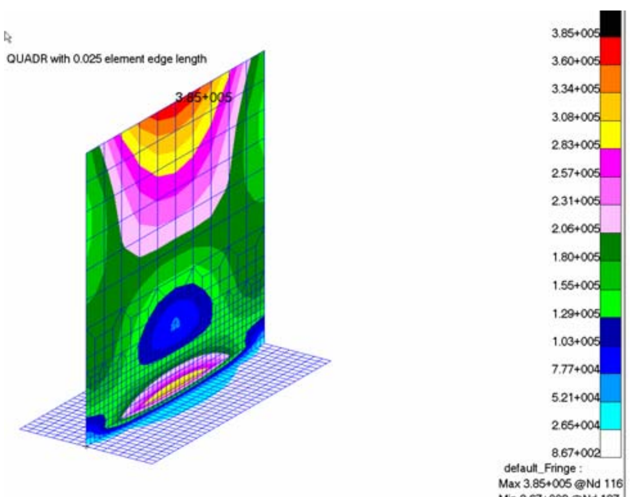


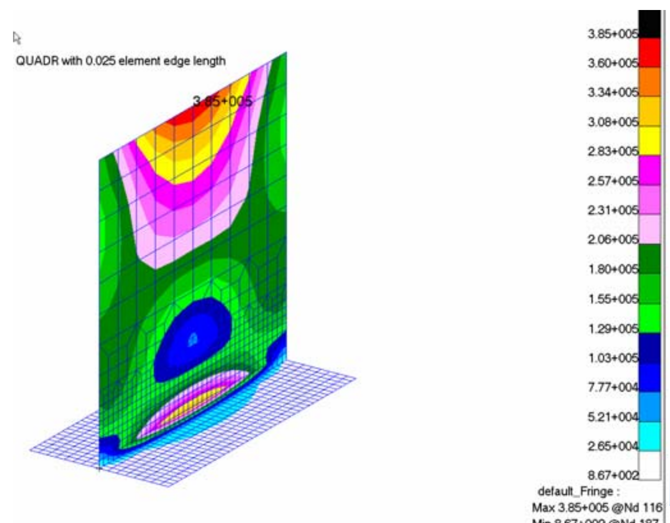
QUADR Study

QUADR Von Mises stresses with various mesh density



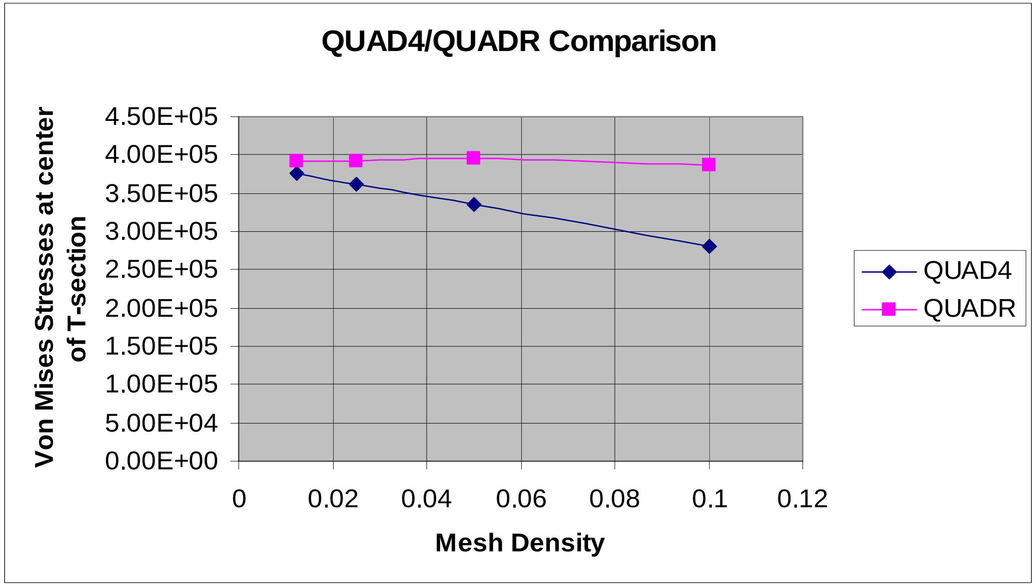






QUADR Study

- The contour plots of the Von Mises stresses show similar stress distribution for all 4 mesh densities with some slight differences
- QUADR yields more consistent results from coarse to fine mesh



QUADR Recommendations

How to change models from QUAD4 to QUADR

- Constrain drilling dof at fixed boundaries
  SPC, 100, 112, 123456
- Do not constrain drilling dof of interior grids, check PS field on GRDSET, or GRID entry
- System cell to convert all CQUAD4 to CQUADR
  NASTRAN QRMETH=5
- Edge loads must be distributed consistently to drilling moments
  - An edge load option for QUADR and TRIAR elements is available on the PLOAD4 bulk data entry

QUADR Remarks

- No extra dof
- No K6ROT
- QUADR is more accurate than QUAD4 for in plane shear
- Shell normals have been added in V70.5, improved accuracy in curved shells
- Differential stiffness has been added in V2004, makes buckling and prestressed normal modes available
- Geometric nonlinear has been added in V2005, improvements for large rotation are coming
- Composites have been added in V2005

QUADR Remarks

- Temperature-dependent composite material
- A new nonsmeared option added for QUADR (param,compmatt,nons)
  - Element matrices calculation using a layered Gaussian integration scheme
  - This approach allows implementation of material nonlinear capability in the future
- All QUADR remarks apply to TRIAR

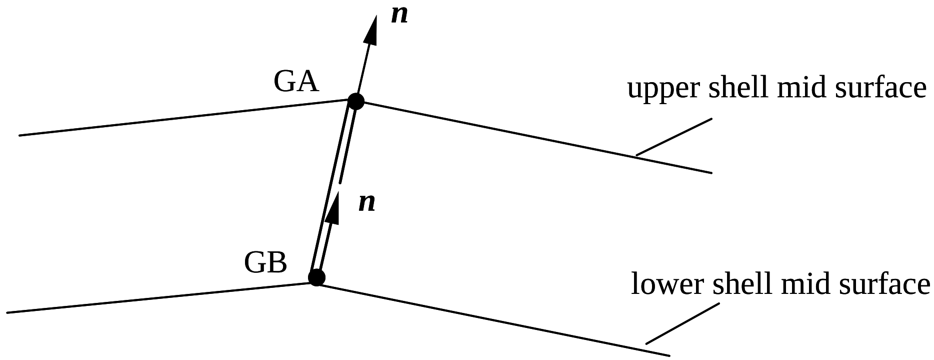
Connector Modeling

CWELD Connectivity

- Point to point connection with format ALIGN for nearly congruent meshes

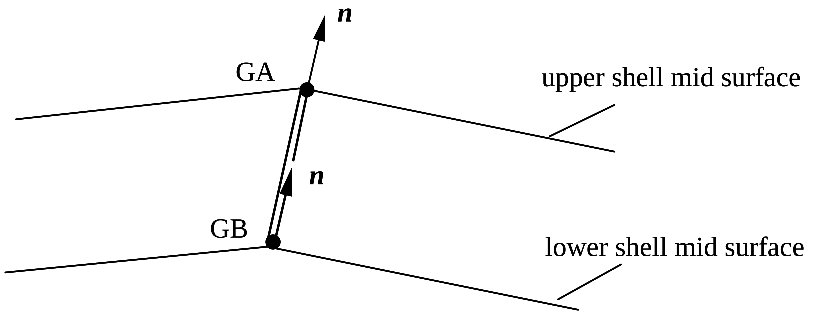
CWELD	EID	PID		ALIGN	GA	GB			

PWELD	PID	MID	D						



CWELD Connectivity

Example of spot welds for nearly congruent meshes



ALIGN Option

2 x (3 x 9) Quad4s	t = 1.0 mm	E = 2.06 e+5 N/ mm^2
2 x 8 Spot Welds	D = 2.0 mm	ν = 0.3
Perturbation	Δy = 0.2 mm	ρ = 0.785 e - 8 kg/mm^2

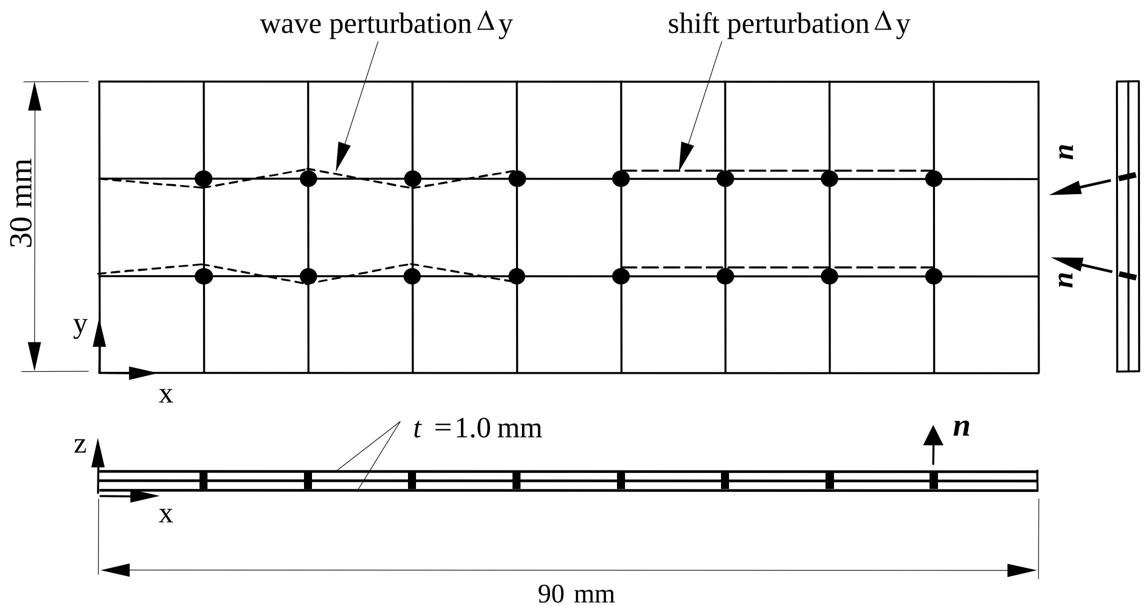
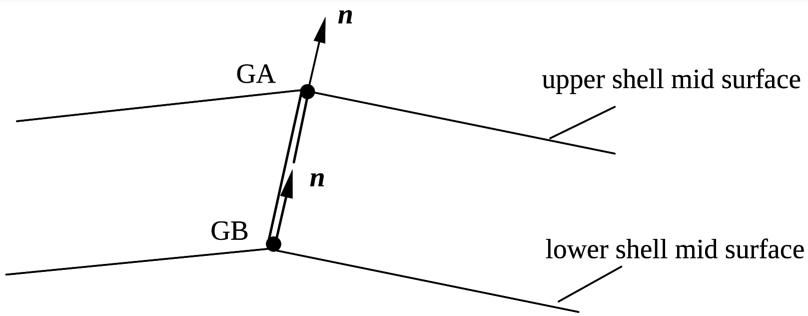


Figure 6. Two Plates Connected with 16 Spot Welds

CWELD Connectivity

- **Comparing**
  - **RBAR with normals which are not aligned**
  - **CWELD – ALIGN**
- **K6ROT=100.**



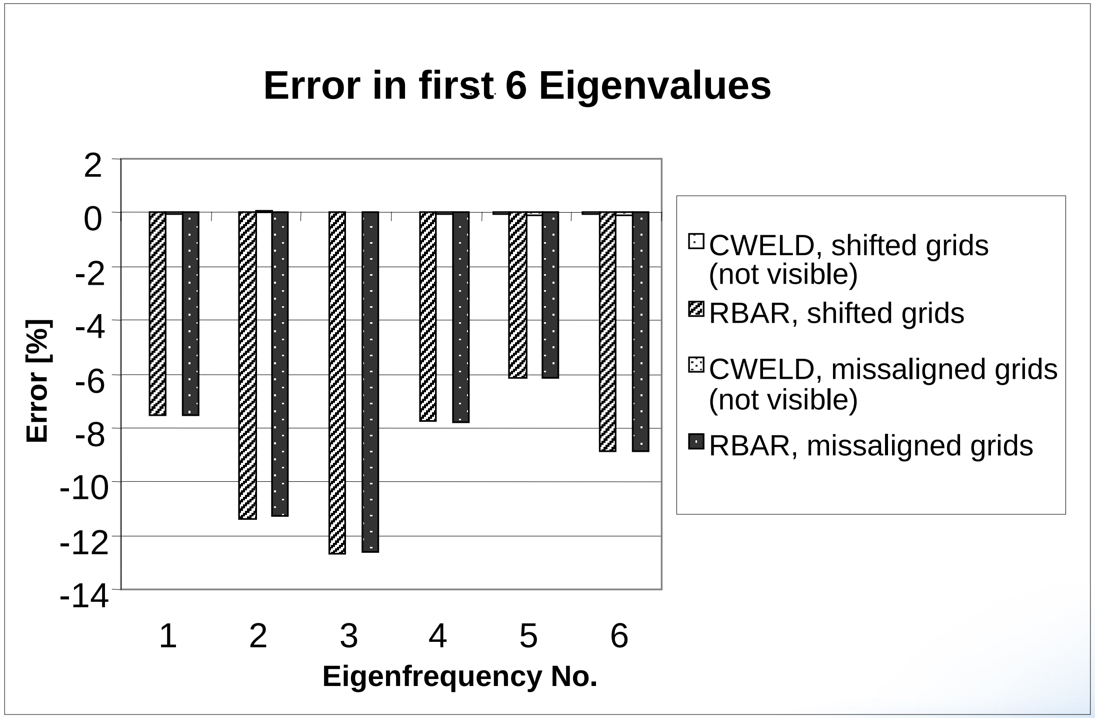
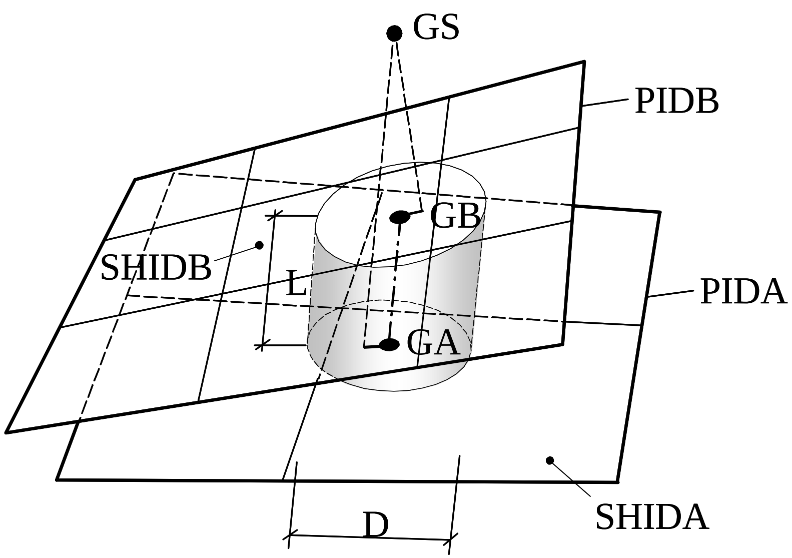


Figure 7. Errors in the first 6 Eigenfrequencies

CWELD New Connectivity Type in V2004

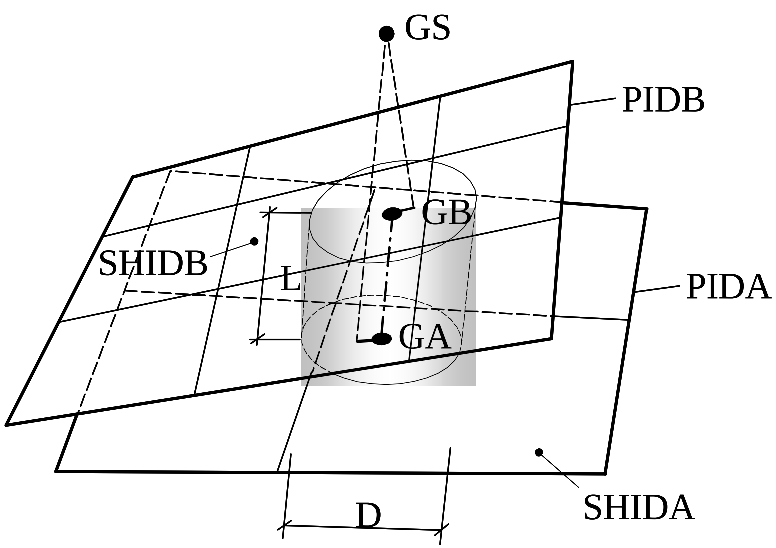
- Patch-to-patch connection with format PARTPAT

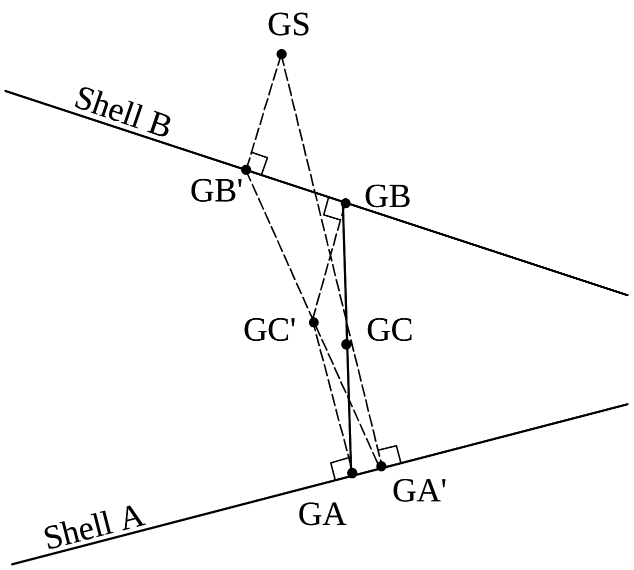
CWELD	EID	PID	GS	PARTPAT					
	PIDA	PIDB							
PWELD	PID	MID	D					SPOT	



CWELD Connectivity

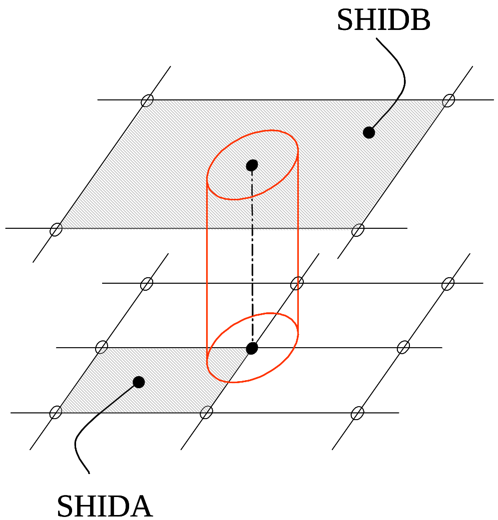
- Definition of surface patches by property ids, shell element ids or grid ids
- Normal projection of the spot weld grid GS on the patches determines the spot weld element axis GA, GB.



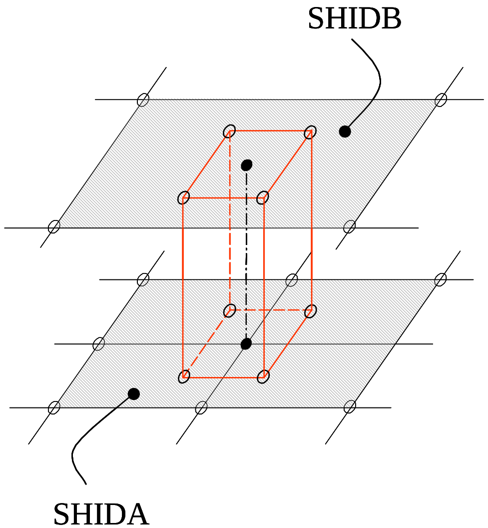


CWELD V2001 versus V2004

- Format ELEMID may make “non symmetric” connections in symmetric meshes
- New V2004 formats ELPAT and PARTPAT preserve symmetry



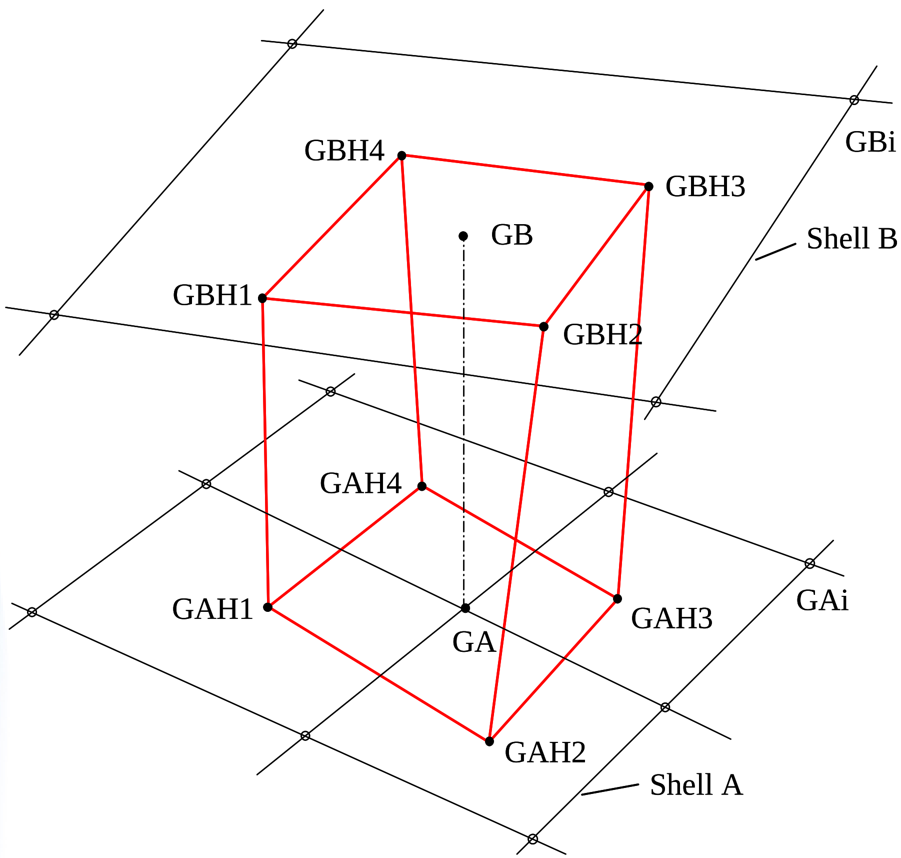
Connected elements for format ELEMID

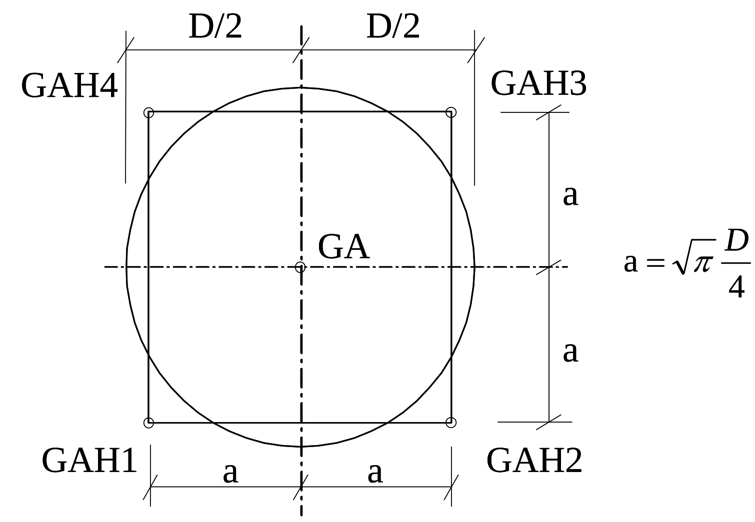


Connected elements for format ELPAT

CWELD With Formats ELPAT and PARTPAT

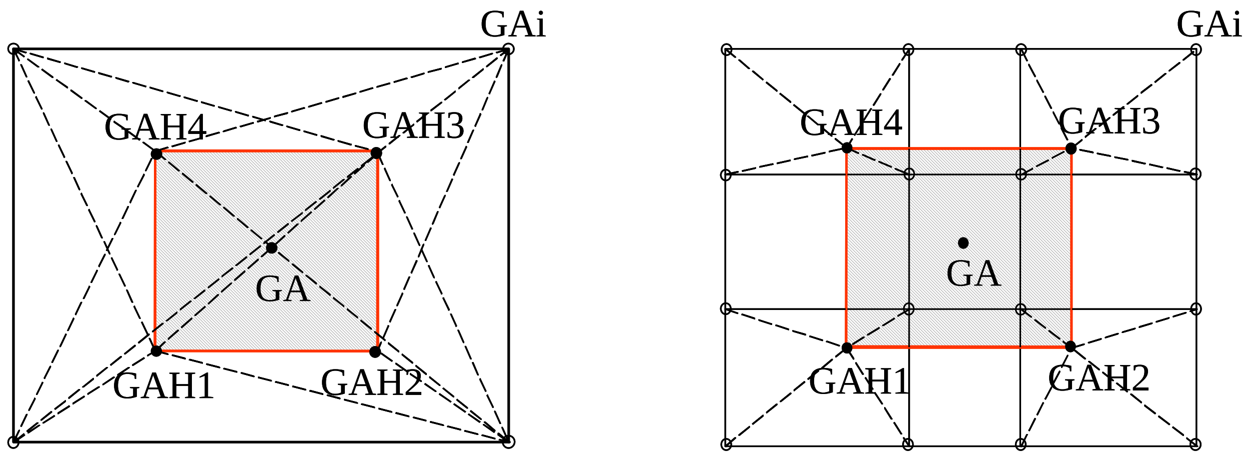
- Internally, a hexahedron is generated to take the area into account





CWELD With Formats ELPAT and PARTPAT

- Format ELPAT and PARTPAT the spot weld area can cover coarse meshes (one element) and fine meshes (3x3 element patch max)

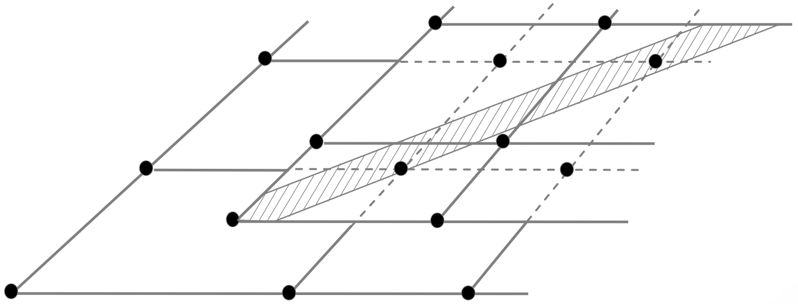


Coarse Mesh   Fine Mesh

Connectors – Work in Progress

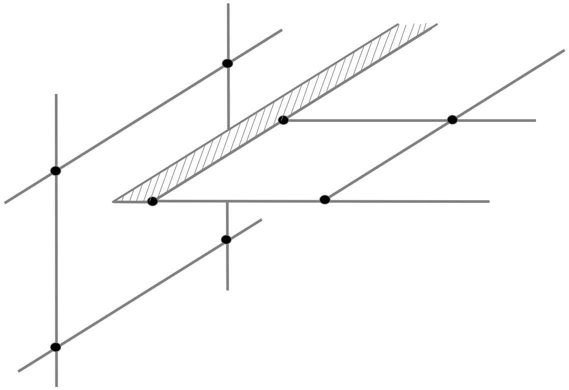
- **CFAST / PFAST (beta release)**
  Fastener with user defined stiffness
  - **Shear stiffness in two directions**
  - **Normal stiffness**

- **CWSEAM / PWSEAM (beta release)**
  Seam weld
  to connect
  dissimilar meshes



Connector Elements - Plans

- **L, T, B –SEAM**
- **Glueing (small thickness)**

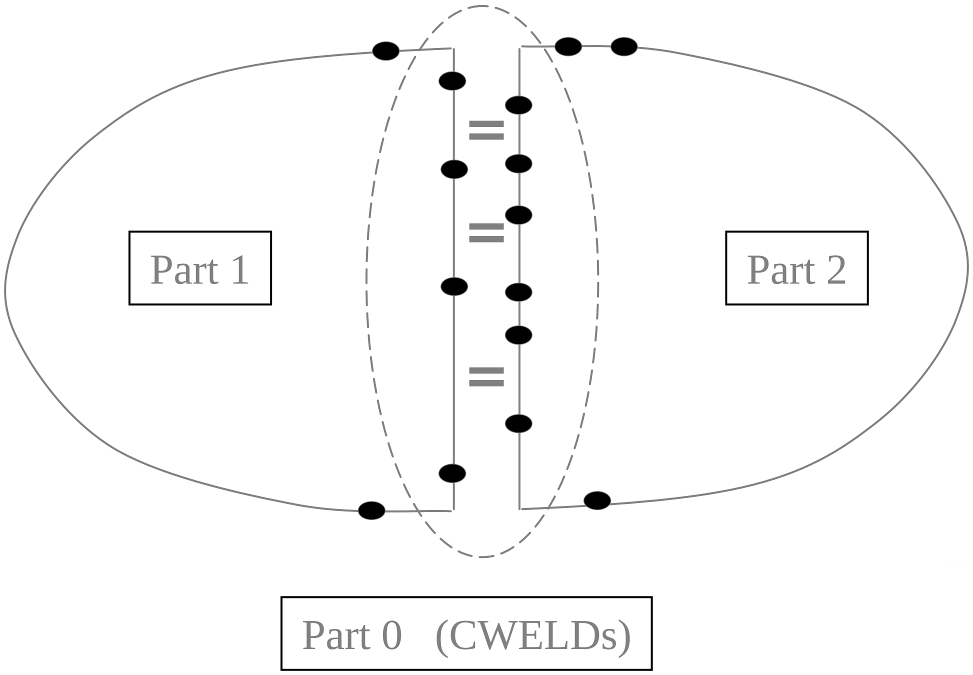


- **Ease of use of connectors with parts**
- **CWELD for more than 2 sheets**
- **Determine diameter D automatically depending on shell thicknesses for Type= “SPOT”**
- **User defined preload and temperature strain**
- **Material nonlinear and failure**
- **Stress output**
- **Force per unit length for seam weld**

MSC SOFTWARE
SIMULATING REALITY

Connectors and Parts

- Parts 1 to N without connectivity information
- Part 0 contains connectivity information only: CWELDs/PWELDs, boundary grids
- Advantages:
  independent numbering in parts, each part is a separate bulk data file, better performance in MSC.Nastran, restarts, distributed parallel, etc.



Dynamics

RESVEC, MODESELECT, Enforced Motion

RESVEC

$$\text{RESVEC}\left[\left(\begin{bmatrix}\text{INRLOD}\\ \text{NOINRL}\end{bmatrix},\begin{bmatrix}\text{APPLOD}\\ \text{NOAPPL}\end{bmatrix},\begin{bmatrix}\text{RVDOF}\\ \text{NORVDO}\end{bmatrix},\begin{bmatrix}\text{DMPLOD}\\ \text{NODMP}\end{bmatrix}\right)\right]=\begin{Bmatrix}\text{SYSTEM/NOSYSTEM}\\ \text{COMPONENT/NOCOMPONENT}\\ \text{BOTH or YES}\\ \text{NO}\end{Bmatrix}$$

INRLOD	**residual vector due to inertia relief**
APPLOD	**residual vector from applied load**
DMPLOD	**residual vector due to viscous damping**
RVDOF	**residual vector using RVDOFi**

- **Included in Sol 103, 111, 112, 200**
- **Used in MDACMS**
- **Used in design sensitivities**

Select Modes in a Modal Response Analysis

- **In MSC.Nastran 2004—Case Control command MODESELECT allowed for inclusion or exclusion of selected modes in response calculation**
- **MODESELECT is applied after residual vector calculation**
- **<u>EXAMPLE: </u>Include modes 1-5, 8-10 in the response calculation**

SET 100 = 1 THRU 10 EXCEPT 6,7

MODESELECT = 100

MSC SOFTWARE SIMULATING REALITY

Select Modes in a Modal Response Analysis

- **Four additional options have been added in MSC.Nastran 2005:**
  - **Include modes based on number of lowest modes**
  - **Include modes based on range of mode numbers**
  - **Include modes based on range of frequencies**
  - **Include modes based on modal effective mass fractions (MEFFMFRA)**

    (Separate MEFFMASS Case Control command not needed for this last option)

Select Modes in a Modal Response Analysis

<u>**EXAMPLES:**</u>

MODESELECT(ALLFR)

- **The default criterion of SUM is used. The modes are sorted based on MEFFMFRA. Modes are then included from this list so that the sum of the fractions exceeds 95% for all directions.**

SET 100 = 20,30

MODESELECT (T2FR=0.1 R3FR=0.15 ALLFR UNCONSET=100 ALLMIN)

- **All modes with T1≥0.05, T2≥0.1, T3≥0.05, R1≥0.05, R2≥0.05, and R3≥0.15 will be included. Mode nos. 20 and 30 will be included regardless of their MEFFMFRA values.**

Dynamic Loads and Enforced Motion

- Enforced motion introduced in V2001 with absolute motion
- Enhanced in V2004 for relative motion with corrections for modal damping

In V2005

- Increased accuracy with double precision SPC / SPCD data
- Improved differentiation scheme in TRLG module for enforced displacement and enforced velocity via SPC/SPCD
- Increased accuracy with double precision computations in DPD and TRLG modules

Initial Condition Specification for Enforced Motion (SPC/SPCD)

- Format of expanded TLOAD1

TLOAD1	SID	EXCITEID	DELAY	TYPE	TID	US0	VS0		

- Format of expanded TLOAD2

TLOAD2	SID	EXCITEID	DELAY	TYPE	T1	T2	F	P	
	C	B	US0	UV0					

  - US0—initial displacement
  - VS0—initial velocity
  - US0 and VS0 can be used in conjunction with other initial conditions (TIC) at independent DOFs

Dynamics - Plans

- Performance enhancements for enforced motion
- Complete the AUTOQSET capability
- Extend MODESELECT with modal effective mass MEFFMFRA to free bodies
- Provide MODESELECT option to always leave the residual vectors in the modal response
- Replace TRD2 with extended TRD1

Thank you