



# **FOUNDATION & BOLT LOADS STUDY**

## **Parametric Stress Analysis**

**February 24, 2011**



# POLOIDAL FOUNDATION COMPLEX – BENDING / SHEAR

## COMPLEX BENDING (CONTINUED):

### MAXIMUM, MINIMUM, AND MAXIMUM ABSOLUTE COMPLEX BENDING STRESS:

$$fb\_max := \max(fb) \quad fb\_max = 4754 \text{ psi}$$

$$fb\_min := \min(fb) \quad fb\_min = -7053 \text{ psi}$$

$$fb\_max\_absolute := \max(|fb\_max|, |fb\_min|) \quad fb\_max\_absolute = 7053 \text{ psi}$$

shear and torsion analysis  $T_x := 538 \text{ in}\cdot\text{lbf}$   $I_x = 6.0615 \cdot \text{in}^4$

$$Q_x := .00080616 \cdot \text{m}^3 \quad t_x := .268727 \cdot \text{m} \quad V_x := 1047.6 \cdot \text{N}$$

$$Q_y := .0001464 \cdot \text{m}^3 \quad t_y := 0.0488 \cdot \text{in} \quad V_y := -1891 \cdot \text{N} \quad I_y = 150.8296 \cdot \text{in}^4$$

$$f_{sx} := \frac{V_x \cdot Q_y}{I_y \cdot t_y} \quad f_{sx} = 286 \text{ psi}$$

$$f_{sy} := \frac{V_y \cdot Q_x}{I_x \cdot t_x} \quad f_{sy} = -326 \text{ psi}$$

Assuming the section is a rectangle when calculating the torsional shear stress, making the largest width and height out of the section:

$$h := 1.685 \cdot \text{in} \quad b := .175 \cdot \text{in} \quad kg := 3 \cdot h + 1.8 \cdot b$$

$$f_{st} := \frac{kg \cdot T}{h^2 \cdot b} \quad f_{st} = 33226 \text{ psi}$$

Note: My : references Mz in loads

Note: Vy : references Vz in loads

### Design Stress Limits

	316L
Minimum Ultimate Tensile Strength, Su	100C
Minimum Yield Strength, Sy	458
Design Stress Intensity Limit, Sm	147
Stress Endurance Limit, Se (=30% Su)	137

The hand calculations Show the Rail Stress is Acceptable Directly at the foundation interface



# Foundation/ Bolt Pad Analysis

## POLOIDAL LOADS ON TOP OF COMB

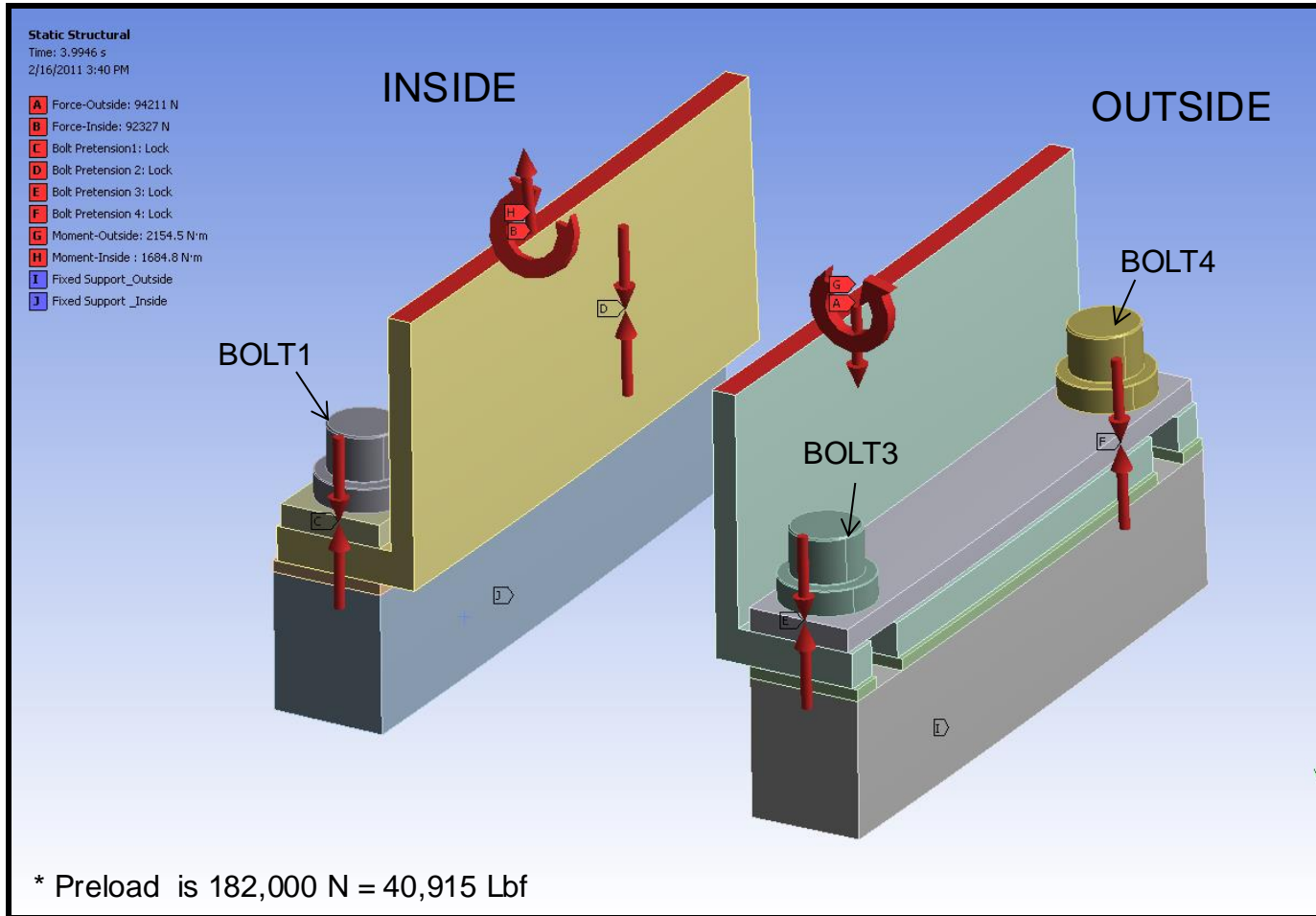
LOADS ON TOP OF POLOIDAL COMB FOR BOLT STUDY									
12-Feb-11									
DESCRIPTION	CORNER	BRACKET	INSIDE	COMB	LOADS				
	STEP	RX_COR_INSIDE	RY_COR_INSIDE	RZ_COR_INSIDE	MX_COR_INSIDE	MY_COR_INSIDE	MZ_COR_INSIDE	RNET_COR_INSIDE	
POLOIDAL BRACKET	1 - Thermal Loading		-486.2	-16741.9	1463.4	122.1	11.8	-215.9	16812.8
	2 - Thermal + Lorentz Away Plasma		-794.4	59510.7	-2509.2	-228.3	-50.7	-2068.5	59568.9
RSYS, 385	3-Thermal + Lorentz To Plasma		-178.1	-92995.9	5436.5	472.5	74.2	1636.7	93154.8
DESCRIPTION	CORNER	BRACKET	OUTSIDE	COMB	LOADS				
	STEP	RX_COR_OUTSIDE	RY_COR_OUTSIDE	RZ_COR_OUTSIDE	MX_COR_OUTSIDE	MY_COR_OUTSIDE	MZ_COR_OUTSIDE	RNET_COR_OUTSIDE	
POLOIDAL BRACKET	1 - Thermal Loading		250	8739.4	-5409.4	-298.6	-37.4	-7.7	10281.1
	2 - Thermal + Lorentz Away Plasma		658.8	-77651.8	-12830	-754.6	-114	2156.8	78707.3
RSYS, 384	3-Thermal + Lorentz To Plasma		-158.7	95127.6	2010.6	157.4	39.1	-2172.2	95148.9

## CORNER LOADS ON TOP OF COMB

LOADS ON TOP OF COMB FOR BOLT STUDY									
9-Feb-11									
DESCRIPTION	CORNER	BRACKET	INSIDE	COMB	LOADS				
	STEP	RX_COR_INSIDE	RY_COR_INSIDE	RZ_COR_INSIDE	MX_COR_INSIDE	MY_COR_INSIDE	MZ_COR_INSIDE	RNET_COR_INSIDE	
CORNER BRACKET	1 - Thermal Loading		360	9114.6	4645.5	346.4	37.5	874.2	10236.5
	2 - Thermal + Lorentz A		372.8	120200.5	-1032.5	469.4	89.2	842.1	120205.5
RSYS, 282	3-Thermal + Lorentz To		347.1	-101952.2	10324.8	223.6	-14.2	905.8	102474.3
DESCRIPTION	CORNER	BRACKET	OUTSIDE	COMB	LOADS				
	STEP	RX_COR_OUTSIDE	RY_COR_OUTSIDE	RZ_COR_OUTSIDE	MX_COR_OUTSIDE	MY_COR_OUTSIDE	MZ_COR_OUTSIDE	RNET_COR_OUTSIDE	
CORNER BRACKET	1 - Thermal Loading		417.2	9114.6	11521.9	382.8	-95.5	1083.4	11537.8
	2 - Thermal + Lorentz A		1030.2	120200.5	16340.7	1496	-76.9	1995.1	59588.5
RSYS, 283	3-Thermal + Lorentz To		-196	-101952.2	6708.3	-729.9	-113.9	170.7	58537.9

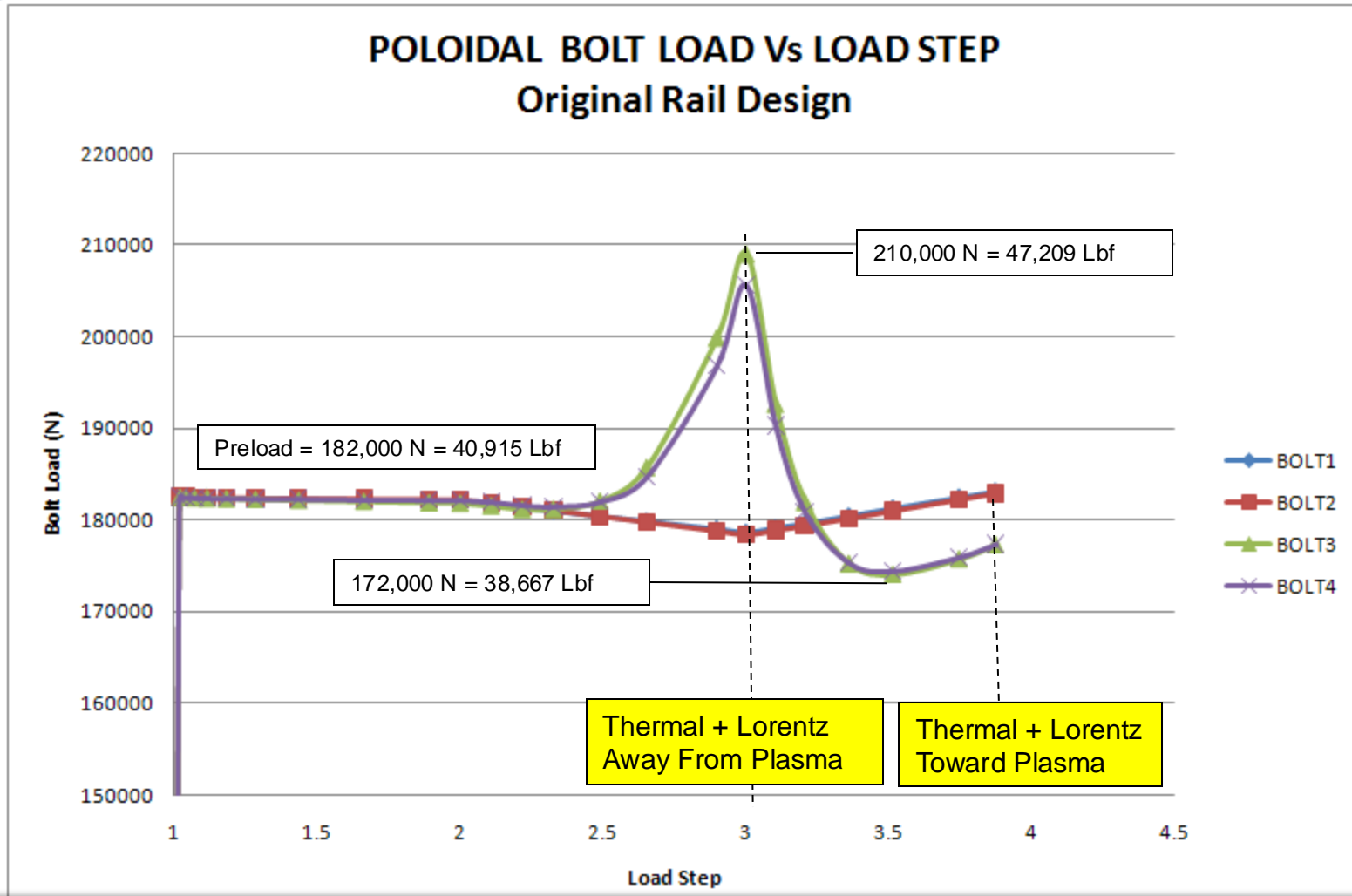


# Poloidal Bolt / Foundation Boundary Conditions





# Normal Bolt Stress



The Load on Bolts 2 and 3 has excessive variation (8,542 Lbf) and will require a higher preload or more bolts –The clamping force is not sufficient



# Poloidal Foundation Parametric Study

## OBJECTIVES:

- 1.) Use Load Step #3 (Lorentz Loads Toward Plasma) + Bolt Preloading
- 2.) Adjust the foundation width parameters and determine the impact on:
  - a.) The bolt working loads
  - b.) The foundation interface stress
  - c.) The rail & Attachment Stresses
- 3.) Make a recommendation based on these trends to assure an adequate design

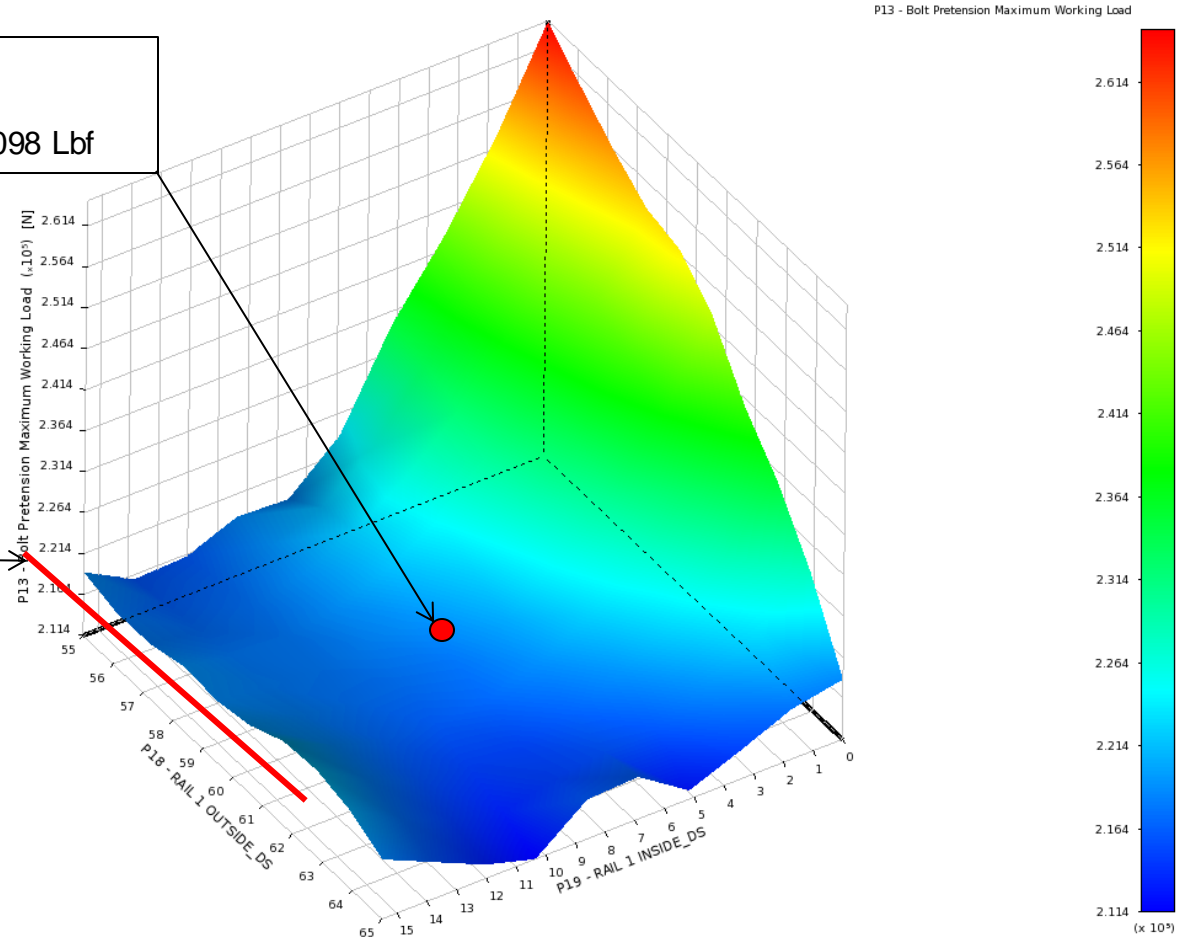


# Bolt #1 Working Load - Response Envelope Function of Rail Width Changes

Preload =  $2.184 \times 10^5$  N = 49,098 Lbf

Inside > 8mm  
Outside = anything  
Load =  $2.184 \times 10^5$  N = 49,098 Lbf

Bolt Pre-Load  $2.184 \times 10^5$  N



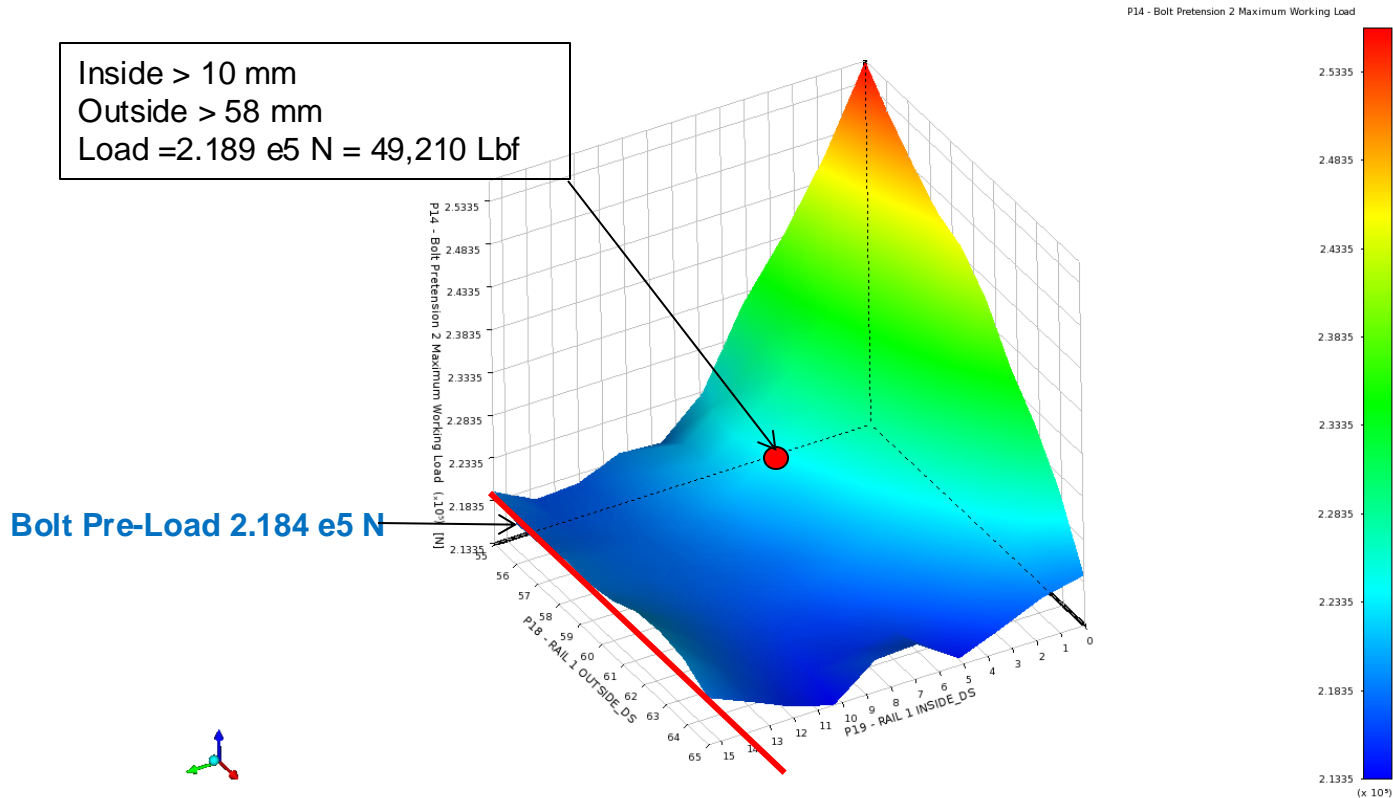
Setting Outside Rail to anything if the inside rails greater than 8 mm  
Results in all working bolt loads of about 49,098 Lbf (very low fatigue Load range)



# Bolt #2 Working Load - Response Envelope Function of Rail Width Changes

Preload =  $2.184 \times 10^5$  N = 49,098 Lbf

Inside > 10 mm  
Outside > 58 mm  
Load =  $2.189 \times 10^5$  N = 49,210 Lbf

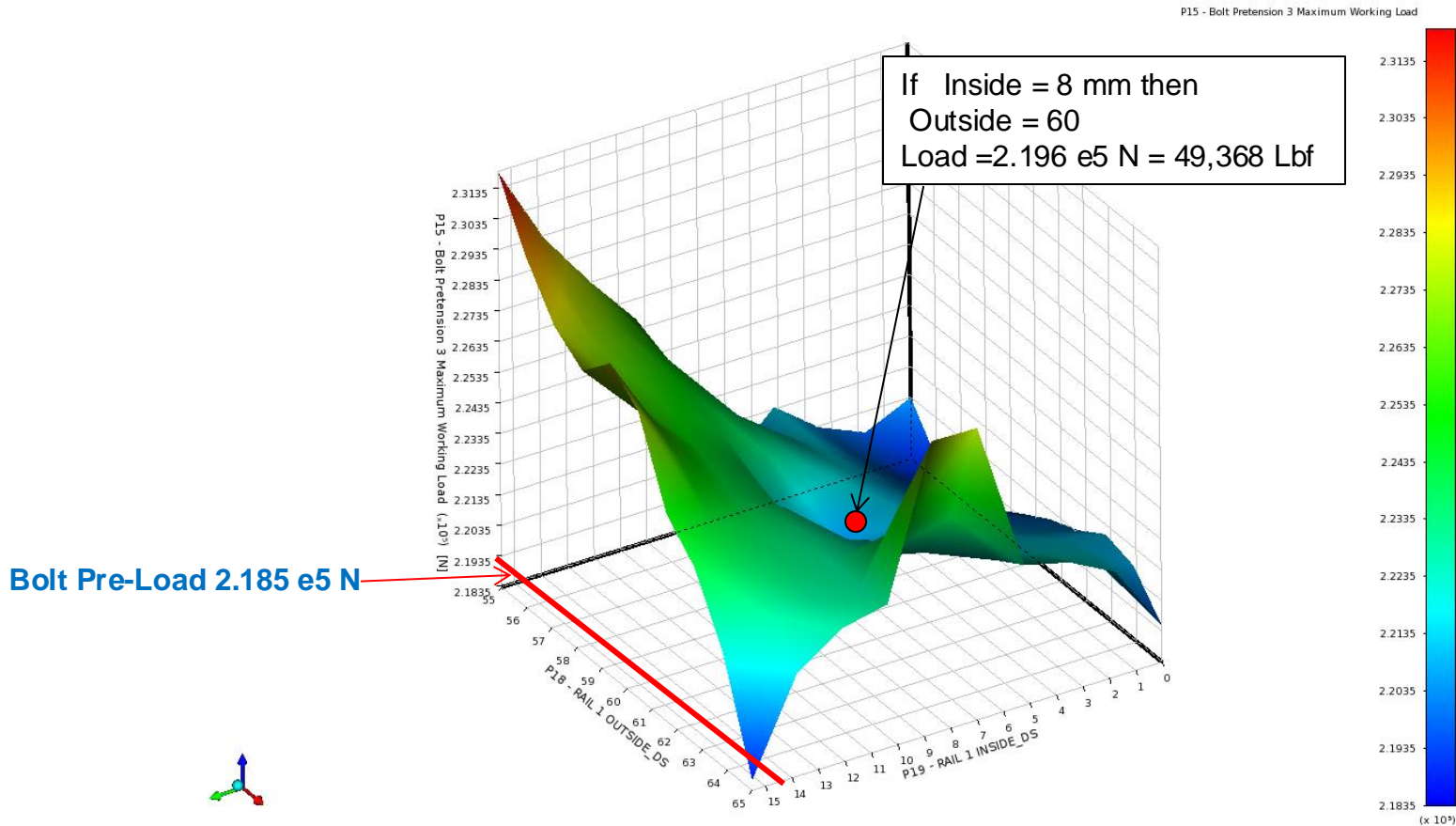


Setting Inside Rail Greater than 10 mm and the Outside Rail 58 mm or greater  
Results in all working bolt loads of about 49,210 Lbf (fatigue Load range of 112 Lbf)



# Bolt #3 Working Load - Response Envelope Function of Rail Width Changes

Preload =  $2.184 \times 10^5$  N = 49,098 Lbf



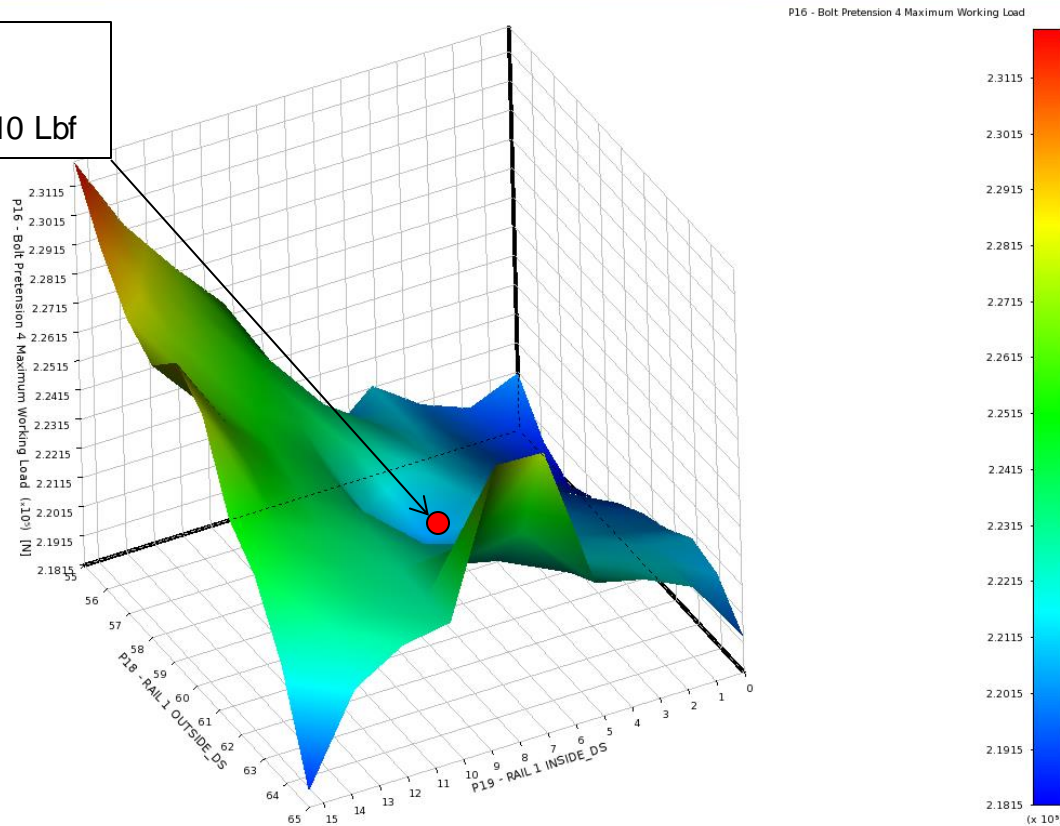
Setting Inside Rail Greater than 8 mm and the Outside Rail 60 mm or greater  
Results in all working bolt loads of about 49,368 Lbf ( 270 lbf fatigue Load range)



# Bolt #4 Working Load - Response Envelope Function of Rail Width Changes

Preload =  $2.184 \times 10^5$  N = 49,098 Lbf

Inside = 8 mm  
Outside = 60  
Load =  $2.189 \times 10^5$  N = 49,210 Lbf

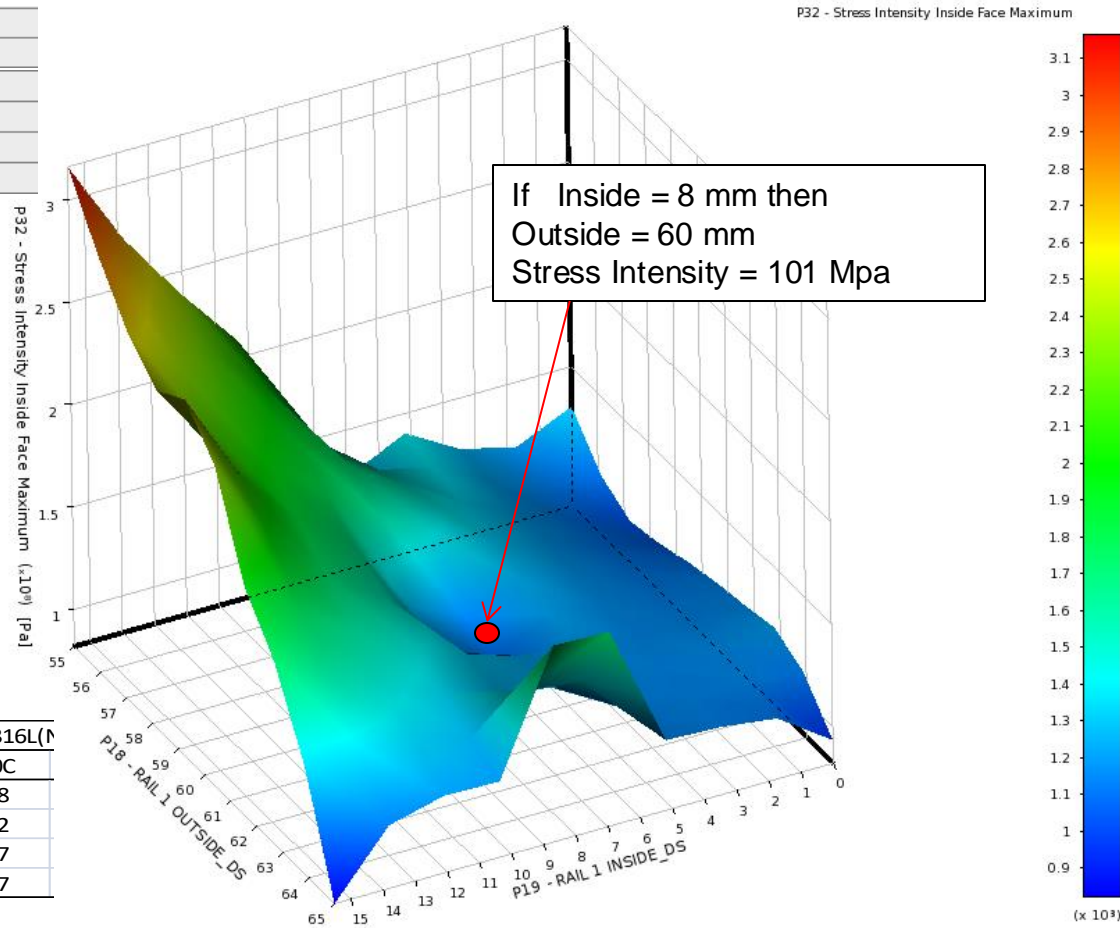


Setting Inside Rail is 8 mm and the Outside Rail 60 mm or greater  
Results in all working bolt loads of about 49,210 Lbf ( 112 lbs working fatigue load)



# Inside Foundation Face - Stress Intensity

P21 - RAIL 2 INSIDE_DS	8.06
P20 - RAIL 2 OUTSIDE_DS	60
P29 - Equivalent Stress Found Outside Maximum	4.8201E+08
P30 - Equivalent Stress Found inside Maximum	4.8105E+08
P31 - Stress Intensity Outside Face Maximum	7.7756E+07
P32 - Stress Intensity Inside Face Maximum	1.0122E+08



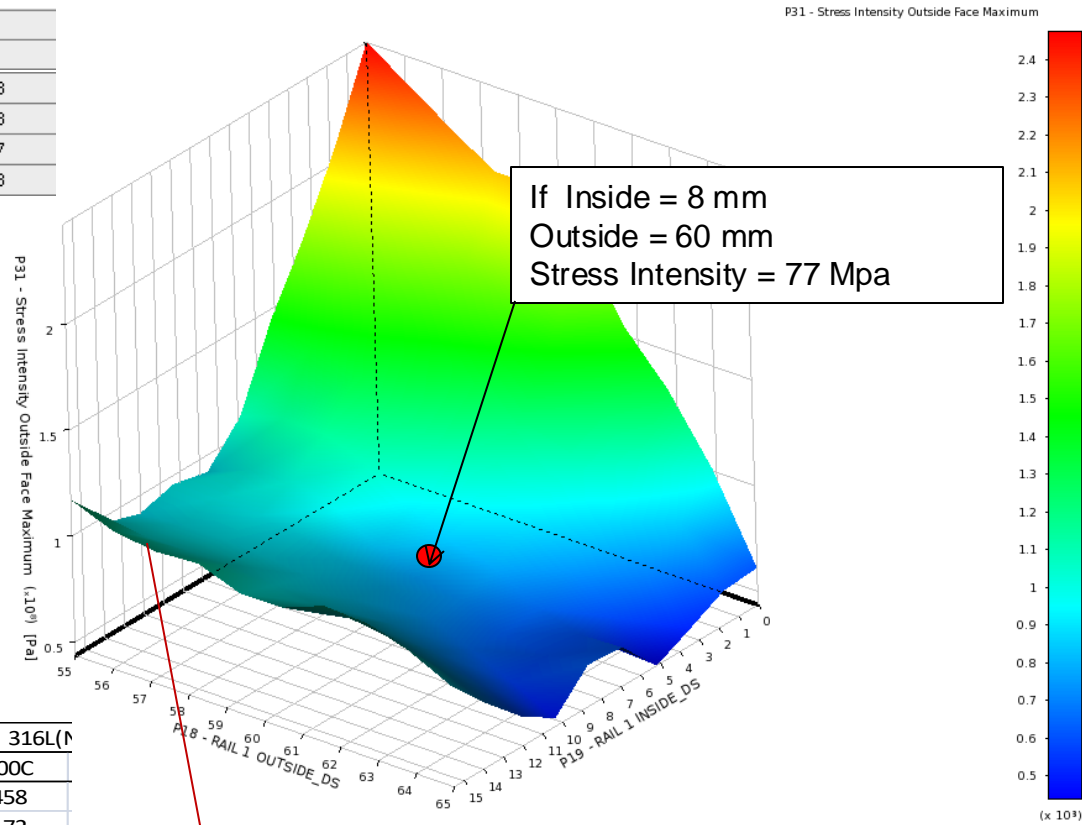
	316L(N)
	100C
Minimum Ultimate Tensile Strength, Su	458
Minimum Yield Strength, Sy	172
Design Stress Intensity Limit, Sm	147
Stress Endurance Limit, Se (=30% Su)	137

Setting Inside Rail to 8 mm and the Outside Rail 60 mm Results in a local minimum on the stress intensity of 101 Mpa which meets the criteria



# Outside Foundation Face - Stress Intensity

P21 - RAIL 2 INSIDE_DS	8.06
P20 - RAIL 2 OUTSIDE_DS	60
P29 - Equivalent Stress Found Outside Maximum	4.8201E+08
P30 - Equivalent Stress Found inside Maximum	4.8105E+08
P31 - Stress Intensity Outside Face Maximum	7.7756E+07
P32 - Stress Intensity Inside Face Maximum	1.0122E+08



	316L(N
	100C
Minimum Ultimate Tensile Strength, Su	458
Minimum Yield Strength, Sy	172
Design Stress Intensity Limit, Sm	147
Stress Endurance Limit, Se (=30% Su)	137

Current Design Approximated by this region 132 Mpa

Setting Inside Rail Greater to 8 mm and the Outside Rail 60 mm Results in a local minimum on the stress intensity 77 Mpa which meets the criteria