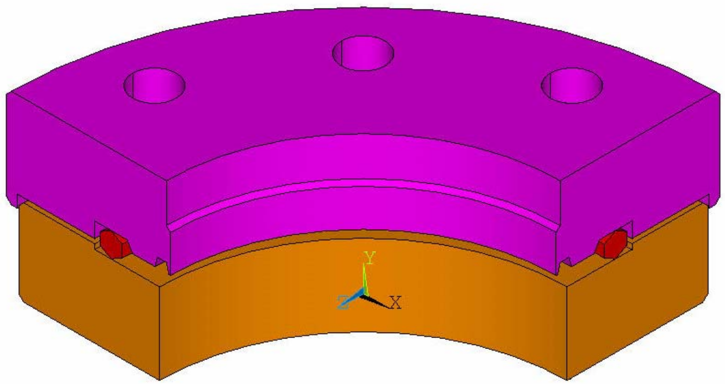
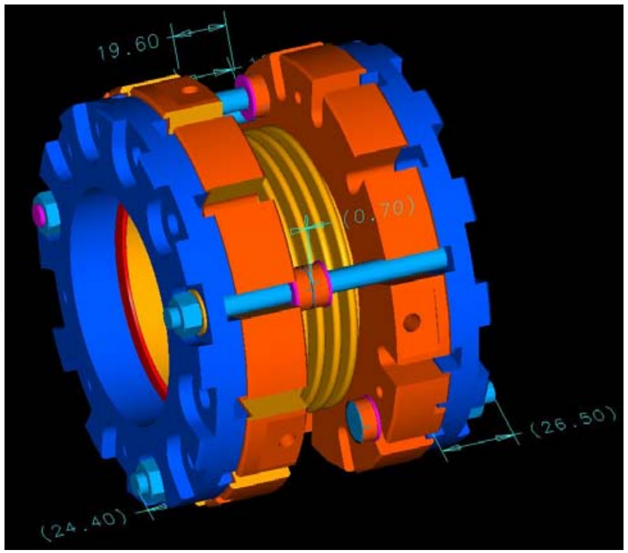
Fermi National Accelerator Laboratory

International Linear Collider at Fermilab

1.3GHz Cavity Interconnect FEA Results & New Design





Salman Tariq, Matt Slabaugh

Accelerator Division

Mechanical Support Department

Fermi National Accelerator Laboratory

2nd Type IV Cryomodule Design Meeting- FNAL   July 13-14, 2006

GOAL: Reduce cavity iris-to-iris spacing from 344mm to 283mm (71.8mm flange-flange spacing)

A. **Optimize existing Desy design** by shortening bellows spool piece to 5 convolutions & partially slotting bolt holes (details in next slides)
- Developed a comprehensive nonlinear (contact) 3-D FEA model of existing TTF design (to serve as benchmark & basis for future designs)
- Results (force vs seal crush) compare well to Desy measurements

Initial FEA results of slotted design indicate it will work and drawings for prototype flanges and a test set-up are currently underway

B. **Evaluate JLab's Radial Wedge (RW) Flange System**

Issues of concern: cleanliness (friction=particulates)
difficult to get off once clamped
} Experiences from Desy??

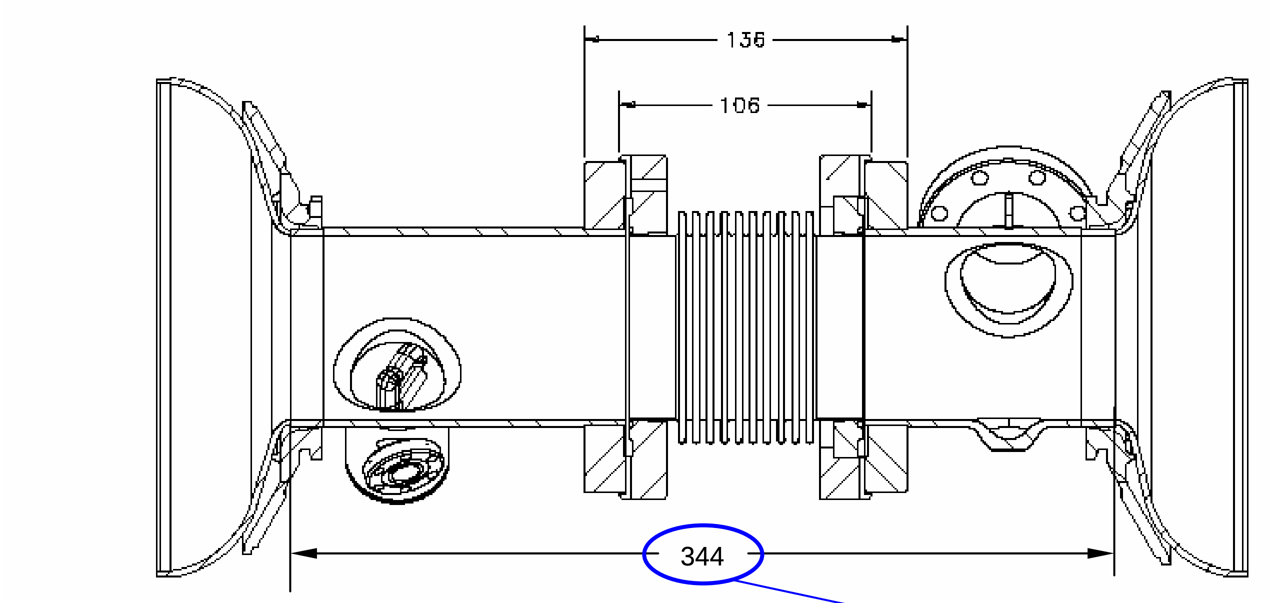
Jlab claims they have rectified these problems (communication with Ed Daly)
3 test setups of RW flange system have been ordered from JLab to be evaluated here at FNAL. Both connection schemes will be tested & compared.

C. **Ultimate aim is Industrialization…**

Quick disconnect type connection is the ultimate goal, OR
Maybe Niobium bellows? **Welded connections eventually??** Other options??

Q's: Do we really need such a high clamping force? Has anyone investigated alternate seal designs, materials, etc.? ... Major R&D effort required, more resources, industrial involvement, etc.

Existing Desy TTF Design Specs



Iris-to-Iris Spacing:
Tesla TDR: 283mm

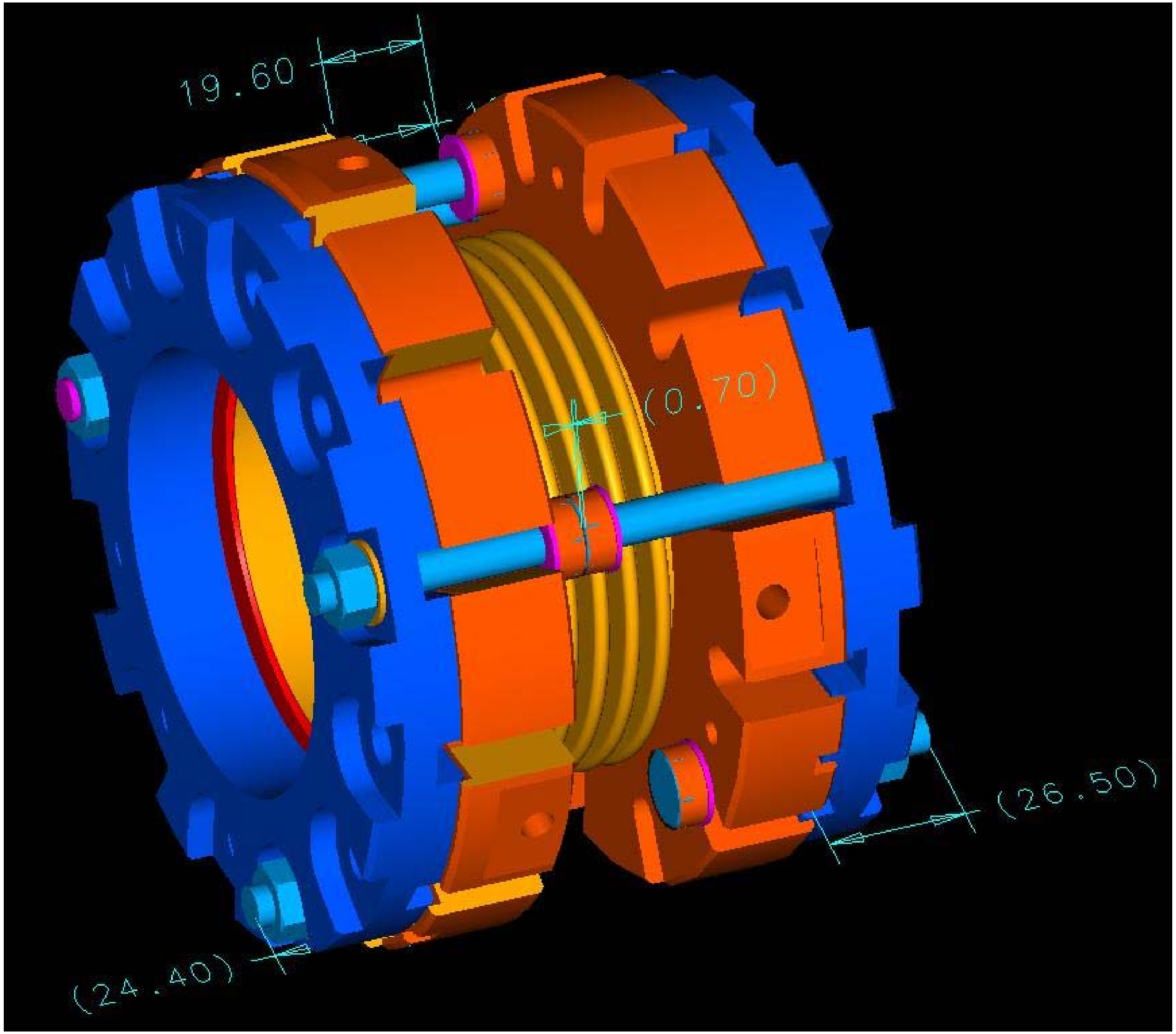
Flange/Bellows Design Specs:

- Bolted flange (12 bolts/flange)
- Convoluted SS Bellows (10 waves, 54mm free length, ±20mm)
  - -Length of bellows were dictated by bolt length & old elastic parameters
- Bellows elastic requirements: ±4mm (~1mm thermal + ~3mm tuning)
- Aluminum Alloy AlMgSi0.5 Diamond Hex Seal (or equiv.)

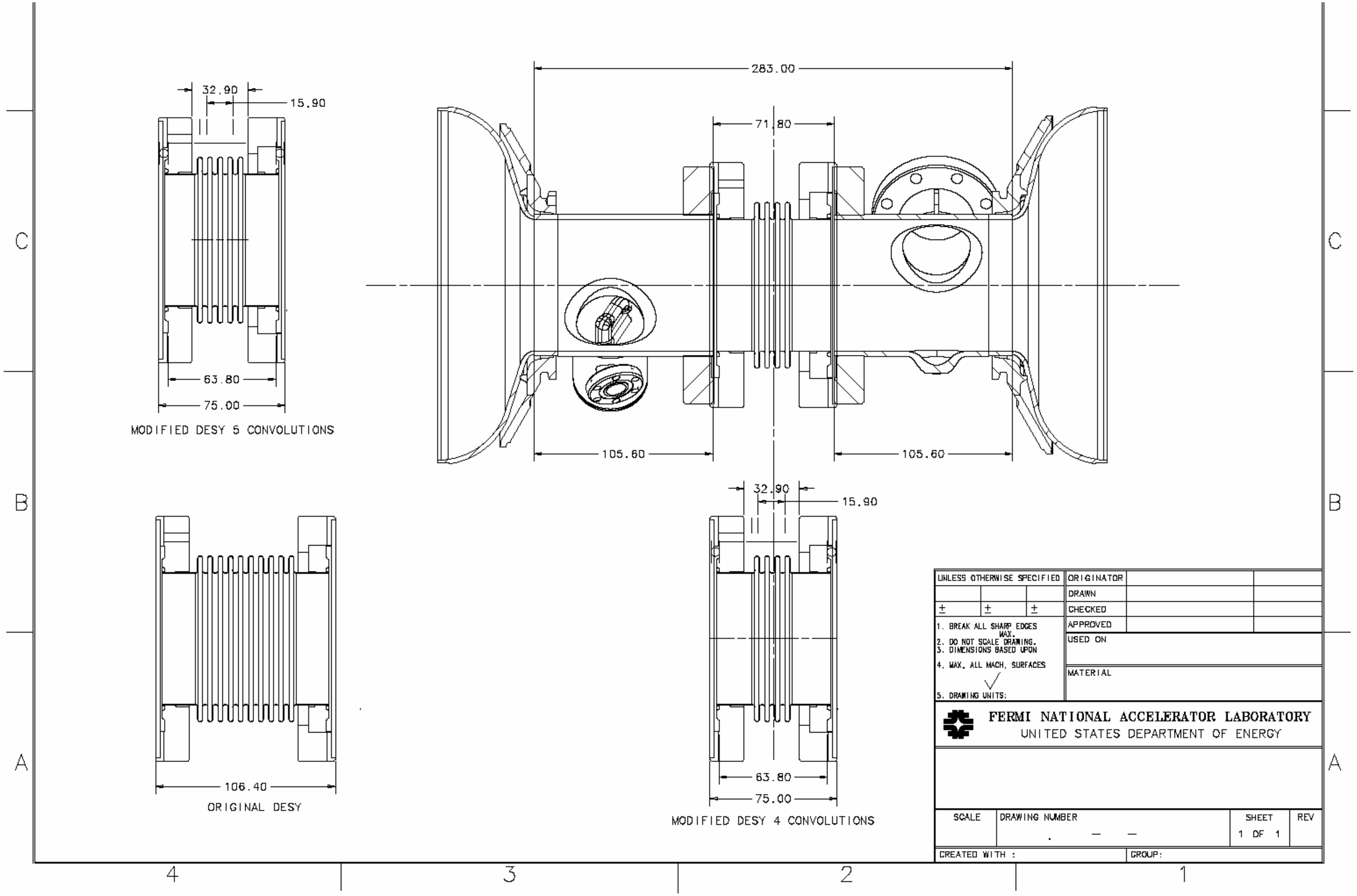
} Needs to be verified

- 116KN (~26 kips) clamping force, 30-35 Nm torque/bolt, 0.4mm seal crush
- Mechanical analysis done @ Desy, INFN
  (Cornelius Martens, Roberto Paulon)

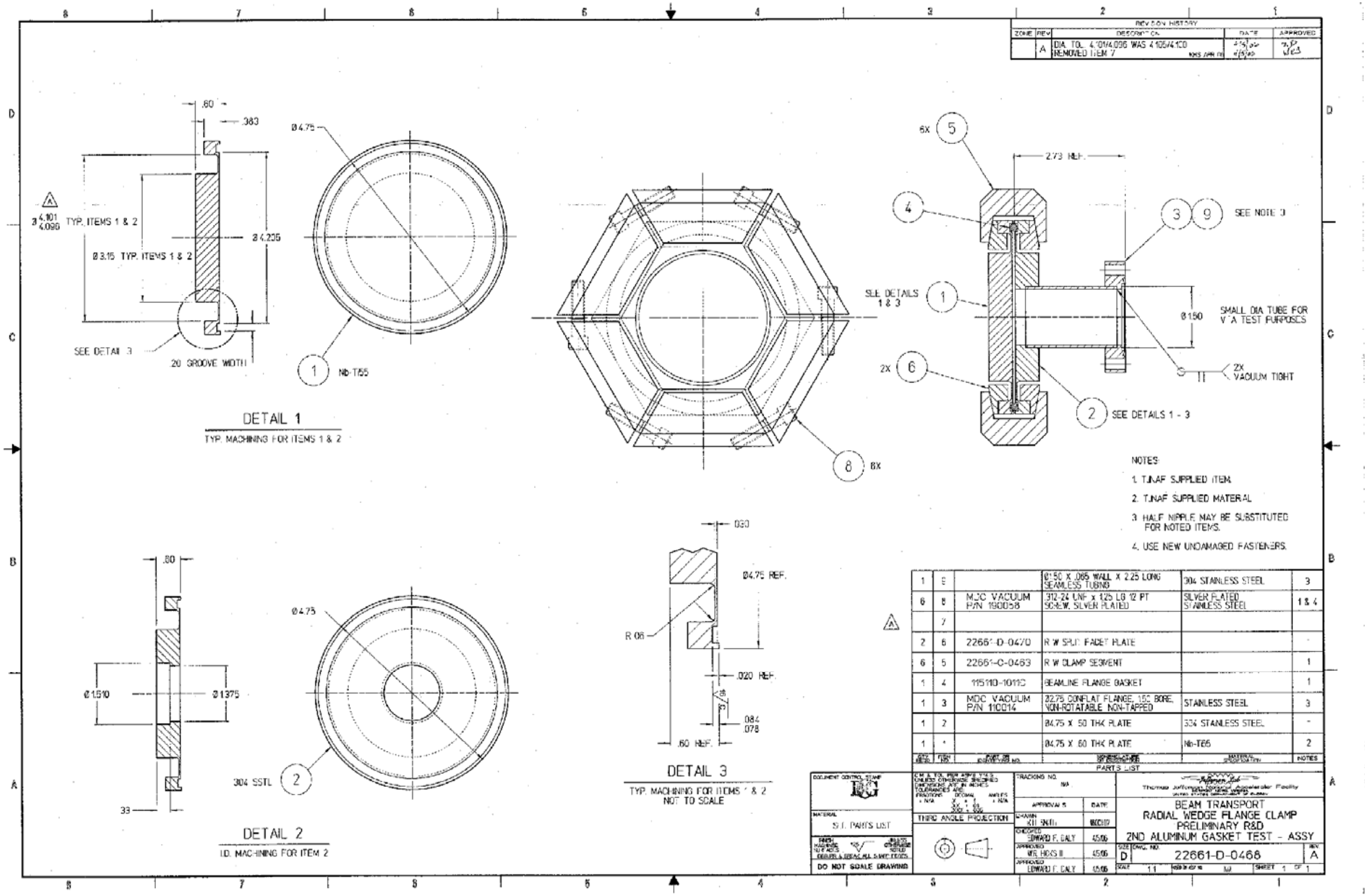
Shortened Design



Shortened Design (drawing)

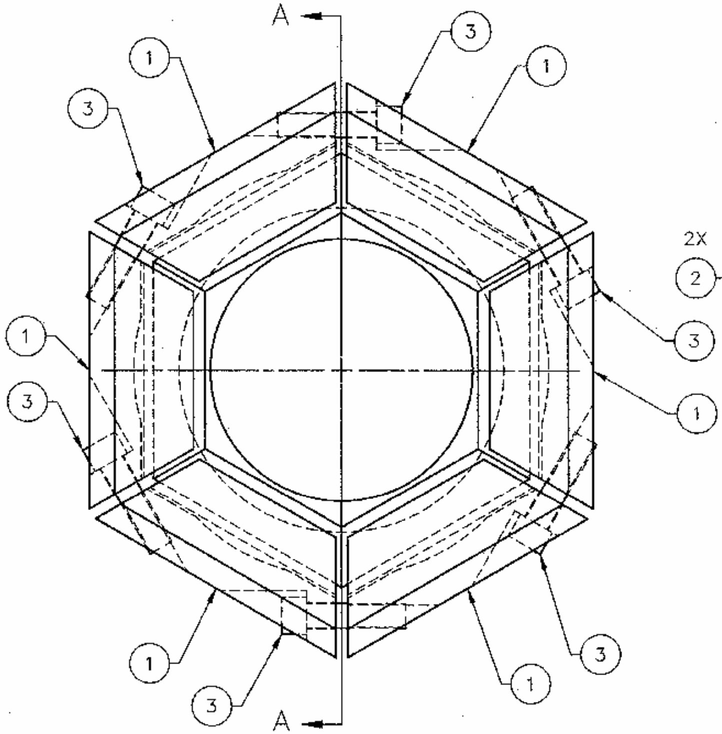


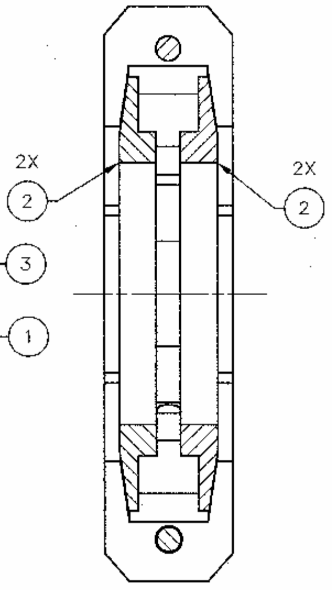
JLAB RW Clamp Test Assembly



JLAB Radial Wedge Flange Clamp
RW Clamp Assembly

REVISION HISTORY				
ZONE	REV	DESCRIPTION	DATE	APPROVED





SECTION A-A

NOTES

1. INSTALL PER JLAB COMMON PROCEDURE: CP-C12-REN-RWFC-INST.

QTY REQD	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	NOTES
6	3		12 POINT BOLT .312-24 UNF X 1.25 LONG	STAINLESS STEEL SILVER PLATED	
4	2	22661-D-0470	SPLIT FACET PLATE		
6	1	22661-C-0463	CLAMP SEGMENT		

PARTS LIST

DOCUMENT CONTROL STAMP: DCG

MATERIAL: SEE PARTS LIST

FINISH MACHINED SURFACES 125 UNLESS OTHERWISE NOTED. DEBURR & BREAK ALL SHARP EDGES

DO NOT SCALE DRAWING

DIM & TOL PER ASME Y14.5. UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS ± N/A; DECIMAL .X ±.1, .XX ±.01, .XXX ±.005; ANGLES ±.50°

THIRD ANGLE PROJECTION

TRACKING NO. N/A

APPROVALS	DATE
DRAWN J HENRY	17JUN04
CHECKED [signature]	9Aug04
APPROVED [signature]	8/10/04
APPROVED [signature]	8/10/04

Jefferson Lab — Thomas Jefferson National Accelerator Facility, NEWPORT NEWS, VIRGINIA, UNITED STATES DEPARTMENT OF ENERGY

CRM
100 MV CRYOMODULE
CAVITY STRING
RADIAL WEDGE CLAMP ASSEMBLY

SIZE: C | DWG. NO. CRM-100-7014-0011 | REV. -

SCALE 1:1 | USED ON ASSY NO. CRM-100-7014-0002 | SHEET 1 OF 1

AL Alloy Diamond Seal Specs

DESY (Al 6060) – now also adopted by FNAL:

- AlMgSi 0.5 F22   Composition: Al 0.5Mg 0.5Si Fe

  Brinnell Hardness: HB 2.5/ 62.5 : 70

FNAL previous "material spec" (Al alloy that has typically been used here at the lab):

- Aluminum 5052-H32, or AA5052-H32 (Strain hardened & stabilized)

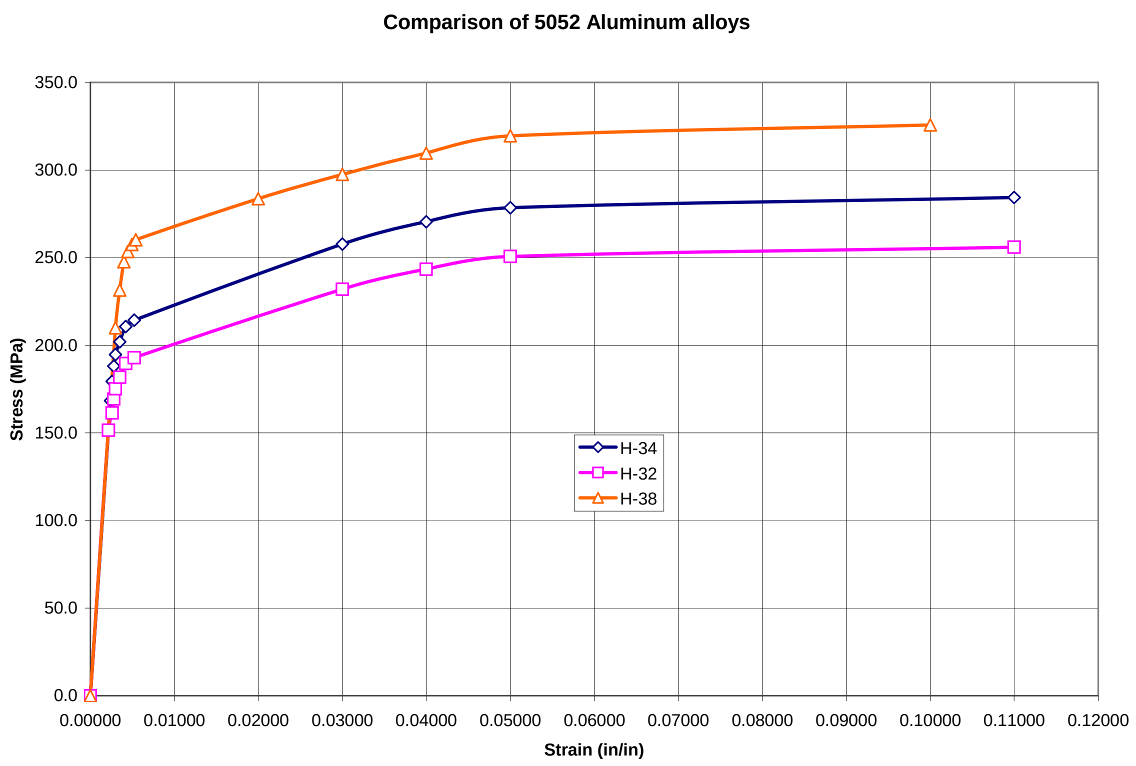
  H32: ¼ Hard HB 10 /60

  (H34: ½ Hard HB 10/ 68)

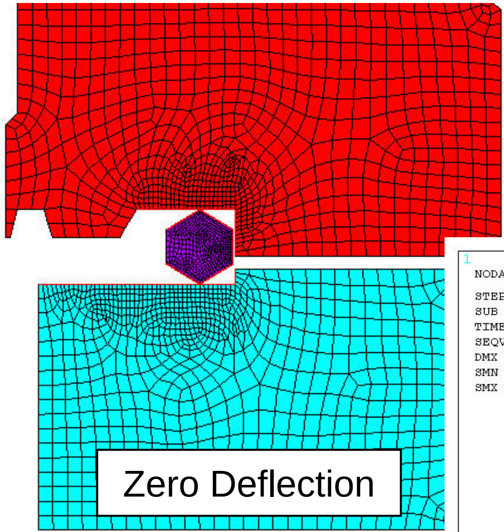
From Dan Olis:

AA6063 is equiv. to DIN AlMgSi0.5

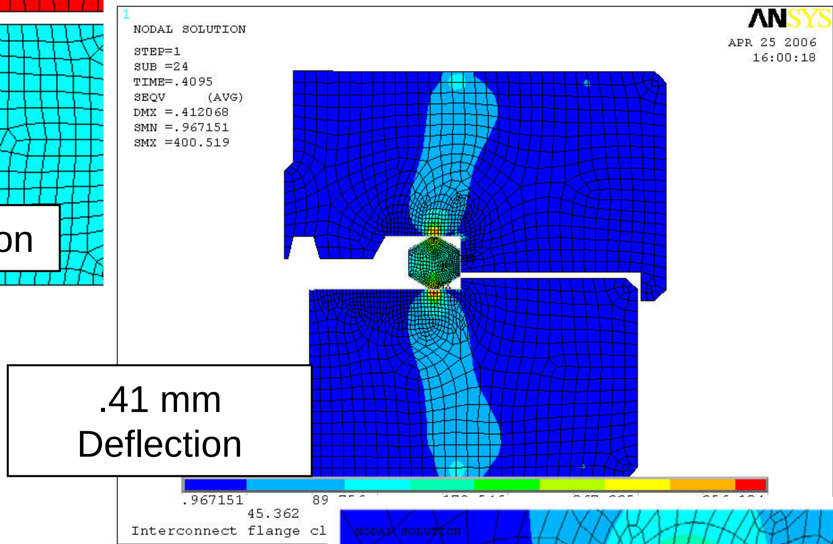
Maybe we should look into using AA6063?

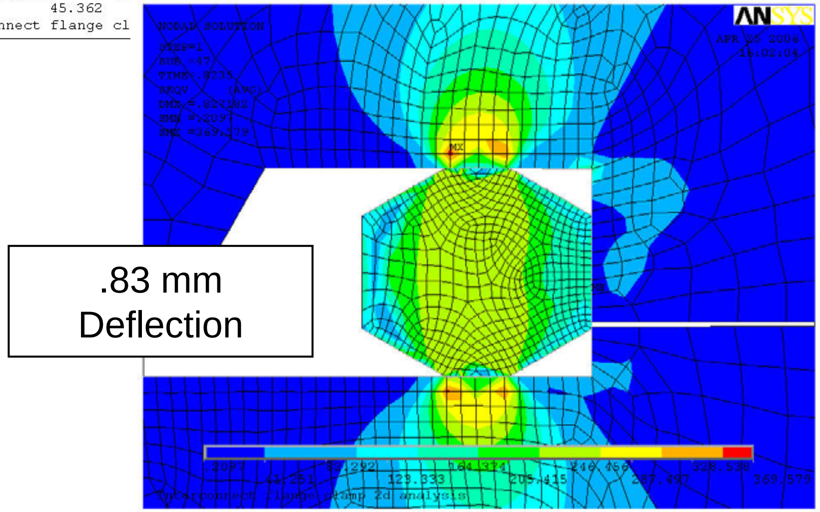


2D Ansys Model of Interconnect Flange



Seal Material:
Aluminum 5052-H32





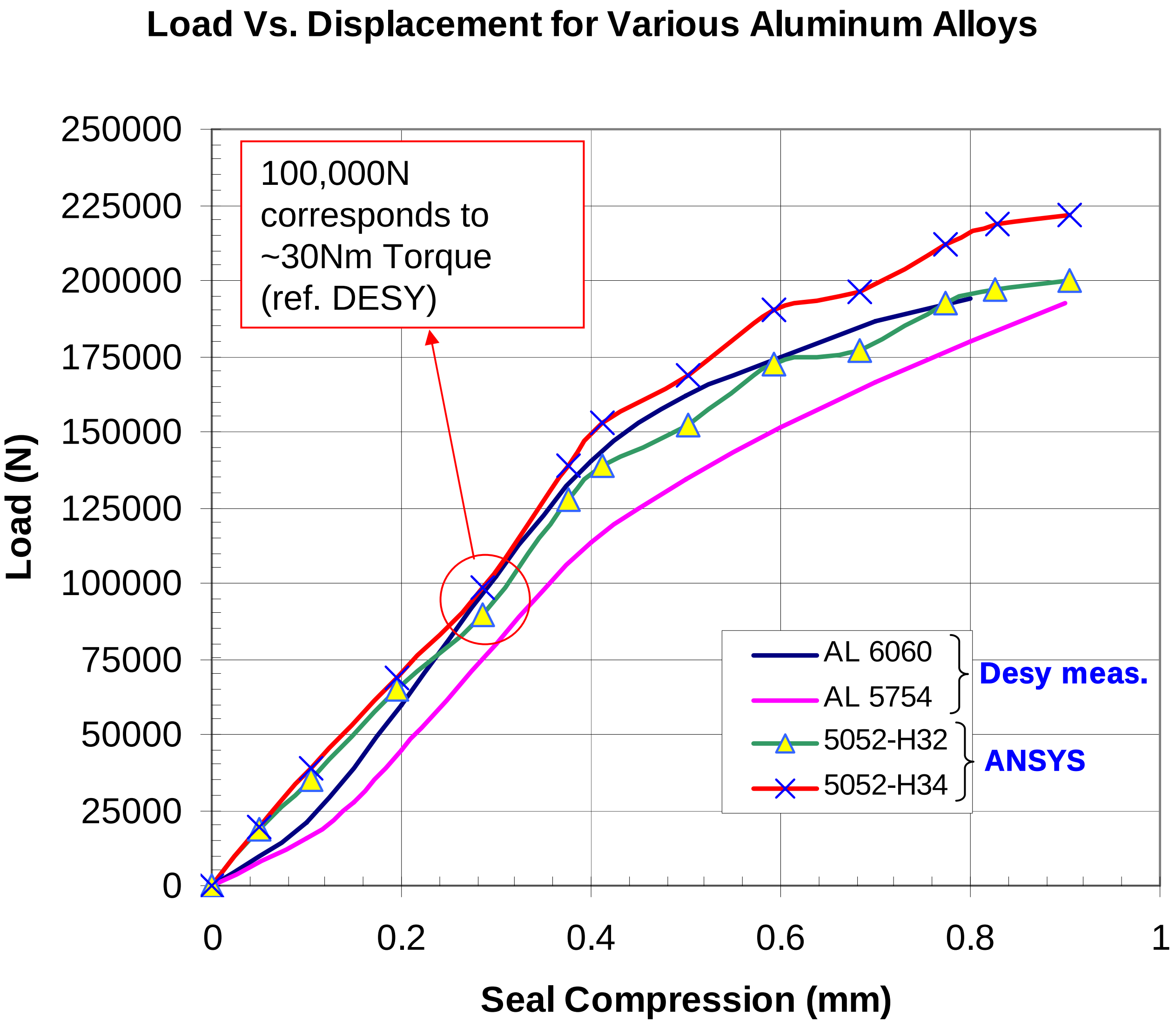
Main Features of MP Benchmark Analysis:

- 2d axisymmetric model with contact
- Geometric nonlinearity with MISO hardening stress-strain curve
- Modeling of sharp seal edge, was able to use surface-to-surface contact elements
- Specified load area (simulated nut/bolt load area)
- Load vs. Displacement closely matched DESY's experimental meas. (see next slide)

2D Ansys Model Results

Material selection :

- Did not have DESY material properties available, used AA5052 instead
- H-32 stress-strain curves mapped from H-34 data
- DESY curves generated from actual compression test measurements
- AA5052-H32 shows good agreement with Desy Spec AlMgSi0.5 (AL 6060)



3D Ansys Model of Interconnect Flange

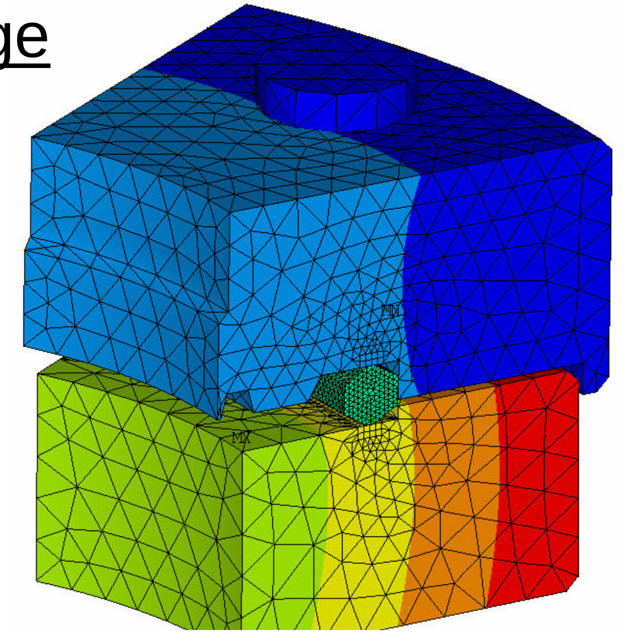
FEA Model Features:

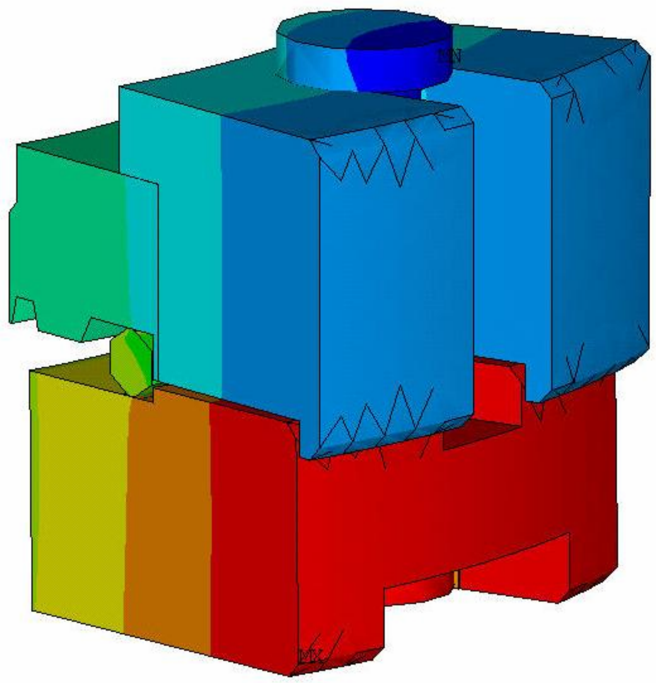
• Fully comprehensive 1/12 symmetry model with complete bolt and seal contact details

• Geometric and material nonlinearity included with MISO hardening stress-strain curves for seal and SS flange

• Preload achieved by slitting bolt equivalent to seal crush displacement dimension and subsequently closing-in this gap.

• Also included is a cool-down load step to study the effect on seal compression





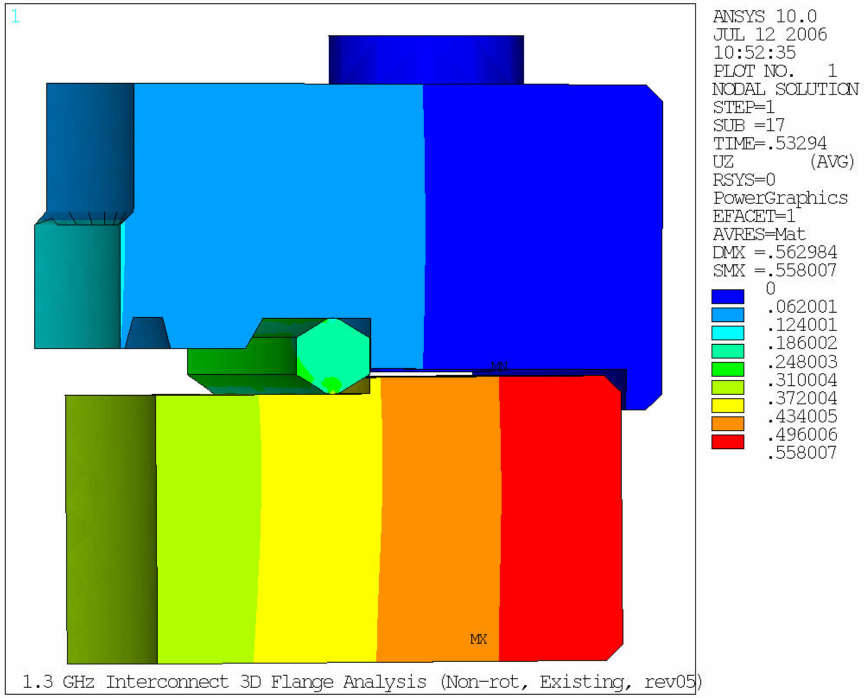
Non-Rotational Flange Displacement Results Comparison

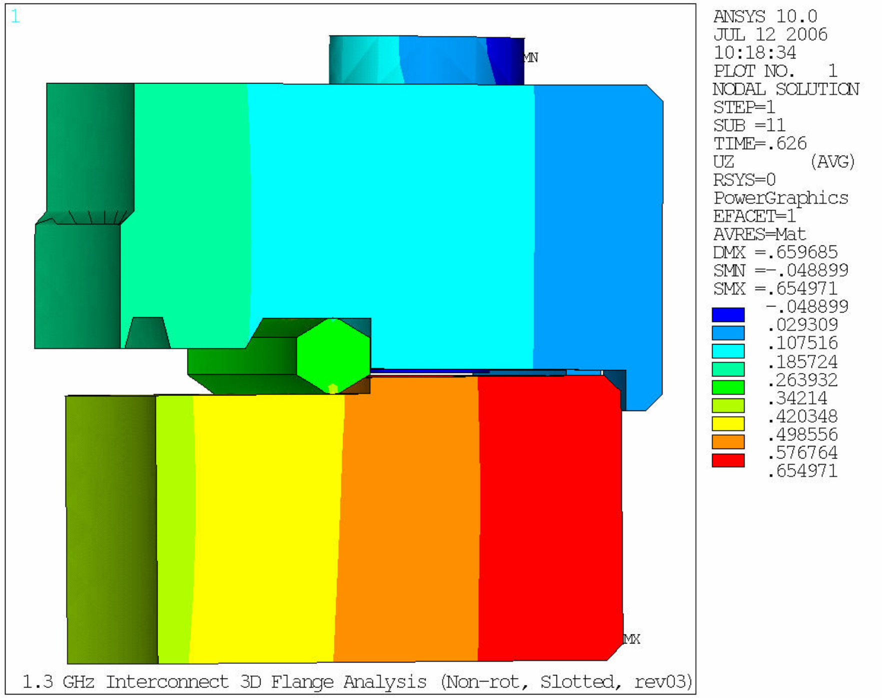
Existing Design

- 0.31mm Seal Crush
- 115kN Force

Slotted Design

- 0.32mm Seal Crush
- 116kN Force





~17.5% more flexure in slotted design

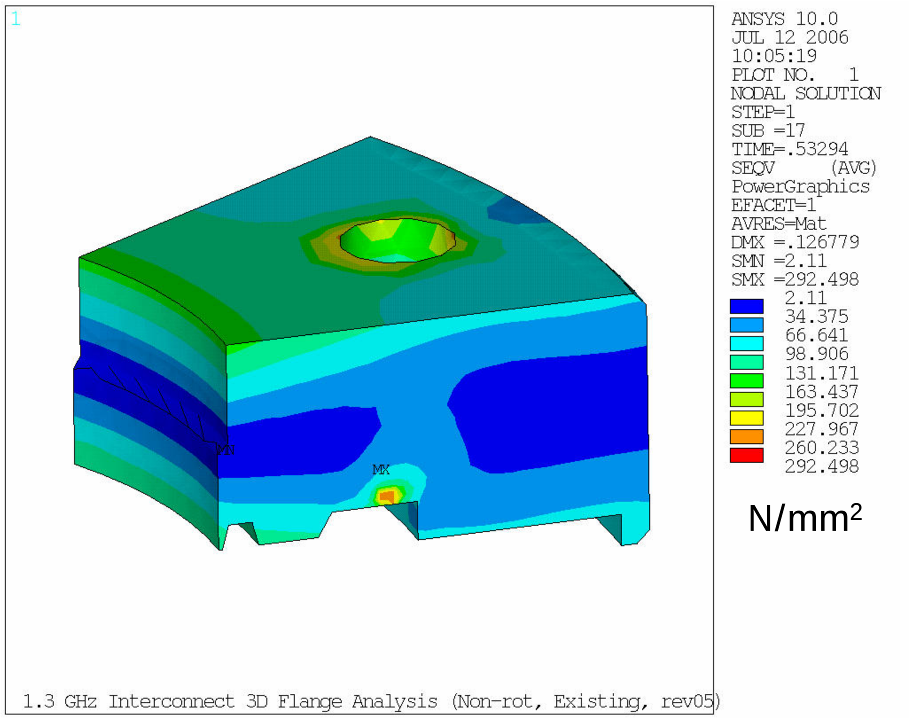
Non-Rotational Slotted Flange von Mises Stress Results Comparison

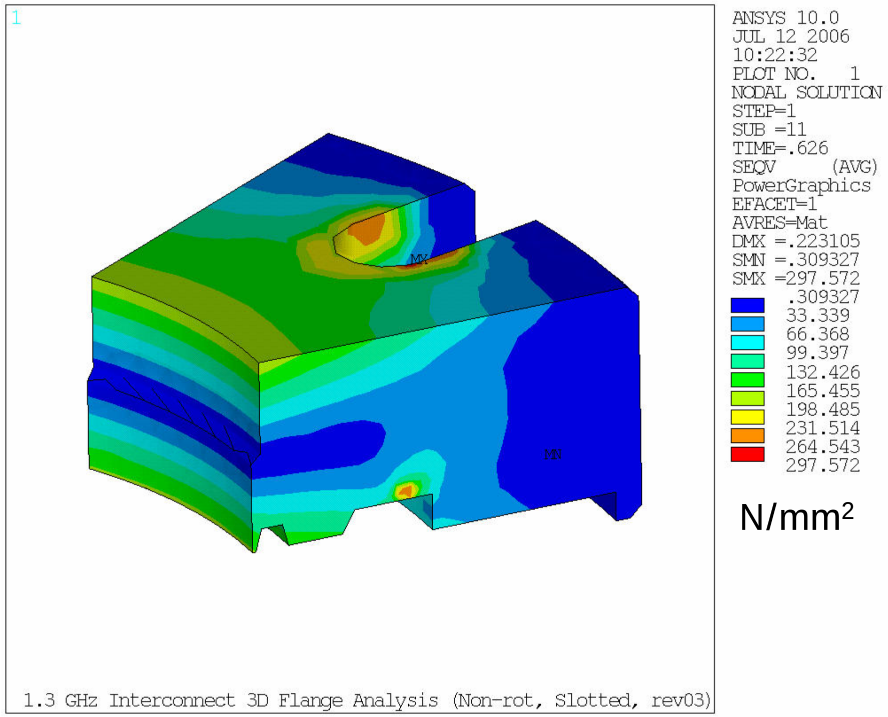
Existing Design

- 0.31mm Seal Crush
- 115kN Force

Slotted Design

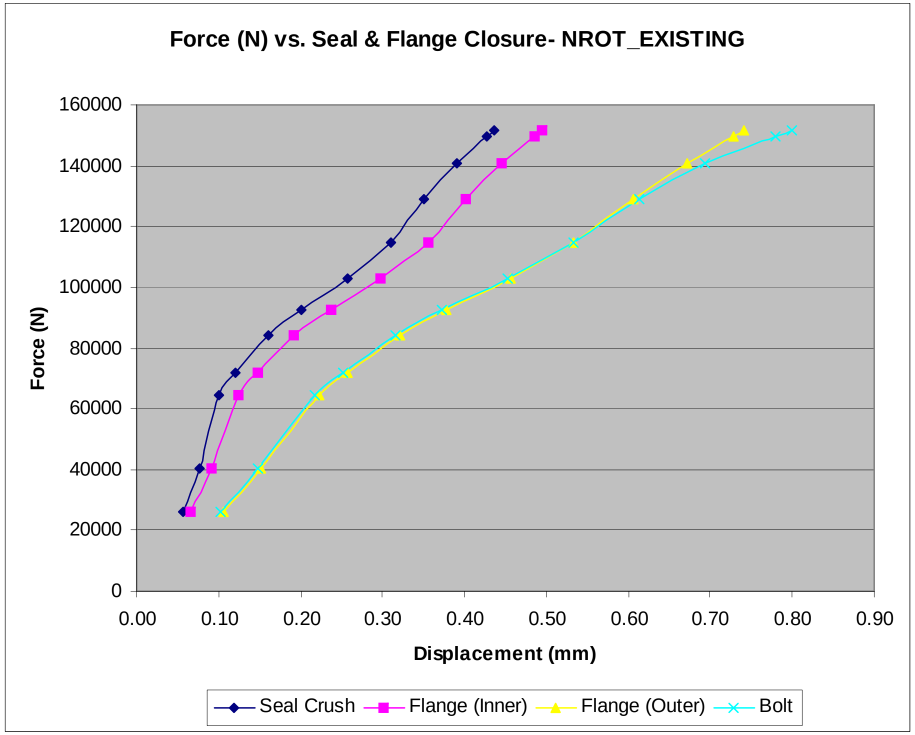
- 0.32mm Seal Crush
- 116kN Force



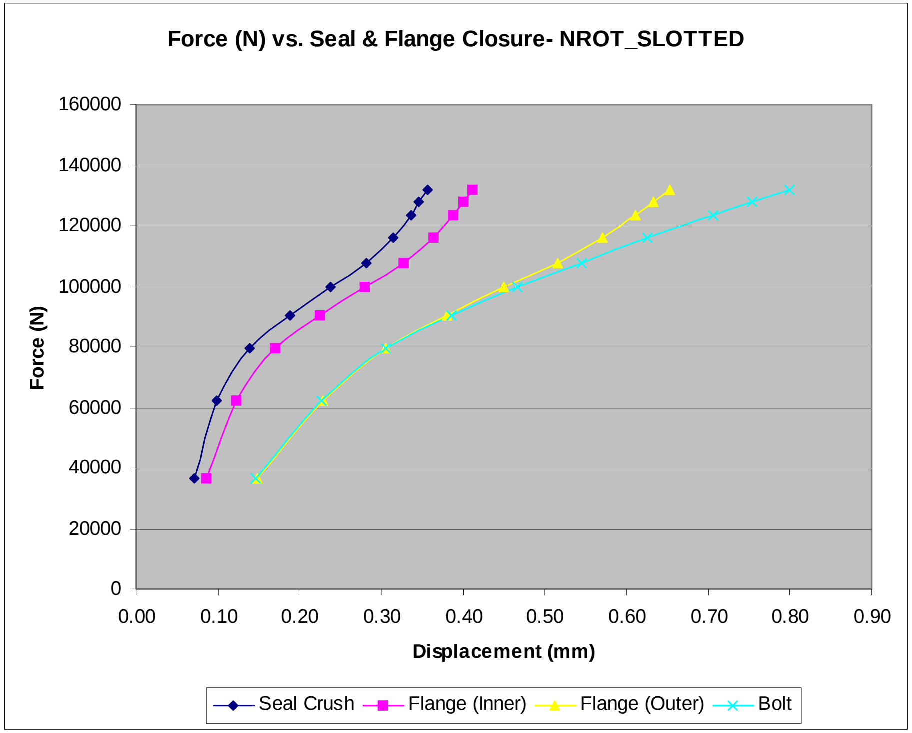


Non-Rotational Seal Crush & Flange Displacement Results Comparison

Existing Design

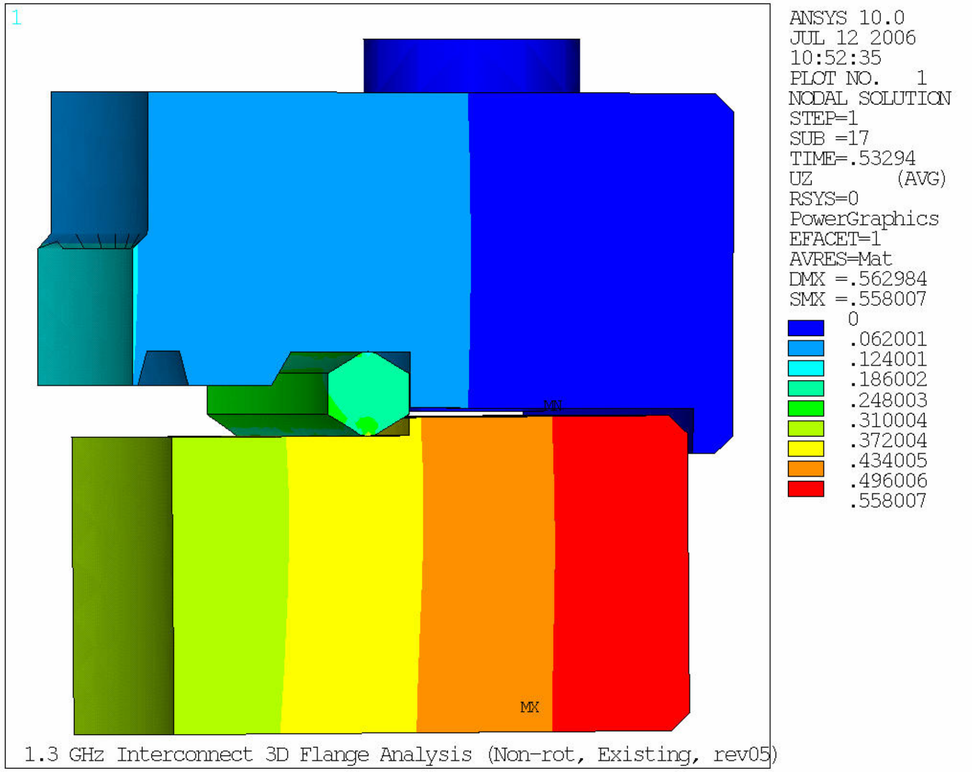


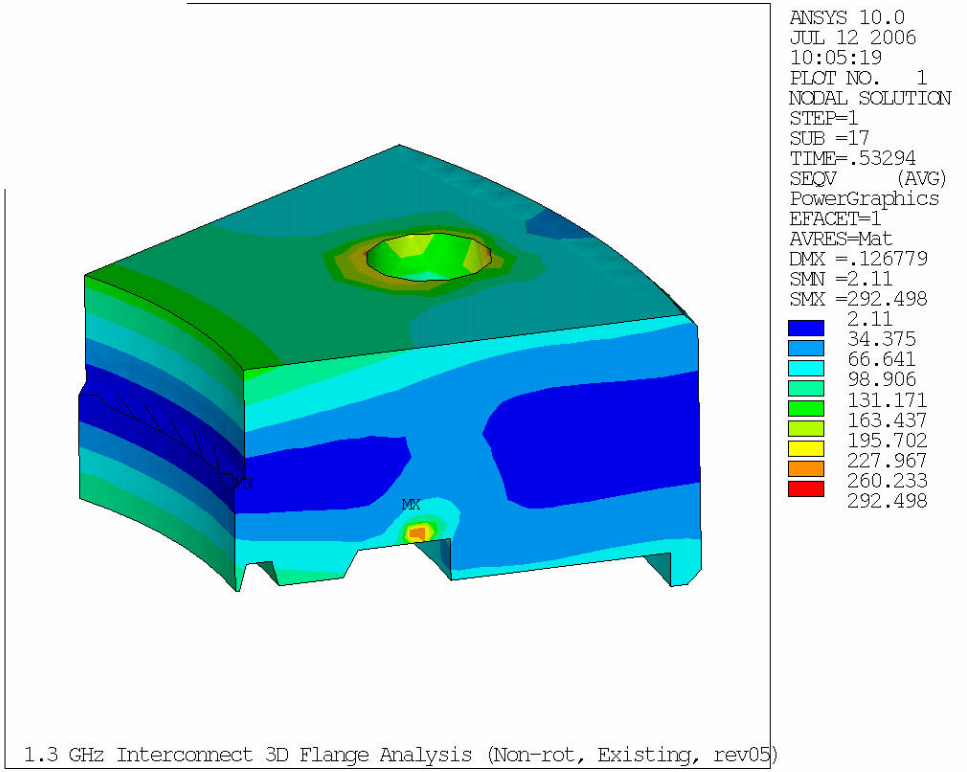
Slotted Design



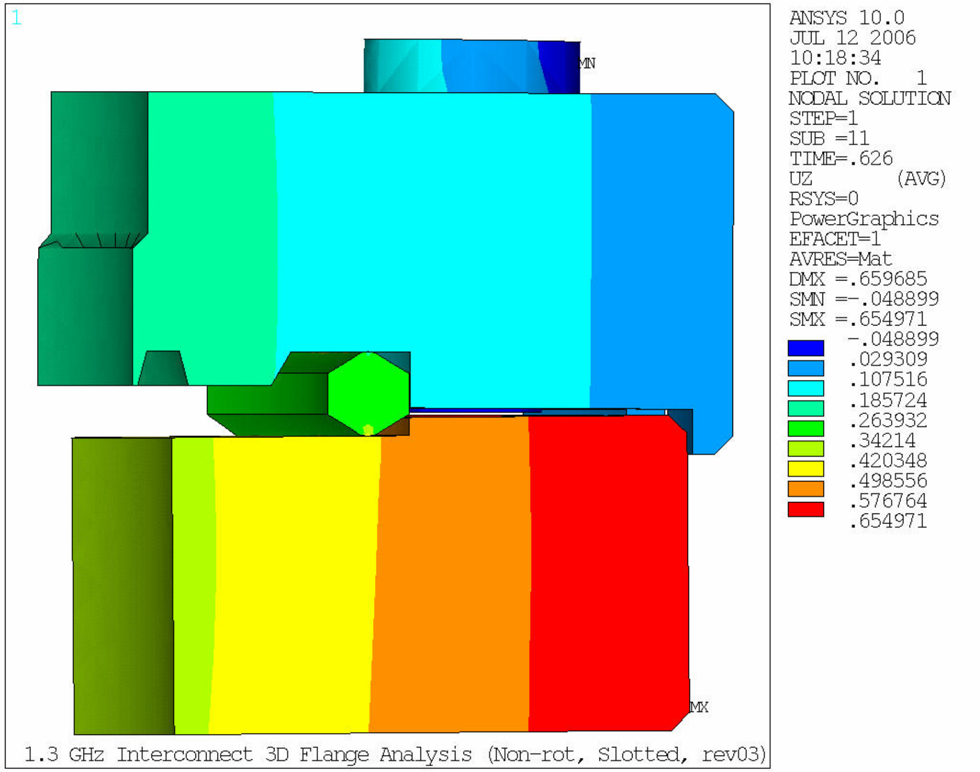
After cooldown to 2K, sealing force increased by approx. 0.7%

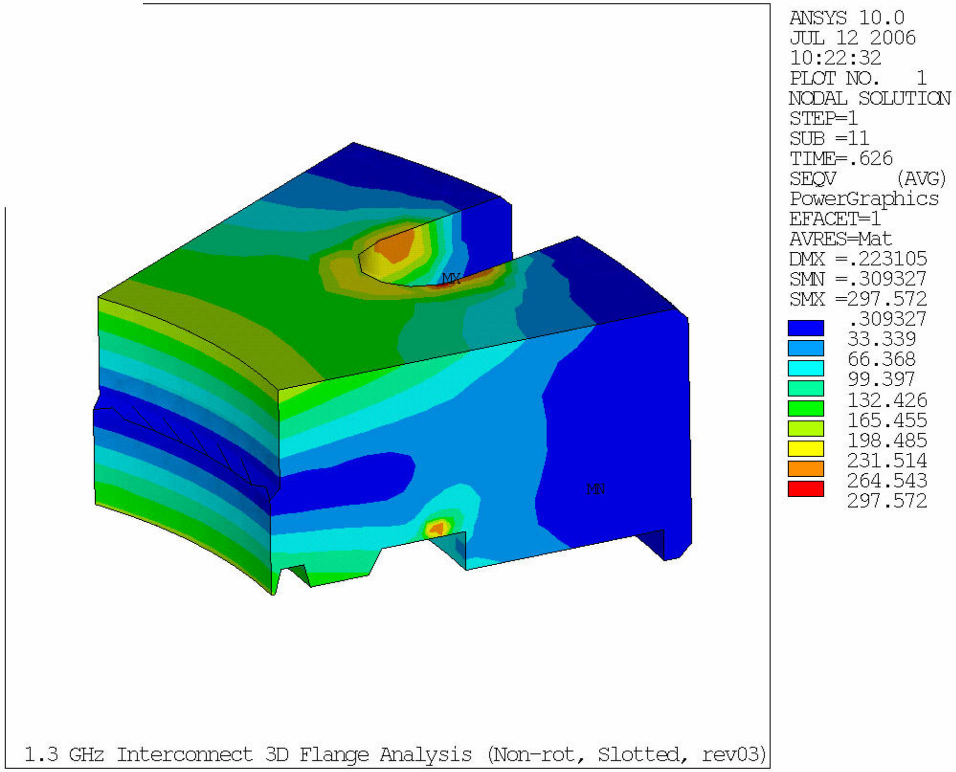
Non-Rotational Existing Flange Results





Non-Rotational **Slotted** Flange Results





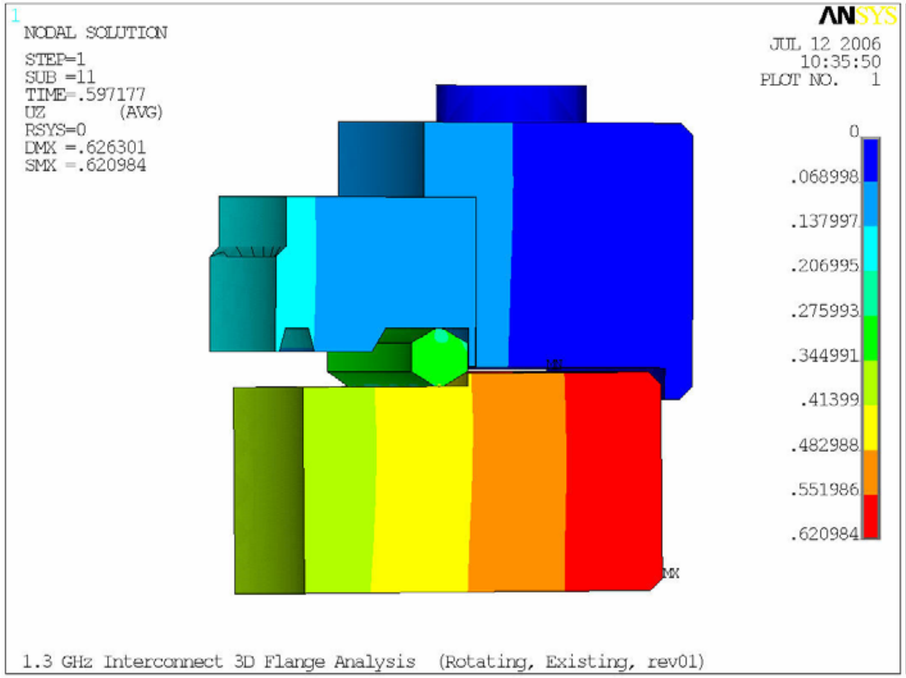
Rotational Flange Displacement Results Comparison

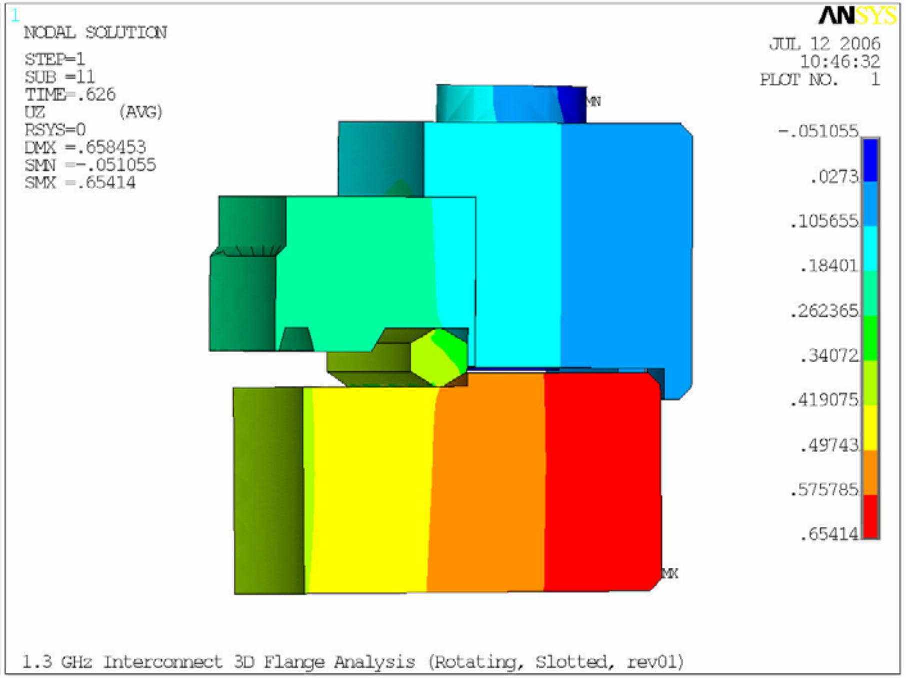
Existing Design

- 0.33mm Seal Crush
- 123kN Force

Slotted Design

- 0.30mm Seal Crush
- 113kN Force





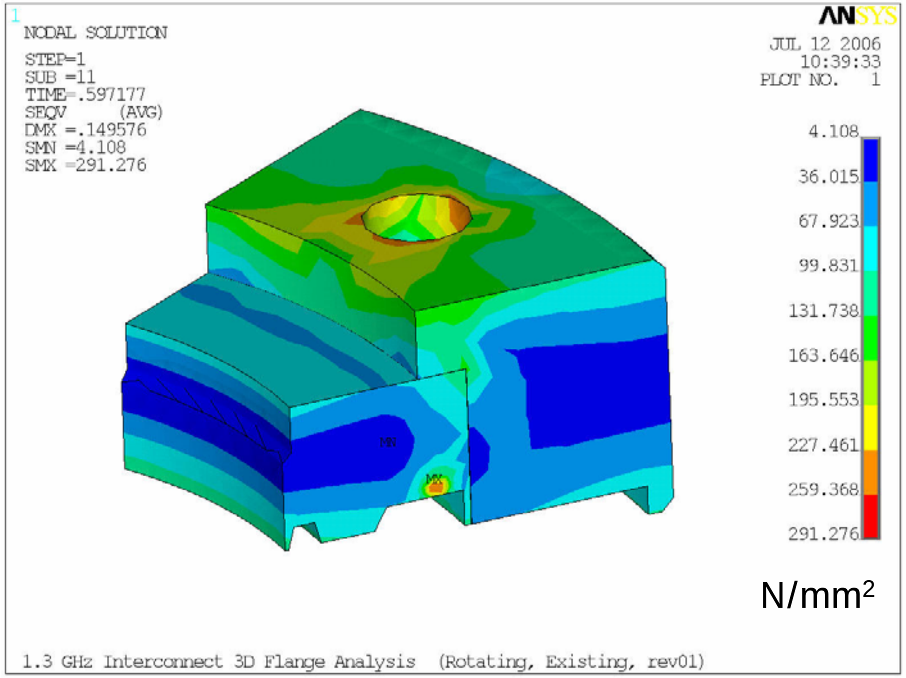
Rotational Slotted Flange von Mises Stress Results Comparison

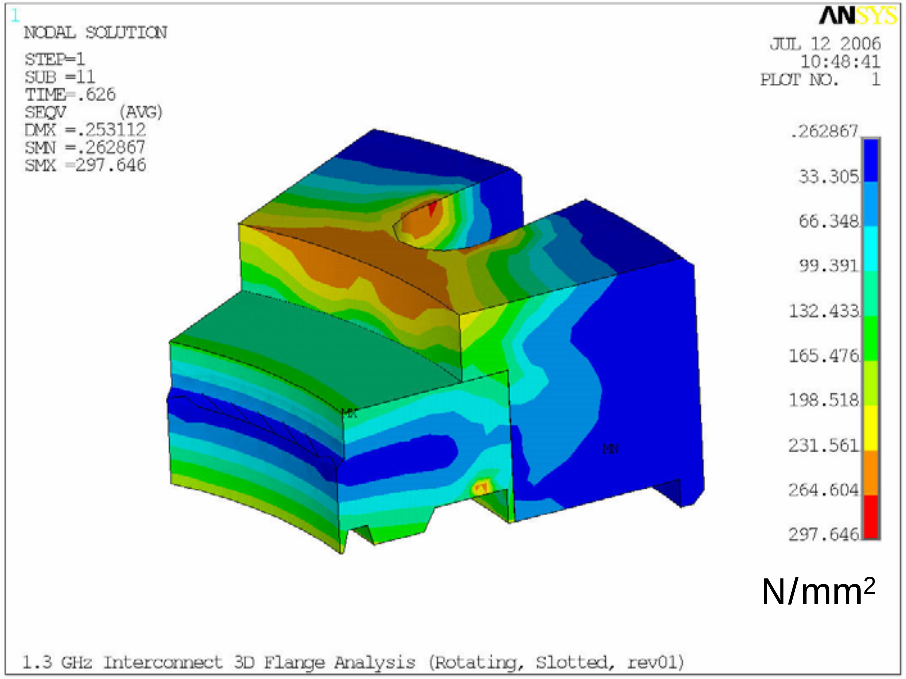
Existing Design

- 0.33mm Seal Crush
- 123kN Force

Slotted Design

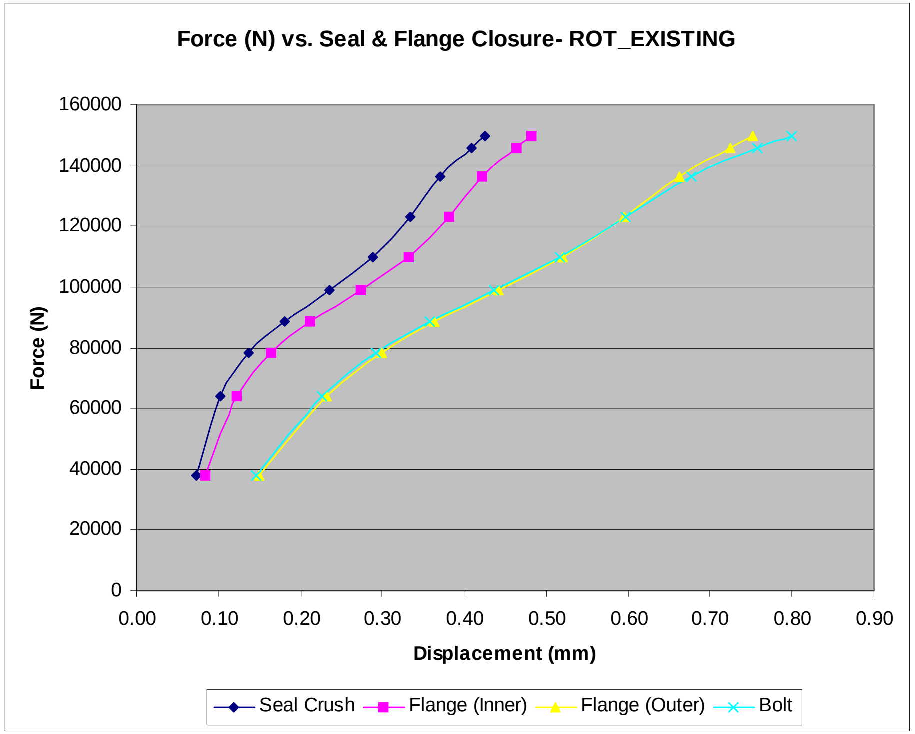
- 0.30mm Seal Crush
- 113kN Force



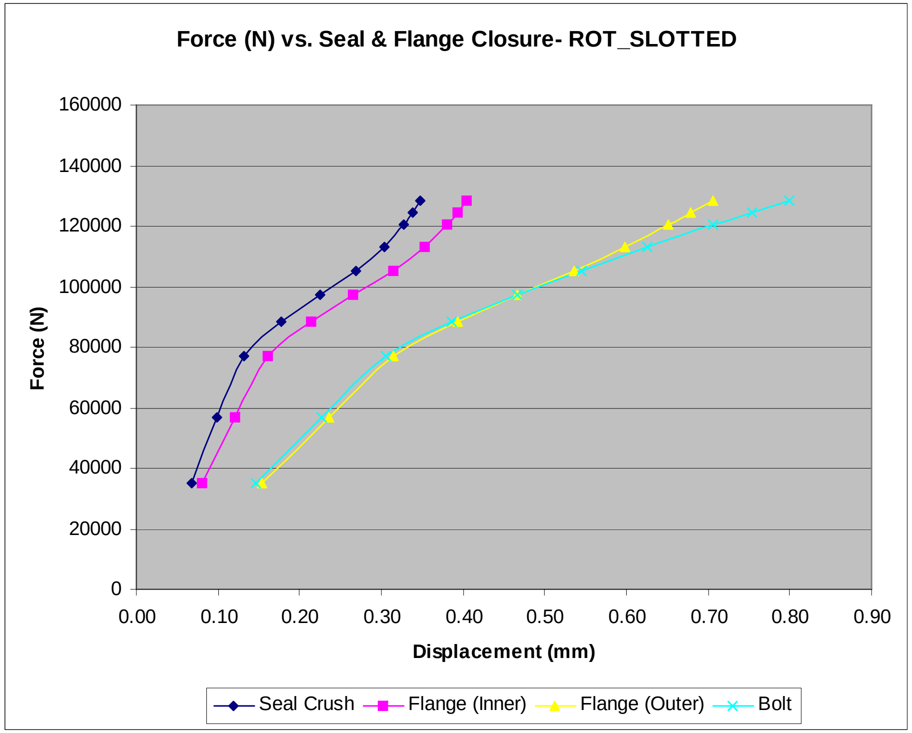


Rotational Seal Crush & Flange Displacement Results Comparison

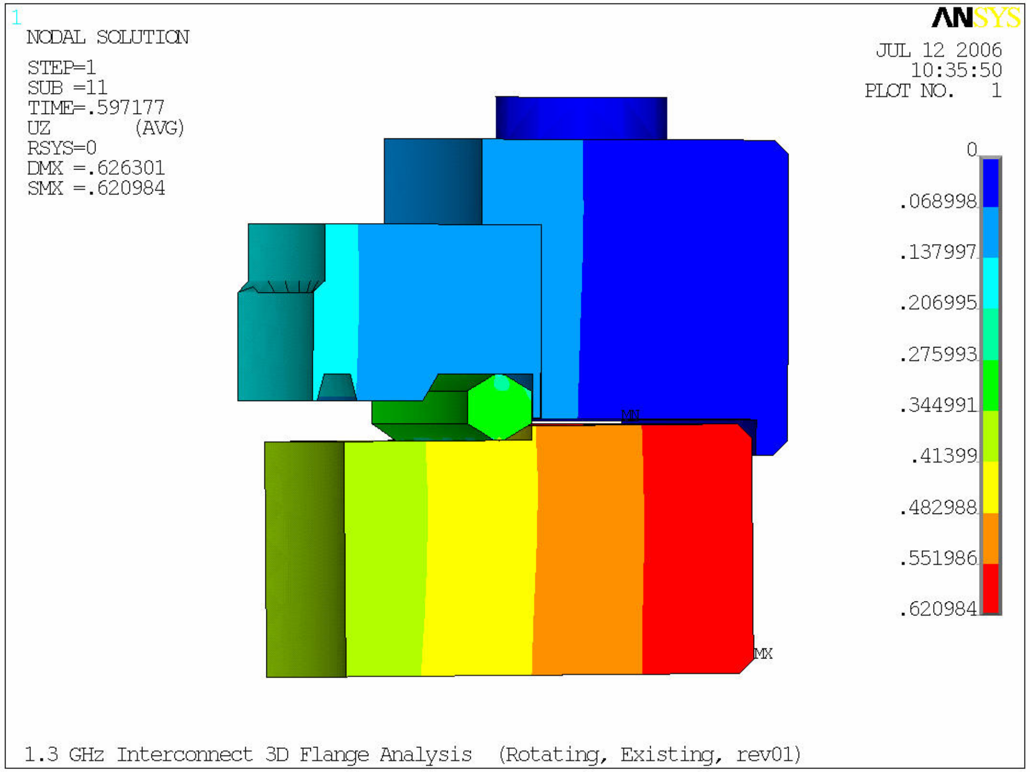
Existing Design

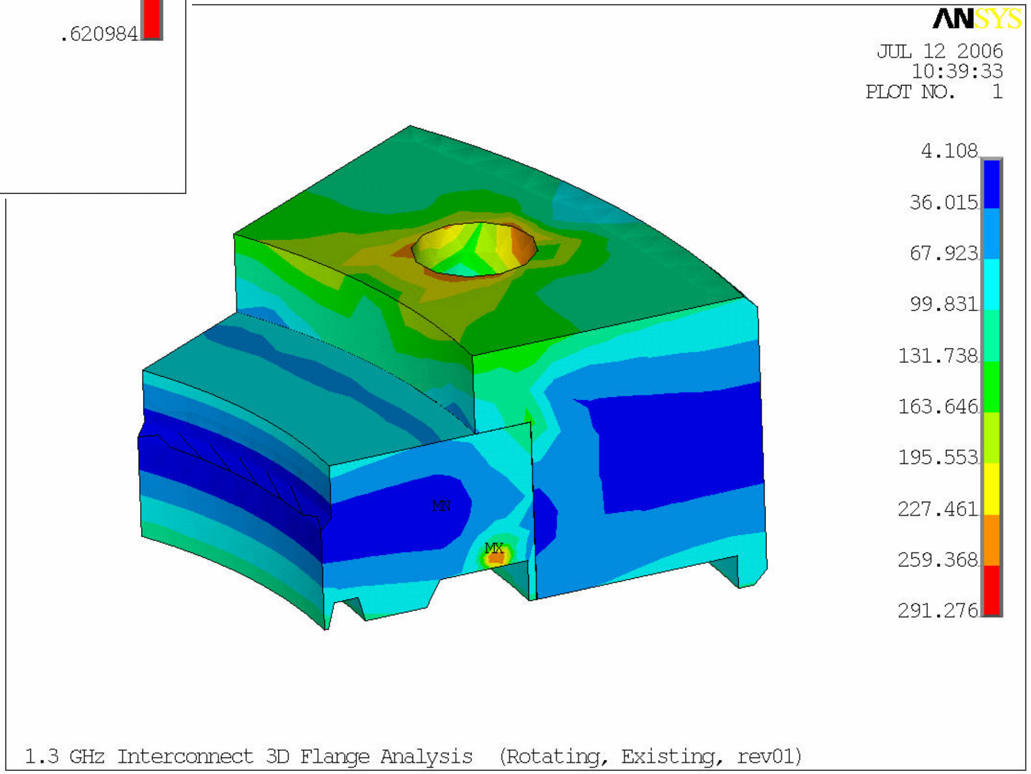


Slotted Design

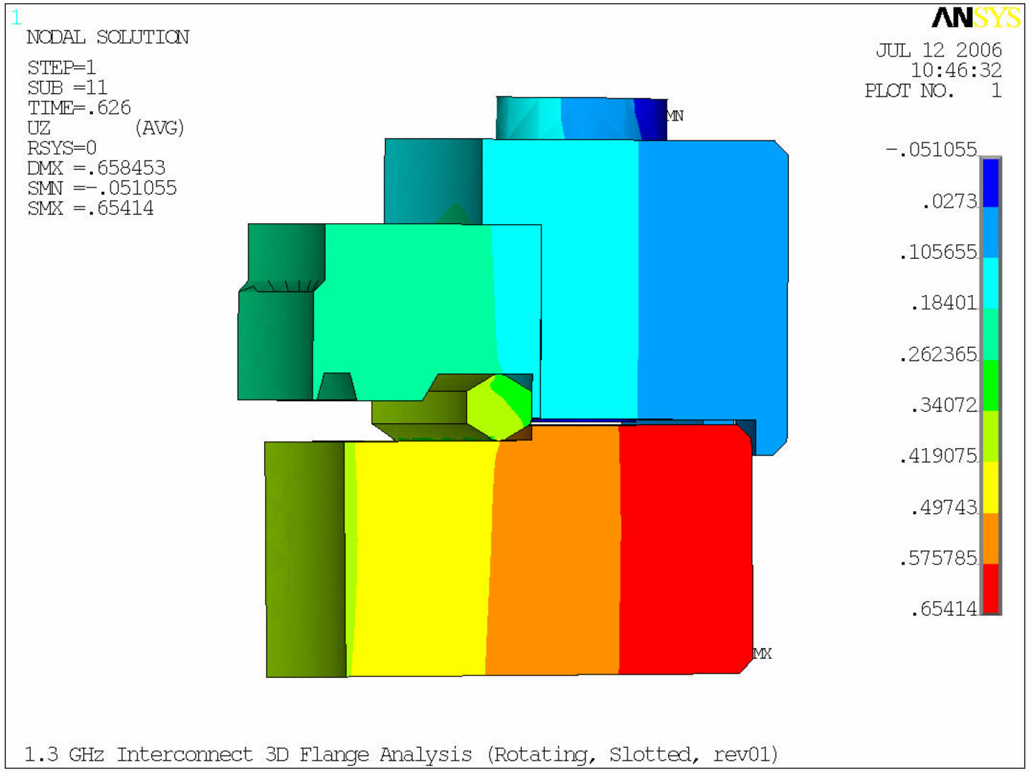


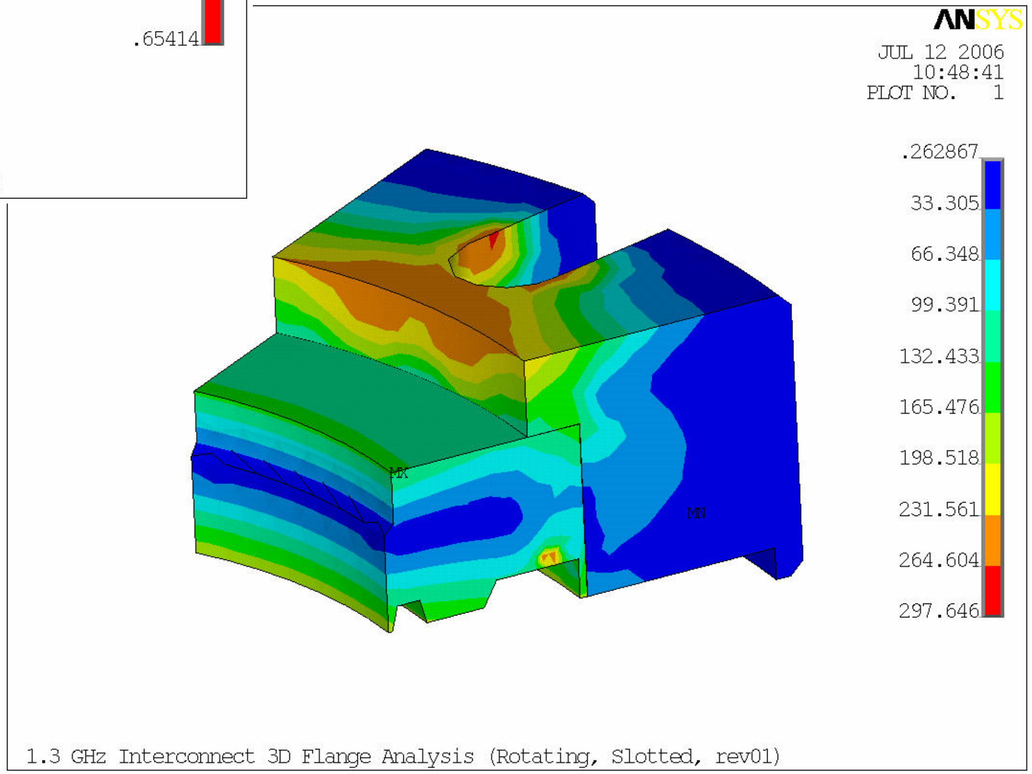
Rotational **Existing** Flange Results





Rotational **Slotted** Flange Results





In Summary

- A first of a kind comprehensive FEA model of the interconnect flange has been developed & results agree well to experimental data plus earlier 2d-FEA work
- Preliminary results show that a slotted flange option could work-- prototype drawings are currently being completed & testing is planned for sometime this summer
- It will be interesting to see how the JLab Radial Wedge (RW) flange compares with the existing Desy design– the RW flange at this point seems the better option in terms of simplicity, ease of assembly, etc, but this yet has to be verified.
- Finally, this benchmark FEA model can now be the starting point & be expanded for further R&D work on quick disconnect type systems, etc. for industrialization -- Obviously, welding the cavities together in a clean way would be the ideal & most reliable solution!