Developing of Vacuum Tight Ceramic-Metal Joints in Accelerator Technology

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The modernity of the problem

Vacuum tight metal/ceramic joints are widely using in particle accelerators as important connections – especially for Ultra High Vacuum (UHV) systems, RF systems, electro-magnetic systems, beamlines as Insulators, feedthroughs, windows, vacuum chambers, etc.;

There are many technologies for ceramic to metal vacuum tight connections (brazing, welding, soldering, etc.). The existing technological processes have many disadvantages and unsolved problems. Especially some lows and equations were received based combination of experemental and theoretical calculations and experiments. Some fundamental (chemical and mechanical) processes totally non described yet for ceramic to metals bonding. There are many non standard and new metal/ceramic joints in charged particle accelerators.

Design and fabrication of new reliable and effective vacuum tight metal/ceramic joints and developing new and improving existing bonding technologies for vacuum systems are modern tasks-problems.

The objectives of this work

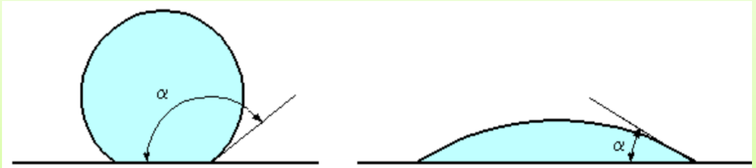
- Review of physical and mechanical characteristics of ceramics and metals for vacuum tight metal/ceramic joints;
- Review of existing technologies for ceramic to metals connections (Brazing, welding, sealing, gluing, etc.);
- Experimental activity - metallization and brazing of ceramics to metals;
- Design of vacuum tight ceramic to metal joints;
- Mechanical simulation of ceramic to metal joints;
- Investigation of pressure receiving and spreading on materials surfaces during brazing process.

1.1. Materials for vacuum tight ceramic/metal joints.

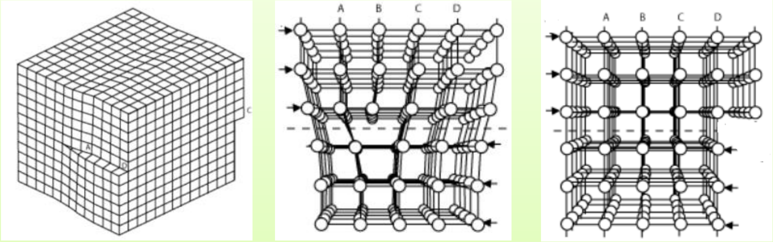
Main requirements

- Low outgassing rate,
- Thermal shock resistance,
- Low material penetration,
- High mechanical strength,
- High weldability and brazability,
- High machinability,
- Reliable during long time,
- Repeatability and Dimentional stability,
- Eappropriate electro-mechanical characteristics,
- Absorbcion and desorbcion characteristics,
- Surface oxidation characteristics,
- Corrosion resistance,
- Metallization characteristics.

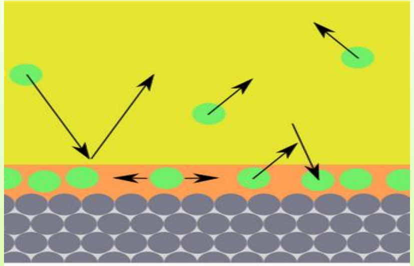
Solders and materials wettability



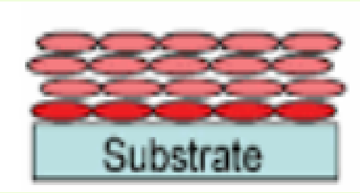
Materials structures - Homogeneity



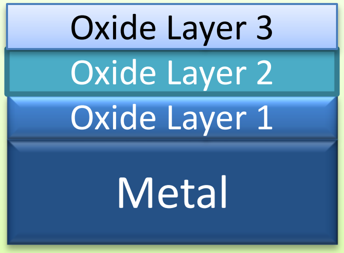
Without dislocations, content inhomogeneities, cracks, inner impurities, etc.



Adsorption and desorbtion

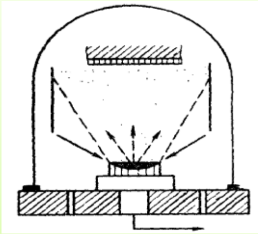


Chemisorption



Oxidation layers

Corrosion



Metallization

Main Properties of Vacuum Materials

	Unit	Alumina Al2O3		BeO	Steatite	Cu	Ag	W	Mo	Mn	Ni	Si	Al	Ti
		> 99.5%	95%											
Density	g/cm3	3.9	3.95	3.01	2.75	8,92	10.49	19.25	10.28	7.21	8.9	2.33	2.70	4.506
Atomic weight	(AMU)					63.5	107.8	183.84	95.94	54.93	58.69	28	27	47.9
Melting point	0C	2072		2,507		1083	961	3422	2623	1246	1455	1414	660.32	1668
Thermal conductavity	W / (m * K)	20 °C- 34.9	32	330	1.5-3.0	401	429	173	138	7.81	90.9	149	237	21.9
Thermal expansion	10-6/ K	7.3 20 - 500 °C -	7,8 10-7/ K	9.0	7-10 10-6 25 °C	16.5 25 °C	18.9 25 °C	4.5 25 °C	4.8 25 °C	21.7 25 °C	13.4 25 °C	2.6 25 °C	23.1 25 °C	8.6 25 °C
Specific heat	J / (kg * K)	20 °C - 900		1020										
Tensile strength	MPa			306	68,9									434
Young's modulus	GPa	380	460	400		110–128	83	411	329	198	200	130–188	70	116
Compressive Strength	MPa	3500	1900	2800	551,58							7000		
Yield strength	MPa												200-600	
Hardness	Vickers Hardness MPa			13000		343–369	251	3430–4600	1400–2740		638		160–350	830–3420
Average Size of Crystallites µm	µm	10												
Dielectric Loss Tangent		30 - 40 GHz 20 * 10-4		0.006 @ 10 GHz	0.0014 1MHZ									
Magnetic ordering		Non magnetic	Non magnetic	Non magnetic		diamagnetic	diamagnetic	paramagnetic	paramagnetic	paramagnetic	ferromagnetic	diamagnetic	Paramagnetic	Paramagnetic
Typical Color		ivory		white	gray-green	reddish-orange						gray color and a metallic luster	silver-colored	silver color

Austanitic Stainless Steels

ANSI Grade	C max	Si max	Mn max	S max	P max	Ni	Cr	Mo max	N max
316	0.08	1.0	2.0	0.045	0.03	10.0-14.0	16.0-18.0	2.0-3.0	-
316L	0.03	1.0	2.0	0.045	0.03	10.0-14.0	16.0-18.0	1.2-2.75	-
316LN	0.03	1.0	2.0	0.045	0.03	10.5-14.5	16.5-18.5	2.0-3.0	0.12-0.22
310S	0.08	1.2	2.0	0.045	0.03	19.0-22.0	24.0-26.0	-	-
304	0.08	1.0	2.0	0.045	0.03	8.0-10.5	18.0	-	-
304N	0.08	1.0	2.0	0.045	0.03	8.0-10.5	18.0-20.0	-	0.1-0.16

Curie Temperature

Material	Temp. K
Iron (Fe)	1043
Cobalt (Co)	1400
Nickel (Ni)	627

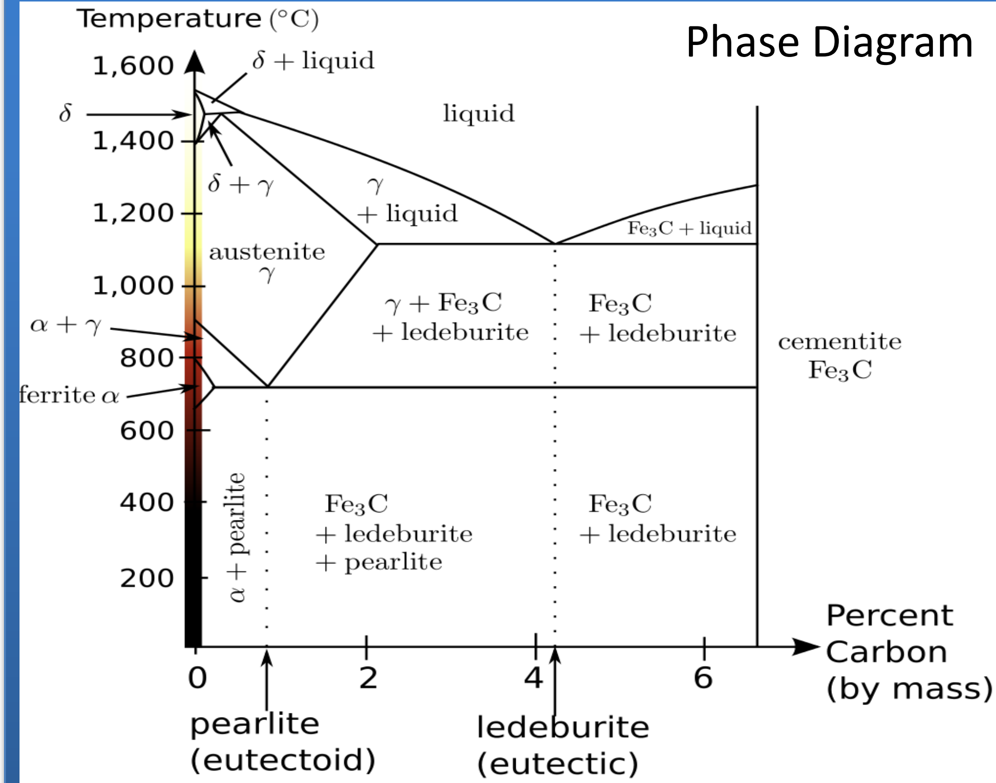
Solders

Solder	M. P. 0C	Sn	Zn	In	Ag	Pd	Cu
Palcusil®10	850				58.5	10	31.5
Palcusil®5	814				68.5	5	26.5
Cusil®	780				72		28
Incusil 10	730			10	63		27
Cusiltin	718	10			60		30
ПСр-45	665—725		25.85		45		30.5
ПСр-65			14.14 - 15.85		64.5 - 65.5		19.5 - 20.5

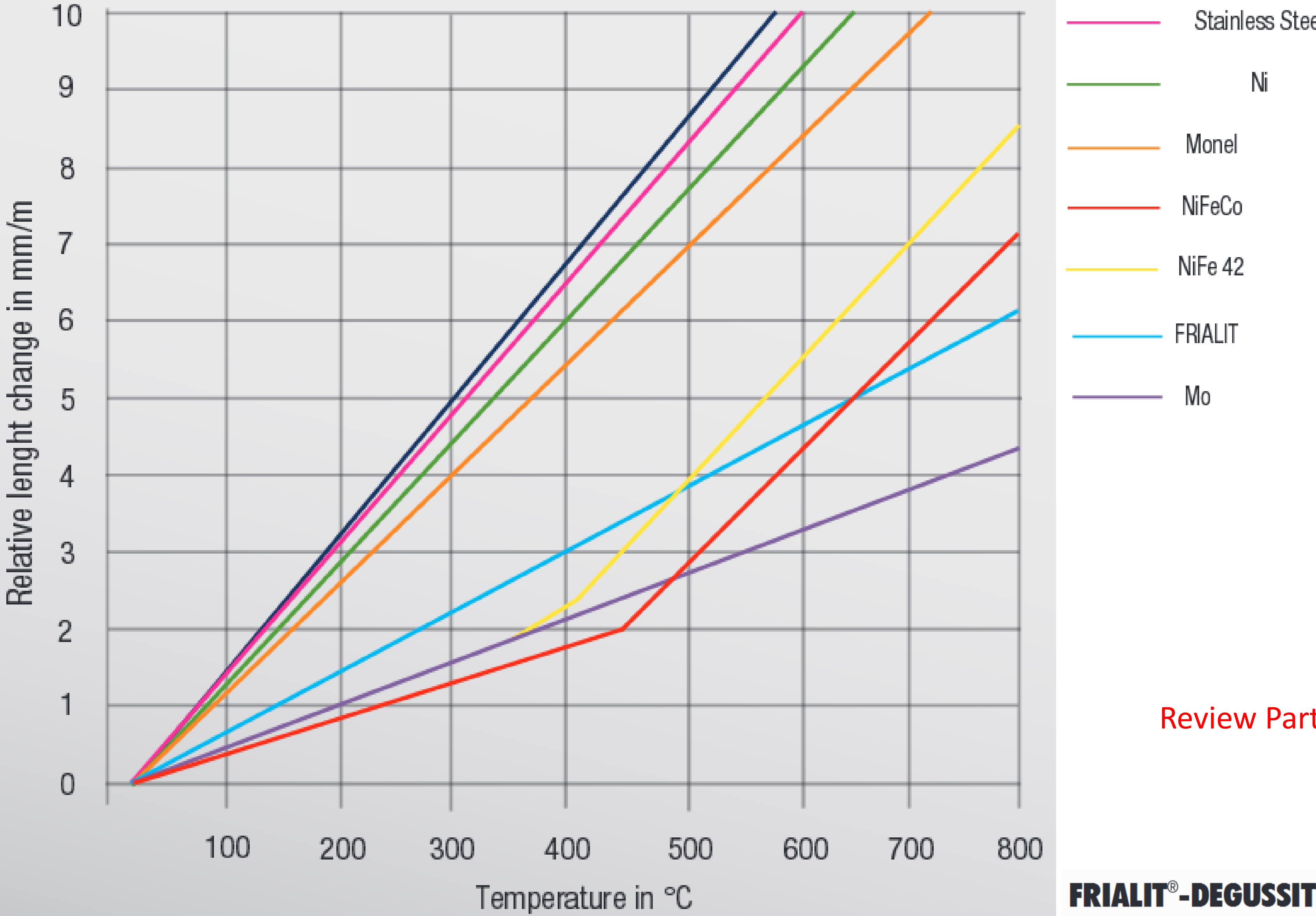
Kovar contant %

Fe	Ni	Co	C	Si	Mn
53.49	29	17	<0.01	0.2	0.3

Phase Diagram

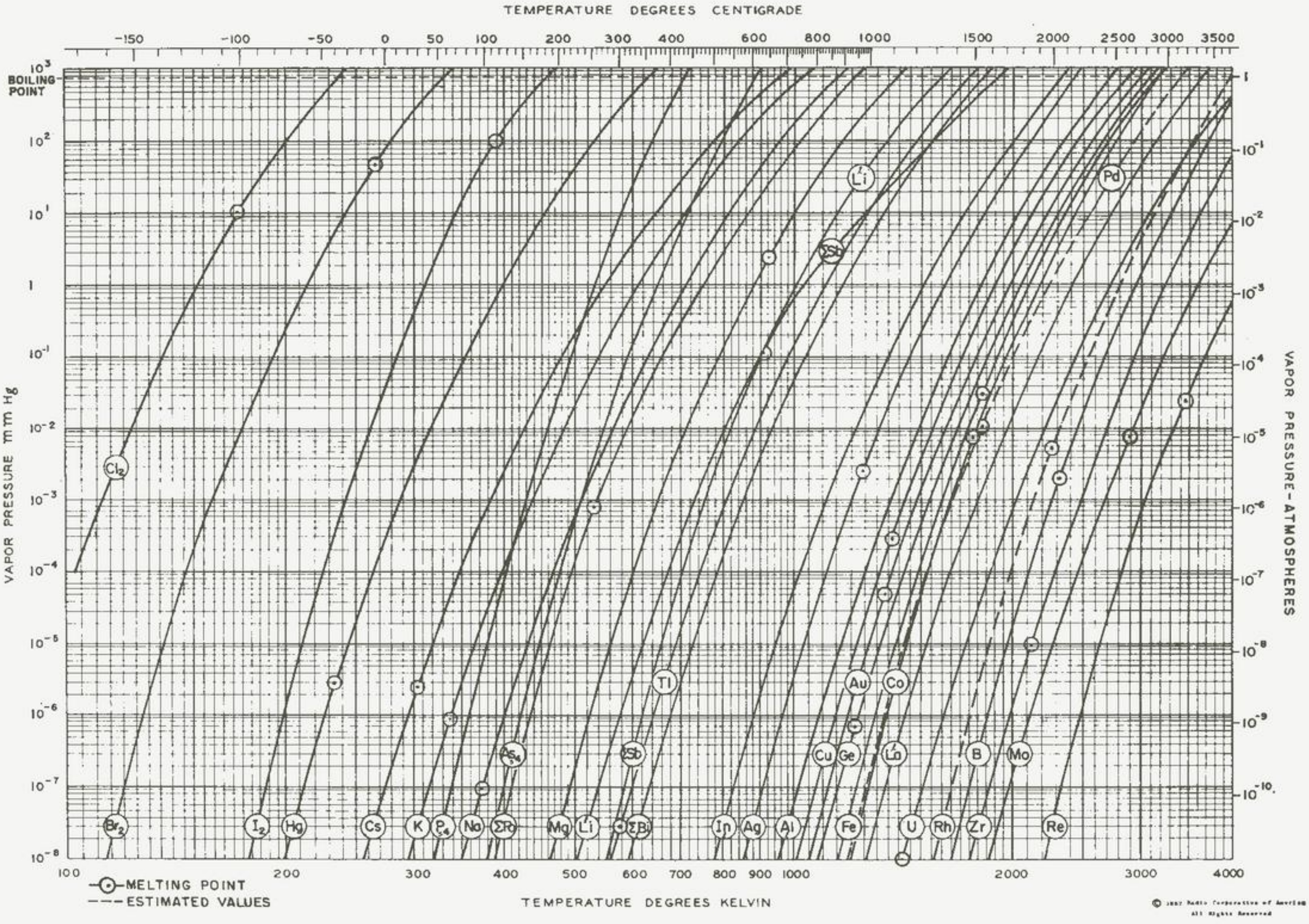


Thermal expansion of metals compared with Al2O3 ceramic

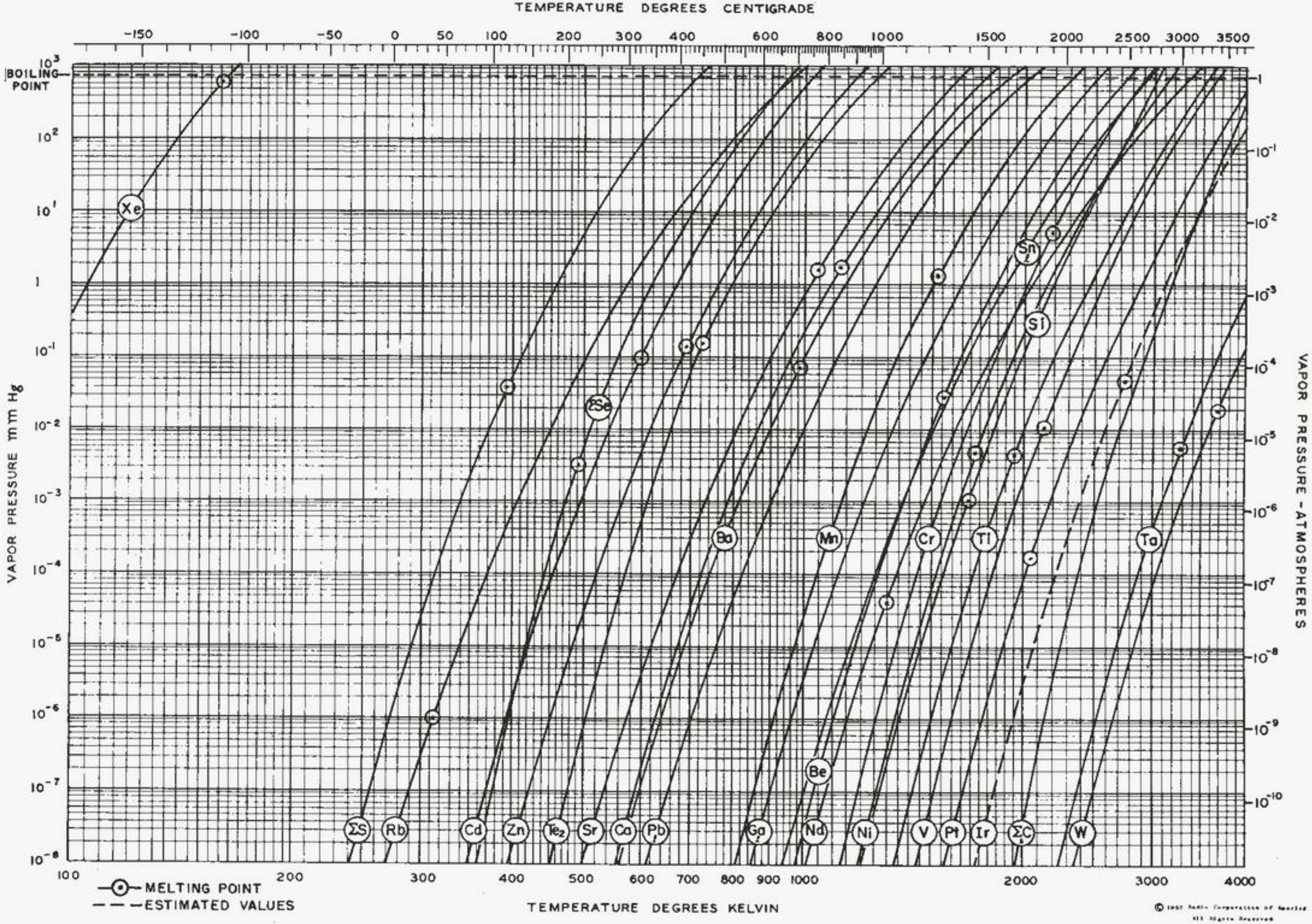


Review Part

FRIALIT®-DEGUSSIT®
Oxide Ceramics



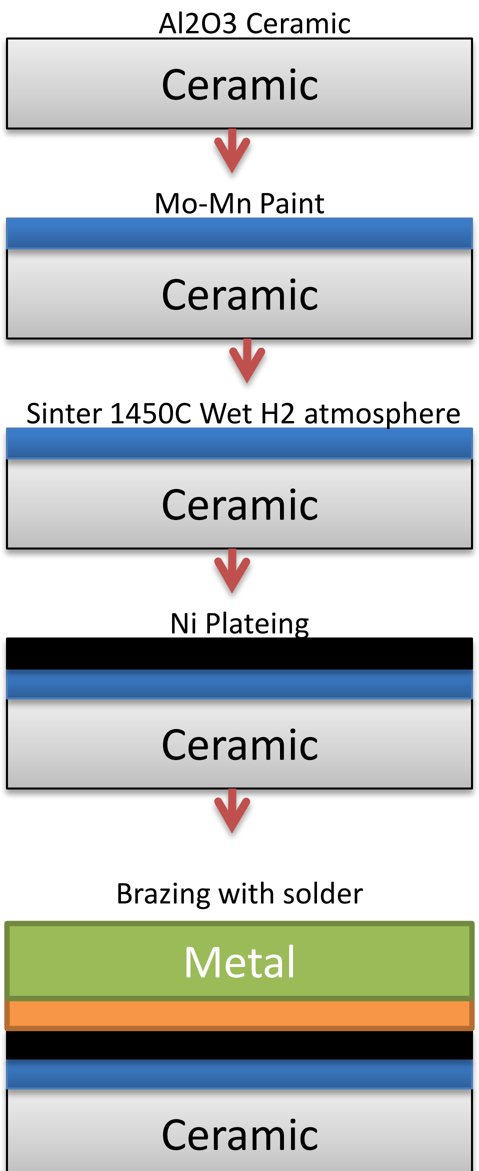
Vapour Pressure Curves for the Common Materials.



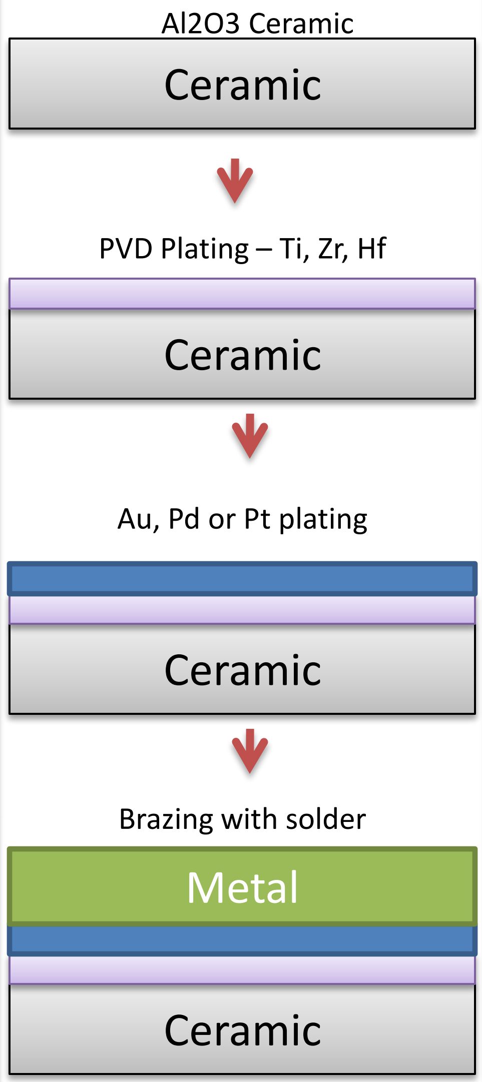
Vapour Pressure Curves for the Common Materials.

1.2. Existing Technologies for ceramic to metal bonding.

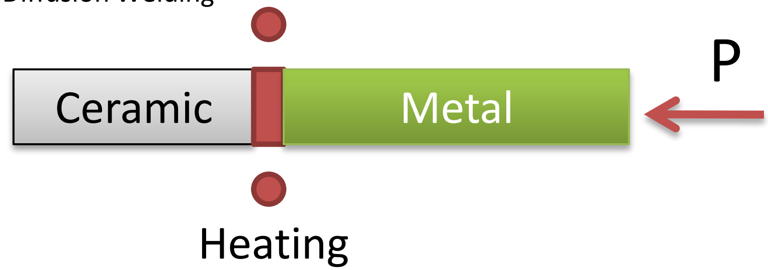
1. Moly Manganese Metallization



2. thin-film metallization process



3. Diffusion Welding



4. Active brazing

5. Gluing

6. Mechanical Fixation

Moly-Manganese Metallization

Ceramic - Type		Metallization Past	Concentration %
Cearmaic Steatit, K-1		Mo : Fe	98 : 2
Ceramic Forsterit, ФС-5Л, АФ-555		Mo : Mn Mo : TiH_2 : Al_2O_3	96 : 4 63.8-74,0.8-6.1
Alumina silicate ceramic		WC : TiC : Fe	60 : 10 : 30
Alumina	22X, 22XC	Mo Mo : Mn Mo : Mn : Si Mo : Mn : TiH_2 Mn : Mo_2B_5 , Mo	100 80 : 20 80:20 (+5) 80 :20 : 10 20 : 10-15 : 70-65
	M7	Mo ; Mn : MoB Mo : Mn : $MoSi_2$ Mo ; Mn : C-48	62.5 : 20 : 17.5 77 : 20 : 3 75 : 20 :5
	ВГ - 4	Mo : Mn : Si	75-78 : 20 : 5-3
	A-995	Mo : Mn : Mo_2B_5 : БД-22	74 : 15 : 5 : 6
	Sapphirite	Mo : Mn : V_2O_5	75 : 20 : 5
	Policore	Mo : Mn : Si	80 : 20 : (+5)
Monocrystal	sapphire	Mo : Mn : Mo_2B_5 : БВ22	74 : 15 : 5 : 6
	Rubine	Mo : glass CT-1	70 : 30
Beryllium ceramic		Mo : Mn : Si	80 : 20 : (+5%)

Metallization process

Coating type	Temperature ^0C	duration	Cooling speed $^0C/min$	Environment
Mn, Mo (22X, 22XC, A-995, M-7)	1 270 – 1 400	20 - 40	5 - 10	$N_2 : H_2 = 2 : 1$ $N_2 : H_2 = 3 : 1$ dew point +15 - +25^0C
Mo, Mn, Si	1 280 – 1 320	40	Cooling - 4.2	$N_2 : H_2 = 3 : 1$ dew point +15 - +25^0C

Chemical Nickel Plating

1. Nickel chloride – 45g/l
2. Ammonium chloride – 50 g/l
3. Sodium citrate – 45g/l
4. Sodium hypophosphite – 20g/l
5. Ammonia water 25% – 50g/l

pH level – 8.0-8.5

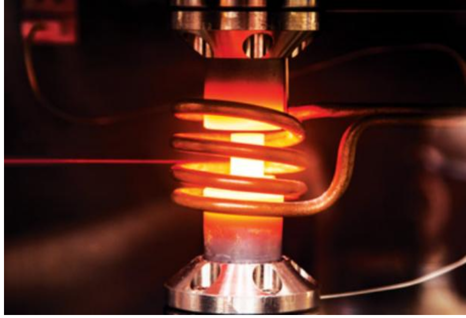
Before nickel plating - preparation in chemical liquid and blowing deionized water at 98 0C

Galvanic Nickel Plating

Plate	Thickness of layer mkm	electrolyte		Electrolit pH	Current Density a/dm2	Time min	Anode material	Electrolit temperature
		Components	Composition g/l					
Galvanic nickel plating	3-6	Sulfuric acid nickel Magnesium sulphate boric acid lemon acid Sodium chloride Sodium citrate	200-250 17-25 10-20 2 0я5-1я0 45	5.2-5.8	0.5-1.0	10-20	Ni	18-25
Galvanic nickel plating	8-12	Sulfuric acid nickel Magnesium sulphate Sodium sulphate Nickel chloride boric acid	220 85 85 10 30	4.5-5.5	3	15-30	Ni NPA-1	18-25

1.3. Test of Ceramic/Metal Joints

- Thermal tests;
- Vacuum tightness tests;
- Mechanical Tests;
- Vibration tests;
- Outgassing tests;
- Electro-mechanical tests;
- Humidity tests;
- Roughness measurement;
- Hardness measurement;
- rotation test.



Techanical test with high tempetature

Universal testing machine

2.1. Materials Selection.

Properties		Unit	Specific value
Main component		-	α - Al_2O_3
Purity		wt-%	> 99.5
Density		g / cm^3	≥ 3.90
Open Porosity		vol.-%	0
Average Size of Crystallites		µm	10
Bending Strength σ_m	DIN EN 843-1	MPa	350
Weibulls Modulus		-	> 10
Toughness K_{Ic}	SEVNB	MPa * $m^{0.5}$	3.5
Compressive Strength		MPa	3500
Young's Modulus	static	GPa	380
Poisson's Ratio		-	0.22
Hardness	Knoop, 100 g	GPa	23
Maximum Service Temperature in Air		°C	1950
Linear Coefficient of Expansion	-100 - 20 °C	10^{-6} / K	3.6
	20 - 500 °C	10^{-6} / K	7.3
	20 - 1000°C	10^{-6} / K	8.2
Specific Heat	20 °C	J / (kg * K)	900
Thermal Conductivity	20 °C	W / (m * K)	34.9
	1000 °C	W / (m * K)	6.8
	1500 °C	W / (m * K)	5.3
Resistivity	20 °C	Ω * cm	10^{15}
	1000 °C	Ω * cm	10^7
Dielectric Strength	20 °C	kV / mm	> 30
Relative Permittivity	70 MHz	-	10
	180 MHz	-	9.9
	30 - 40 GHz	-	9.8
Dielectric Loss Tangent	70 MHz	-	270 * 10^{-4}
	180 MHz	-	150 * 10^{-4}
	30 - 40 GHz	-	20 * 10^{-4}
Typical Colour		-	ivory

Kovar Ni-Co-Fe

Kovar contant %					
Fe	Ni	Co	C	Si	Mn
53.49	29	17	<0.01	0.2	0.3

Titanium - Ti

2.2. Laboratory equipment.

UHV Test Stand

Vacuum level – 10-9Torr

Ceramic Cutting machine

Mixing machine

Metallurgical microscope

100X – 1600X

Vacuum Furnace

Vacuum up to 10-6

Heat – 2000 C

2.3. Methods.

3.1. New Diffusion Brazing Method for Dissimilar Details with Difficult Geometry.

New Diffusion Brazing Method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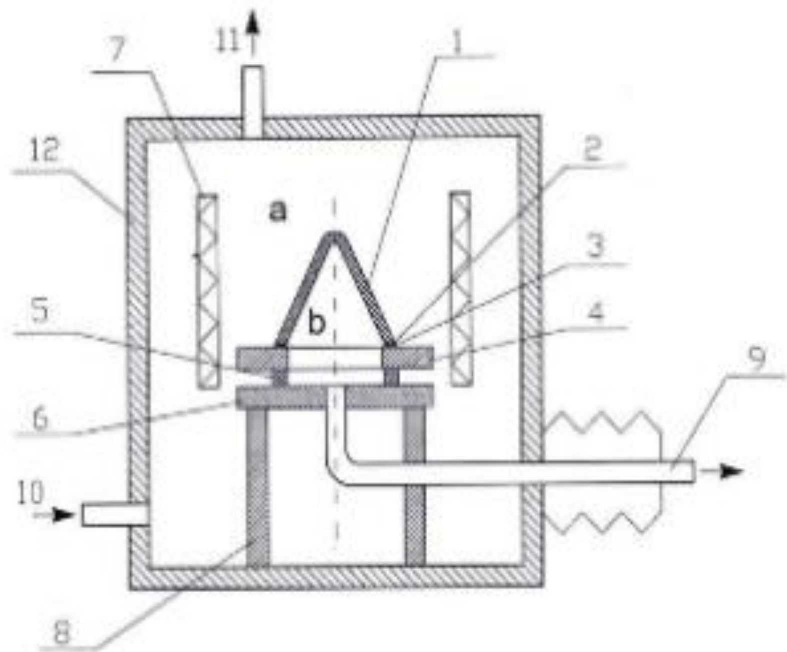
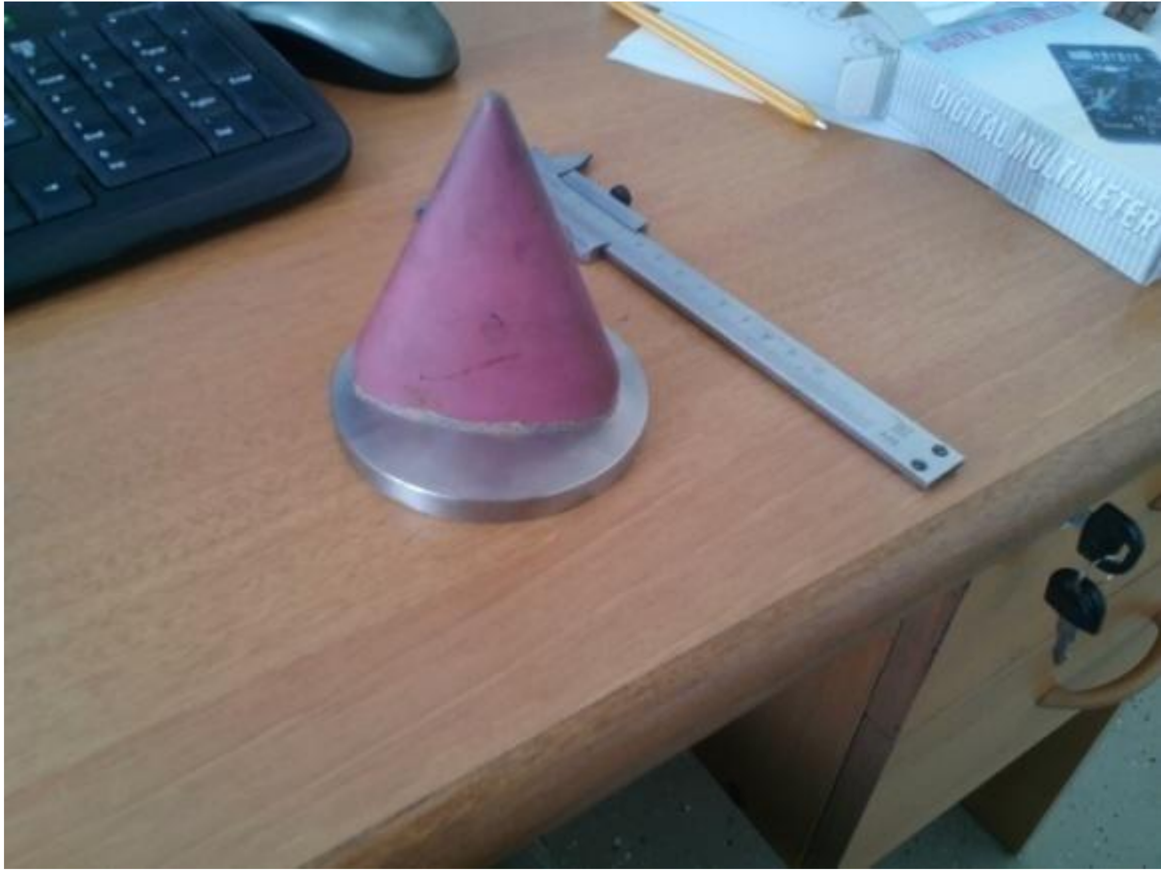
№ 2883 A



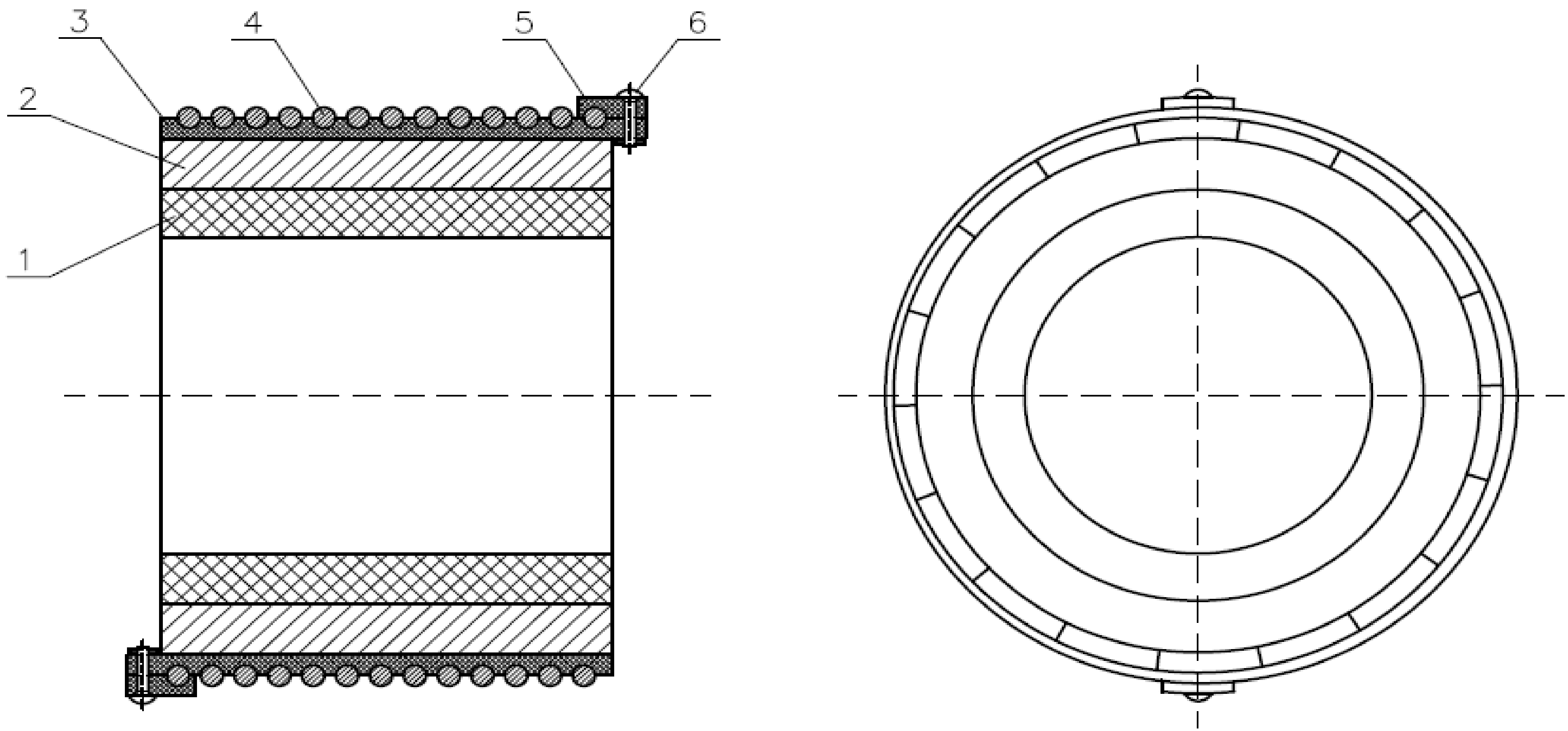
Diffusion brazing methods of difficult geometry dissimilar details.
Patent number – AM201453
Vardan Shavarsh Avagyan, Vahagn Vanik Vardanyan
Intellectual Property Agency of the Republic of Armenia

Experimental results



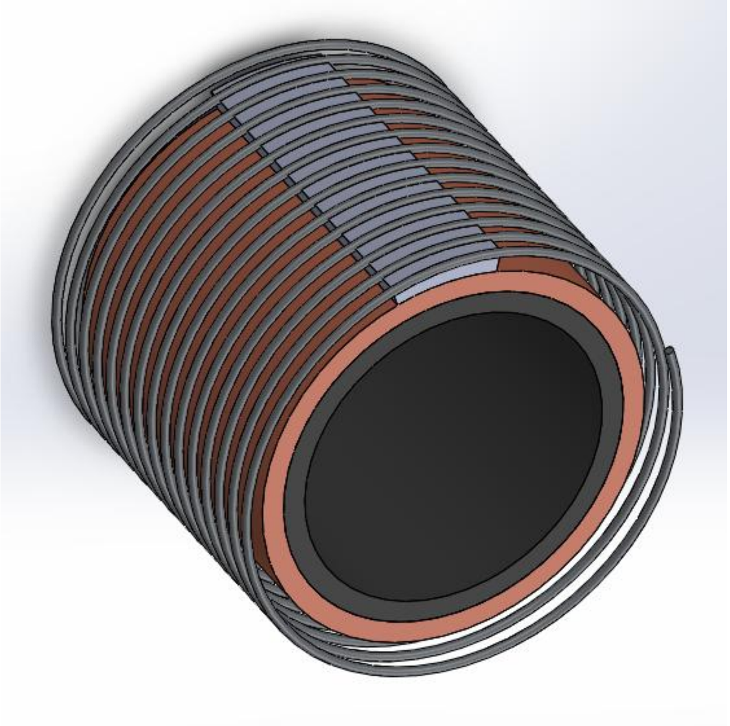
Side a) – 10-3Torr
Side b) – atmospheric or 0.5atm pressure.

3.2. Brazing method with heating and pressure combination.

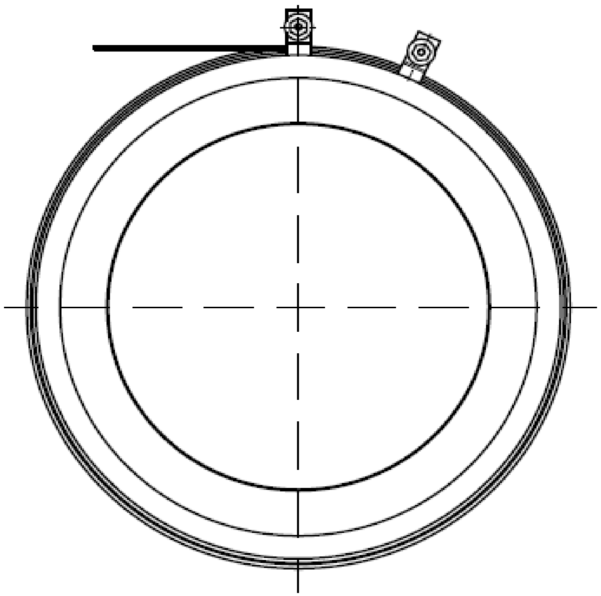


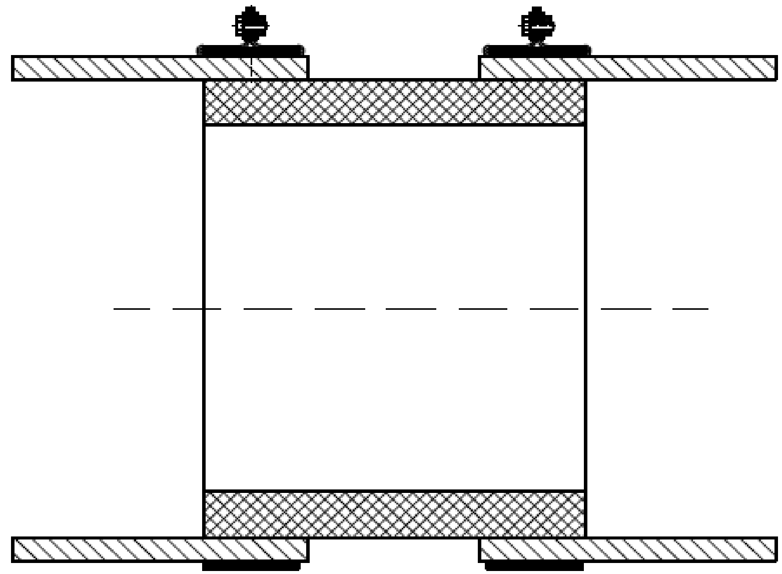
1. Ceramic,
2. Metal,
3. Ceramic,
4. Molybdenum wire,
5. 6. Wire fixators.

Advantage – local heating and temperature control,
Equal Pressure exert

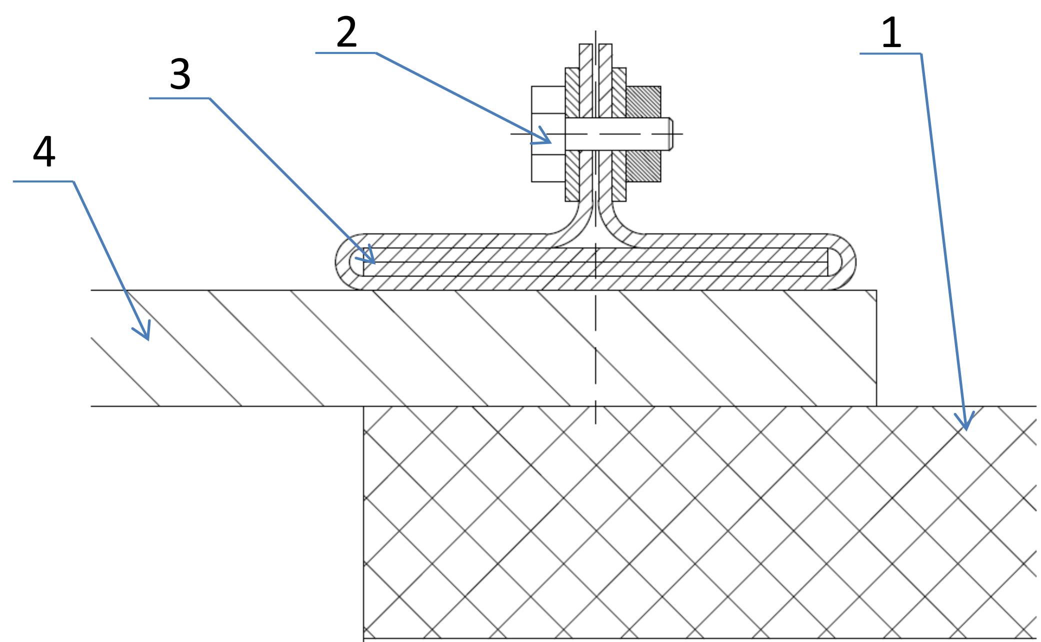



3.3. Pressure receiving based molybdenum sheet.

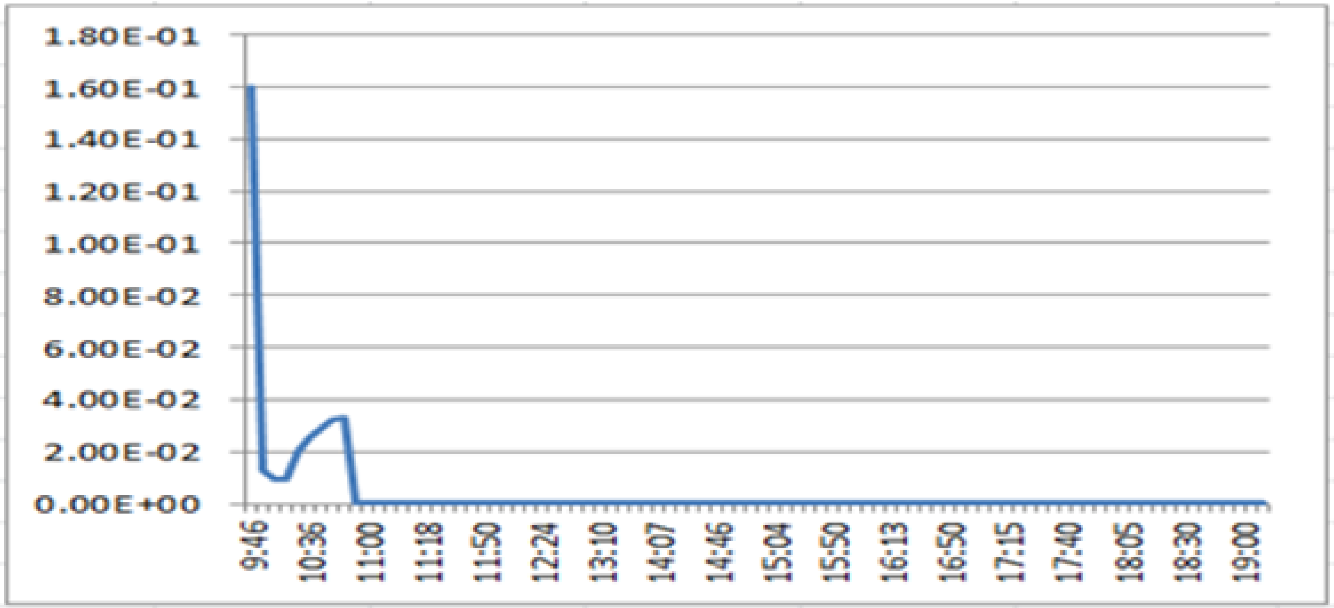


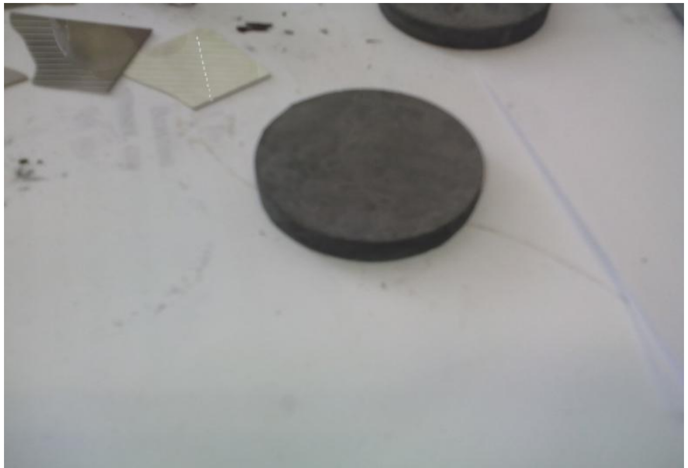


1. Ceramic,
2. Sheet Fixing Parts,
3. Molybdenum Sheet,
4. metal

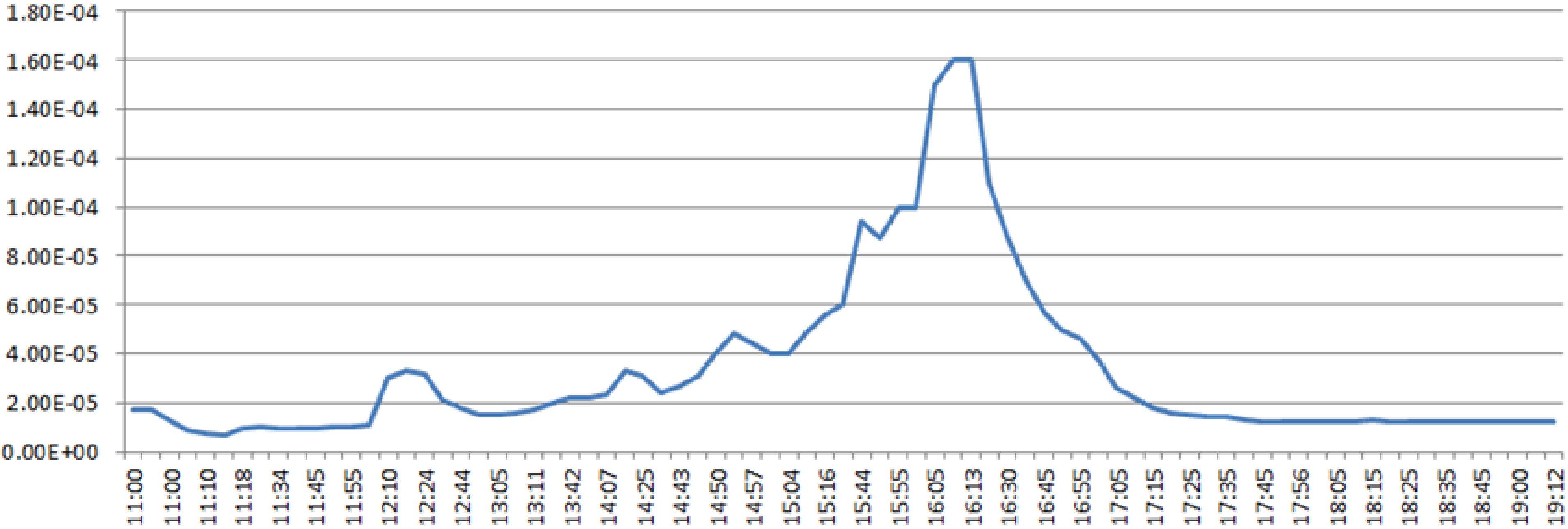


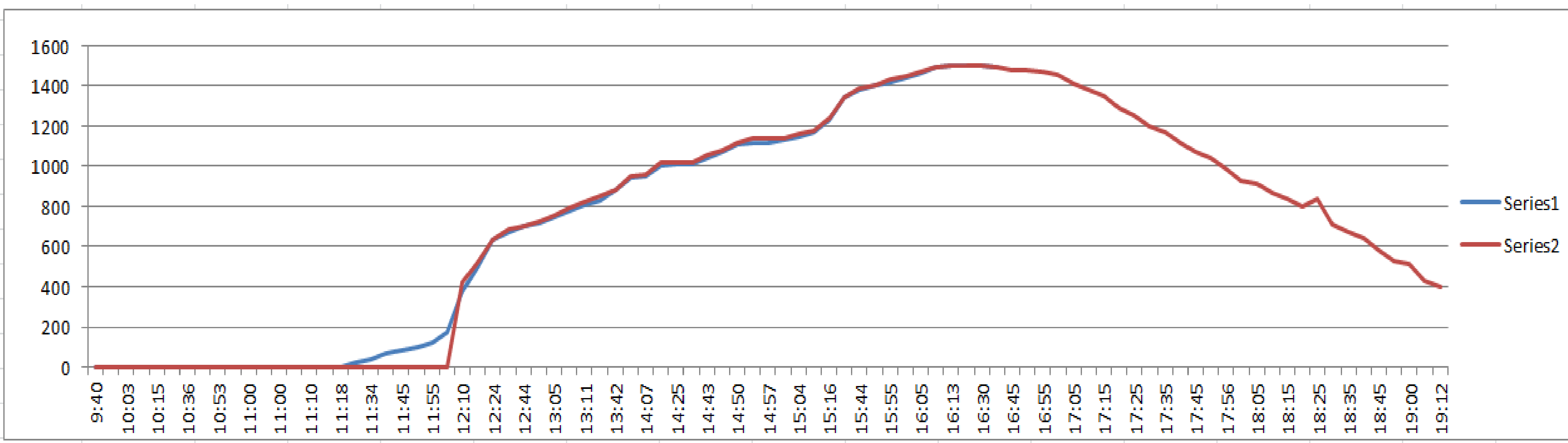
4.1. Metallization of Ceramics



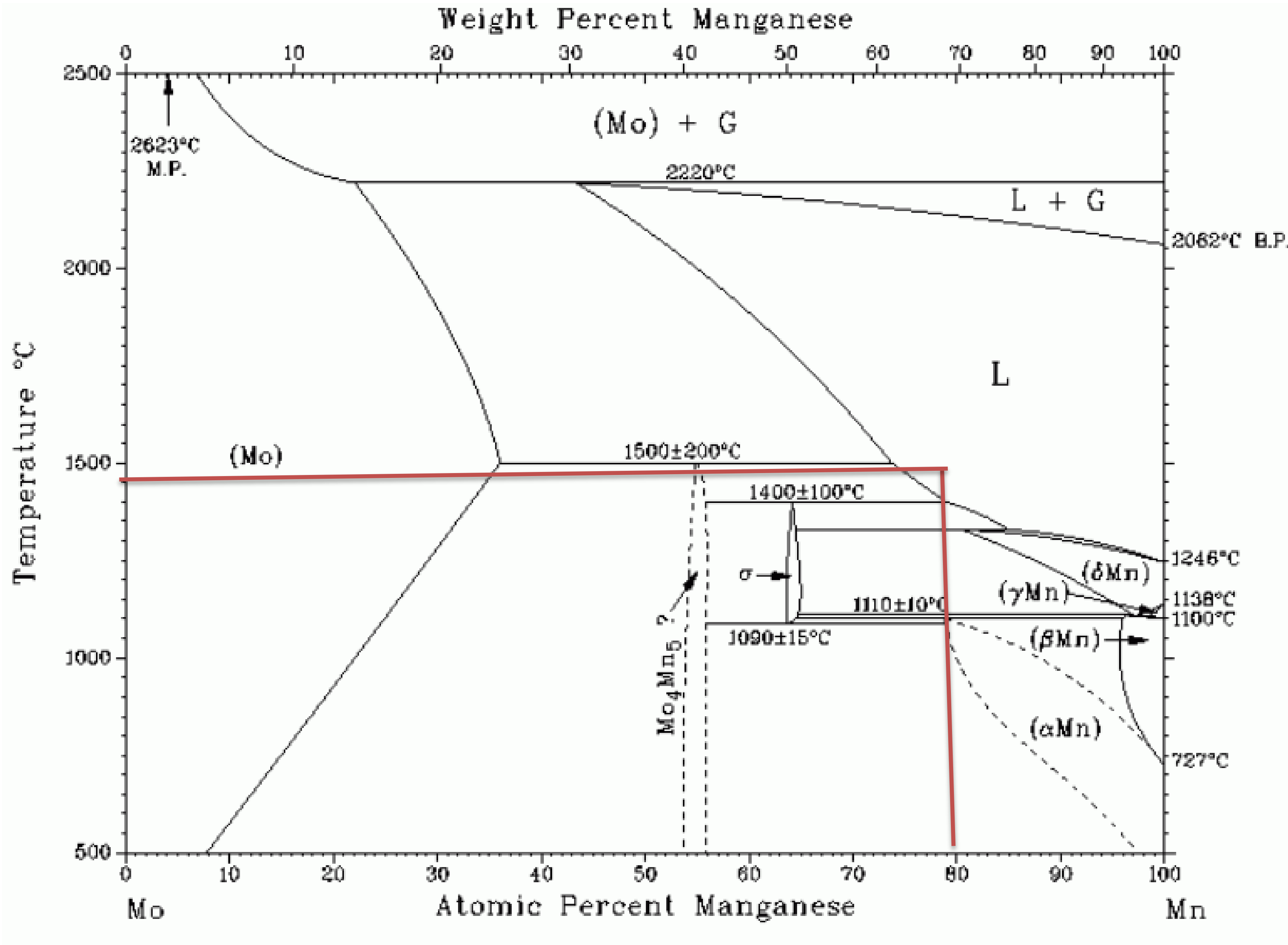


Mn-Mo metallization on Ceramic Surface





Mo-Mn pleting on F99.7 Ceramic Surface

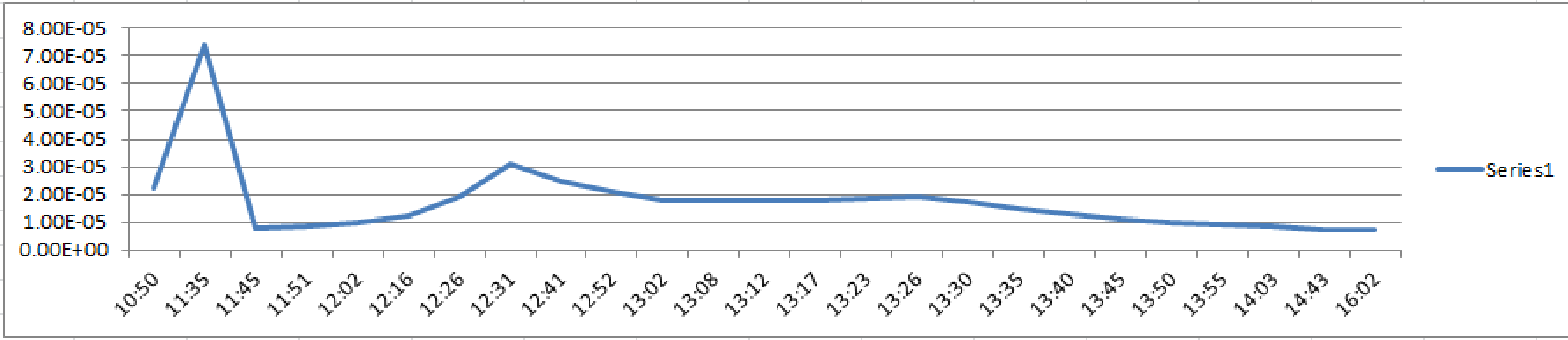


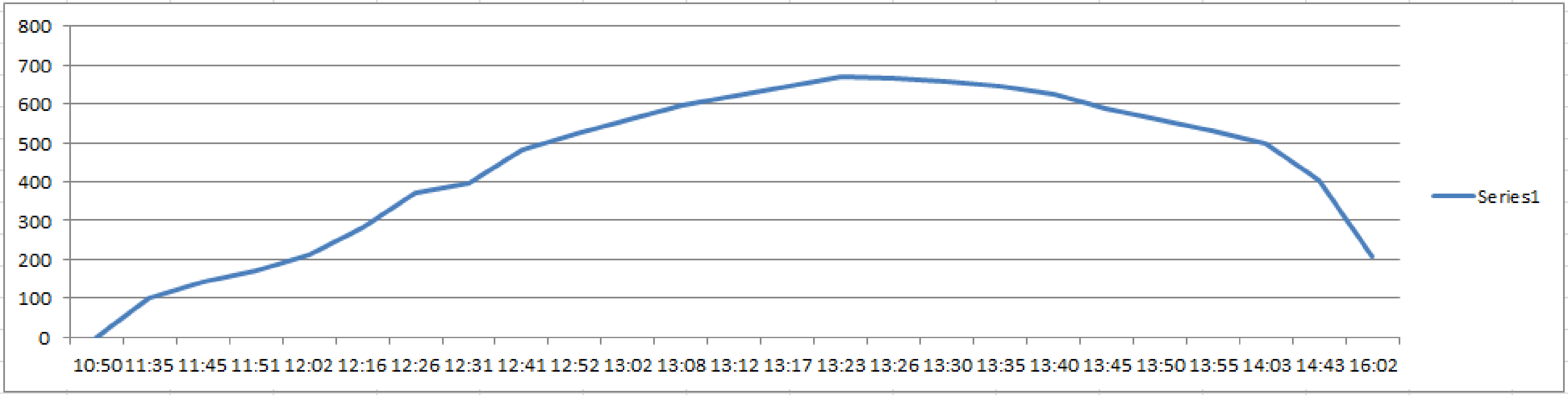
Metallized Alumina

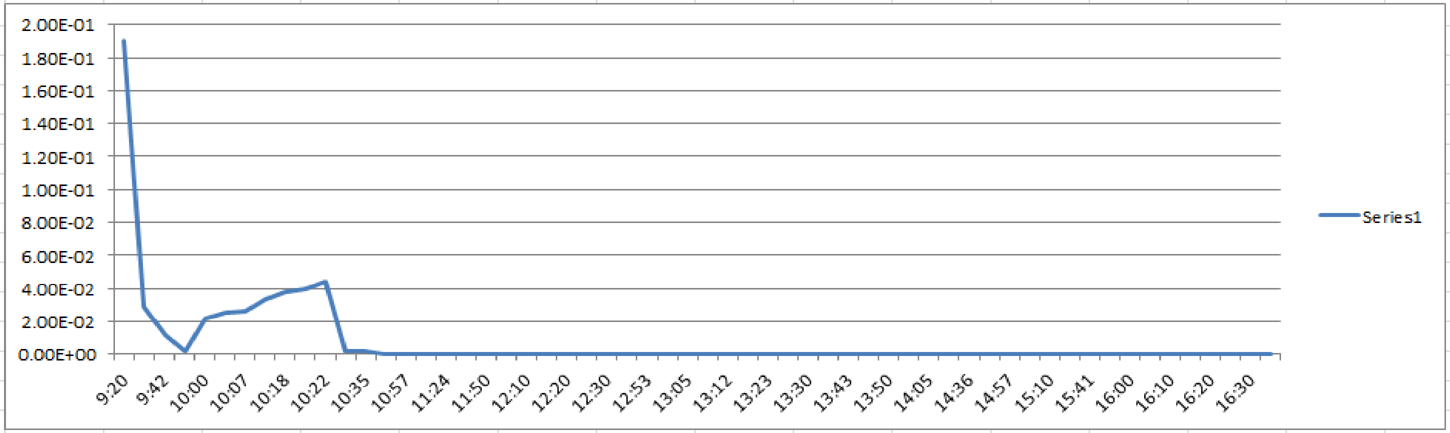


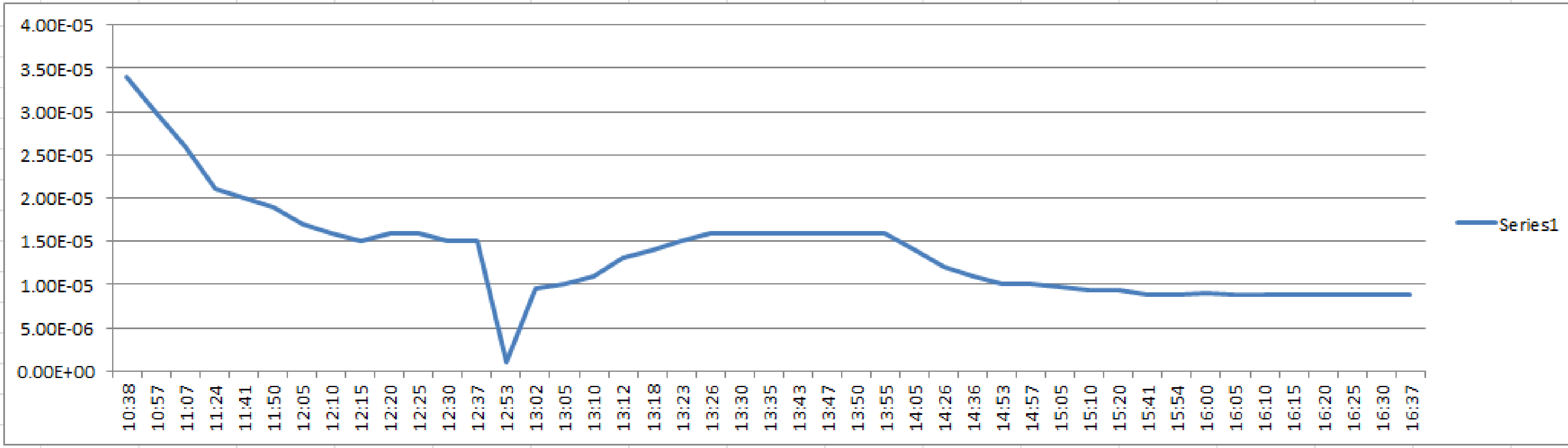

4.2 Nickel Plating based on Galvanic method.


4.3. Silver Soldering Max 670





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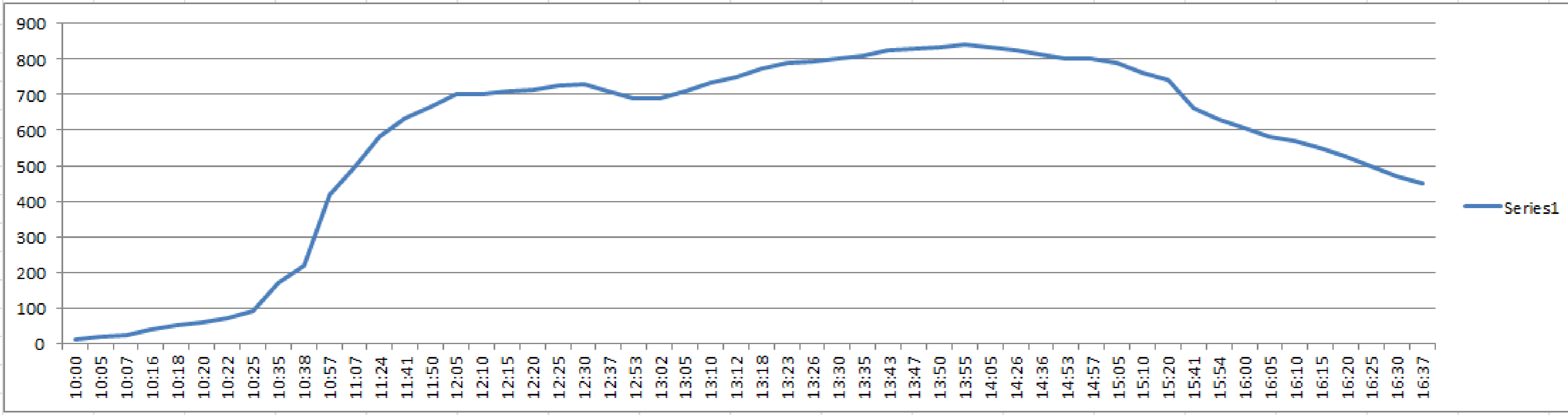
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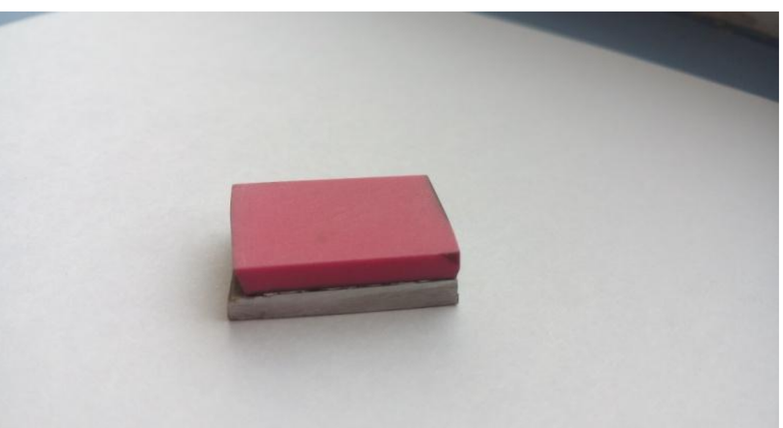
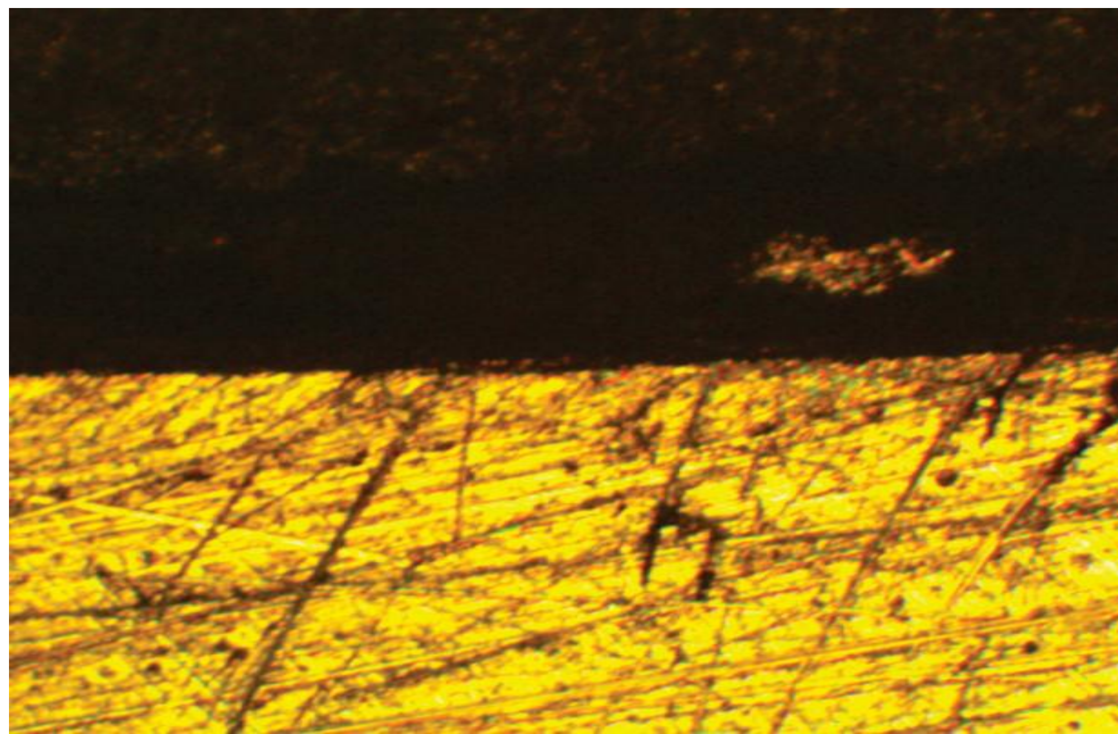
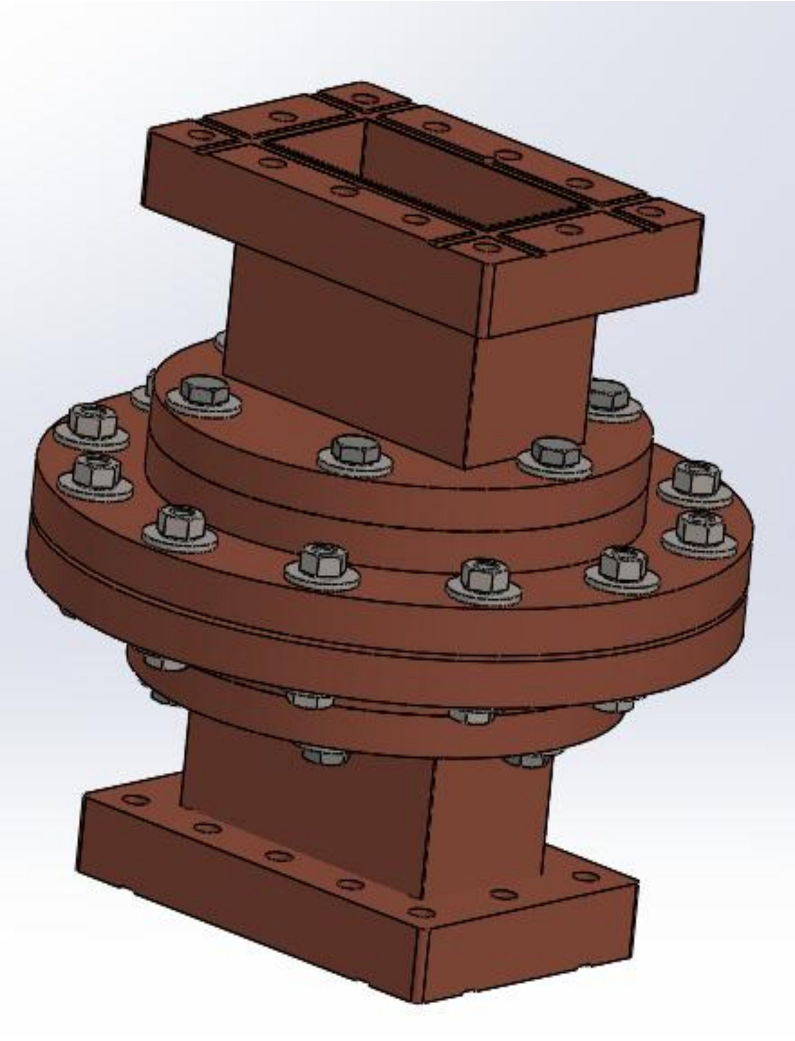
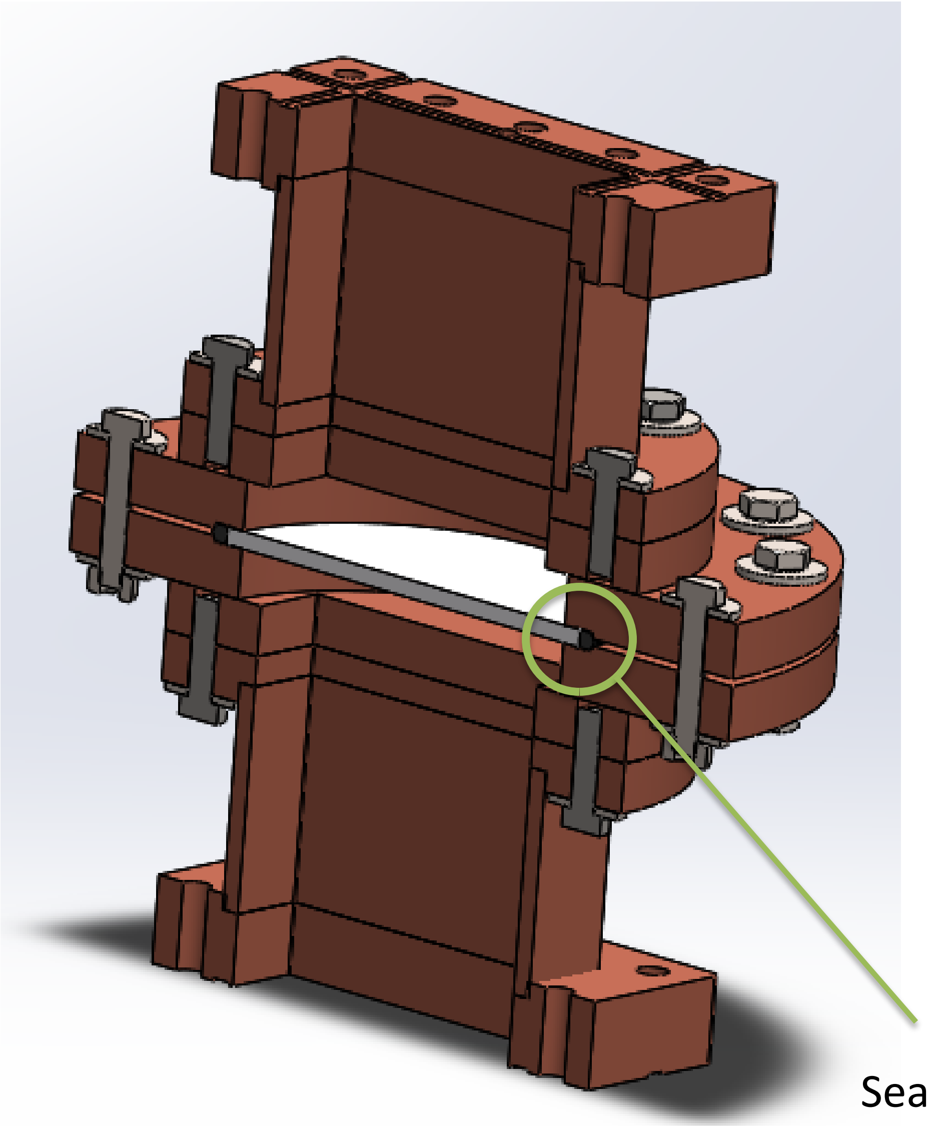



5.1. RF Window (S-band, C-band, etc.)

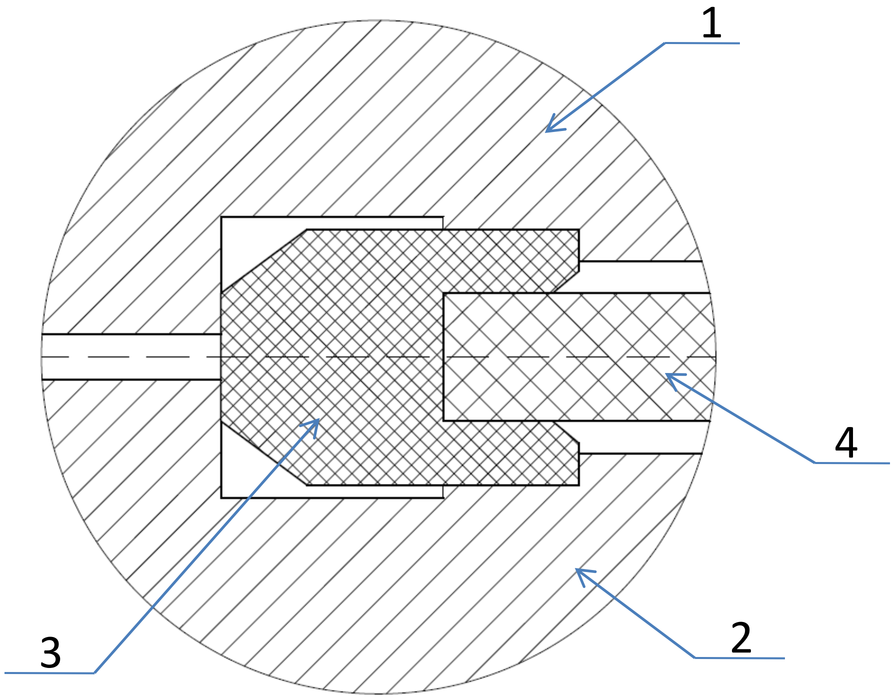


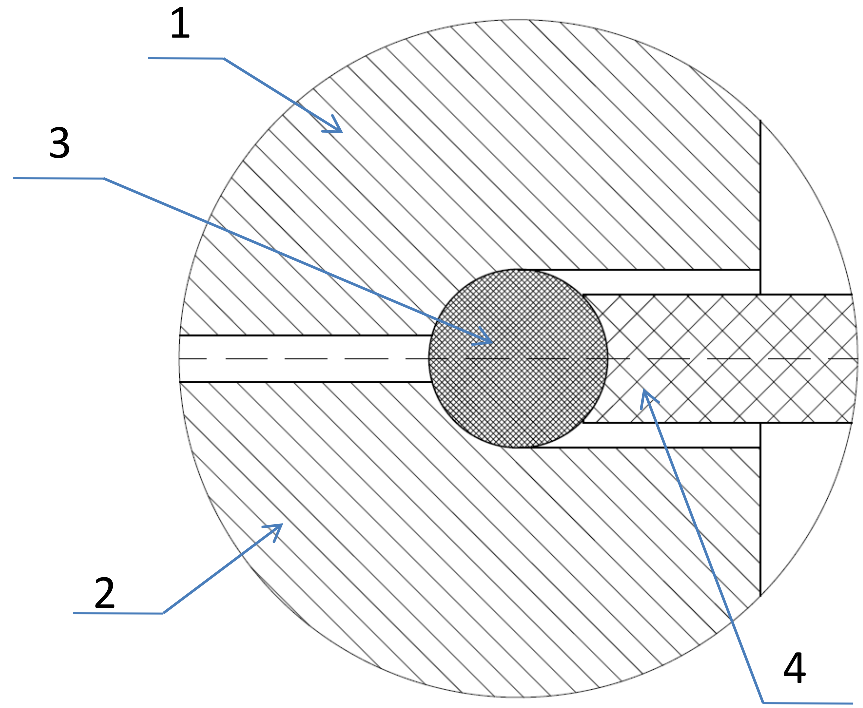
3D Model of RF Window



Section view of RF Window

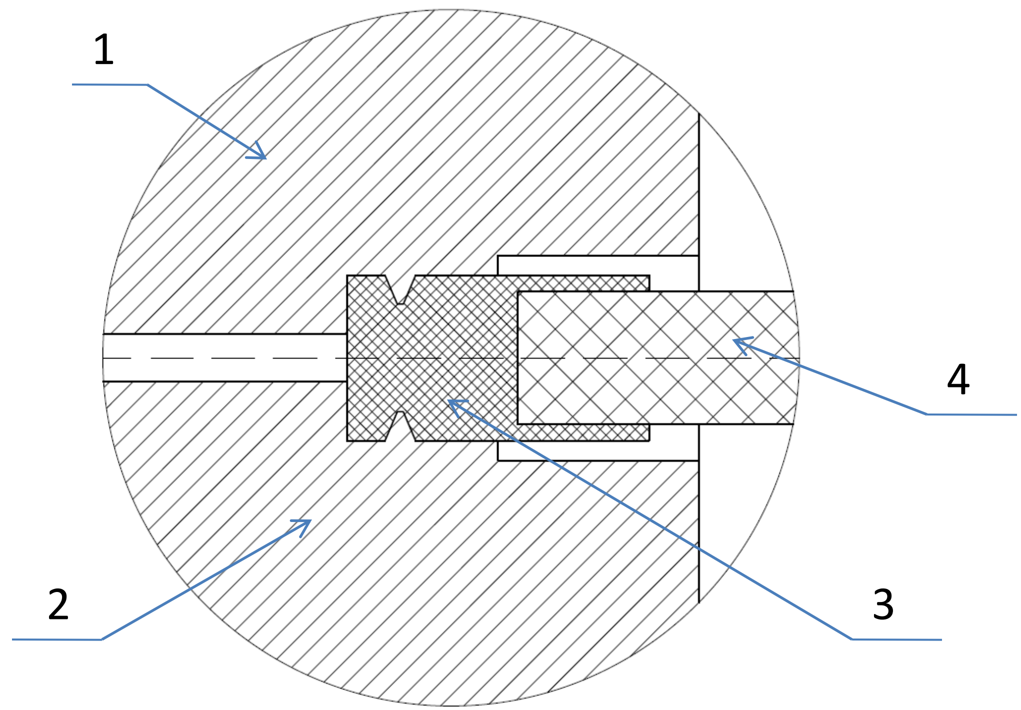
Sealing Zone



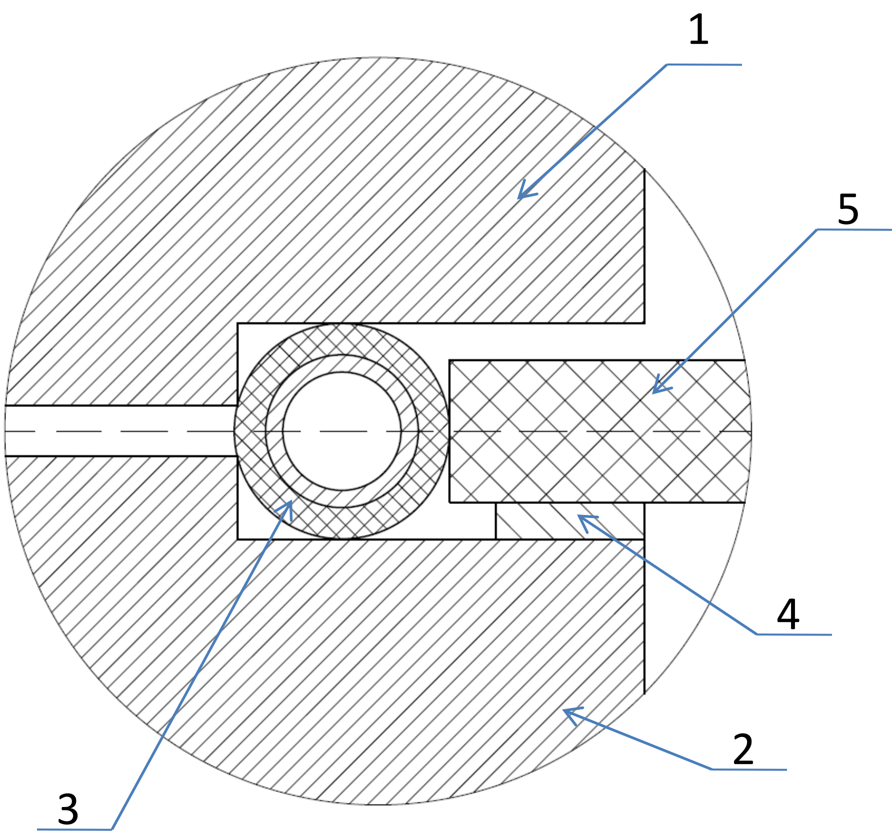


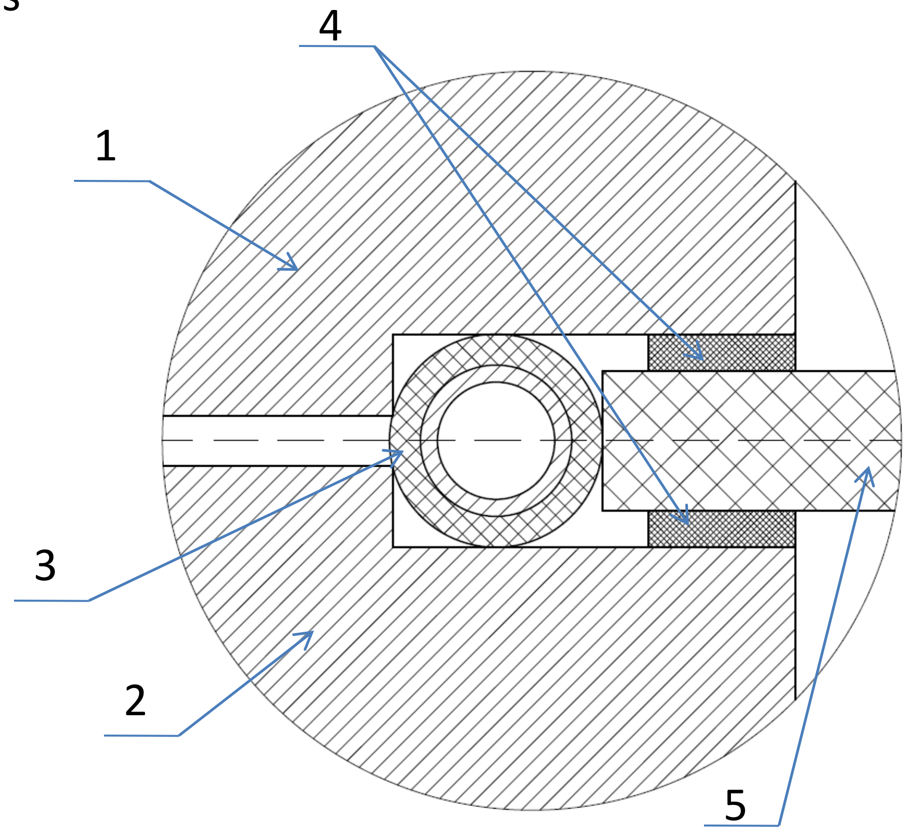
Viton - specific fluoroelastomer polymer,
Working Temperature - -20°C до +200°C,
Outgassing approx. ... 1 x 10-8
(strongly depending on treatment)

1. Metal – 1;
2. Metal – 2;
3. Viton or Teflon (sealing);
4. Ceramic.

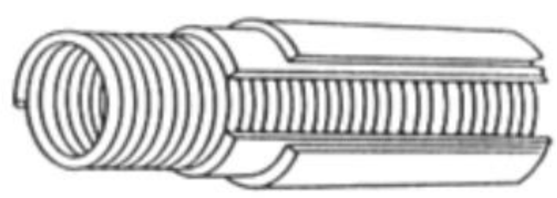


Sealing with Combination of Helicoflex and metals



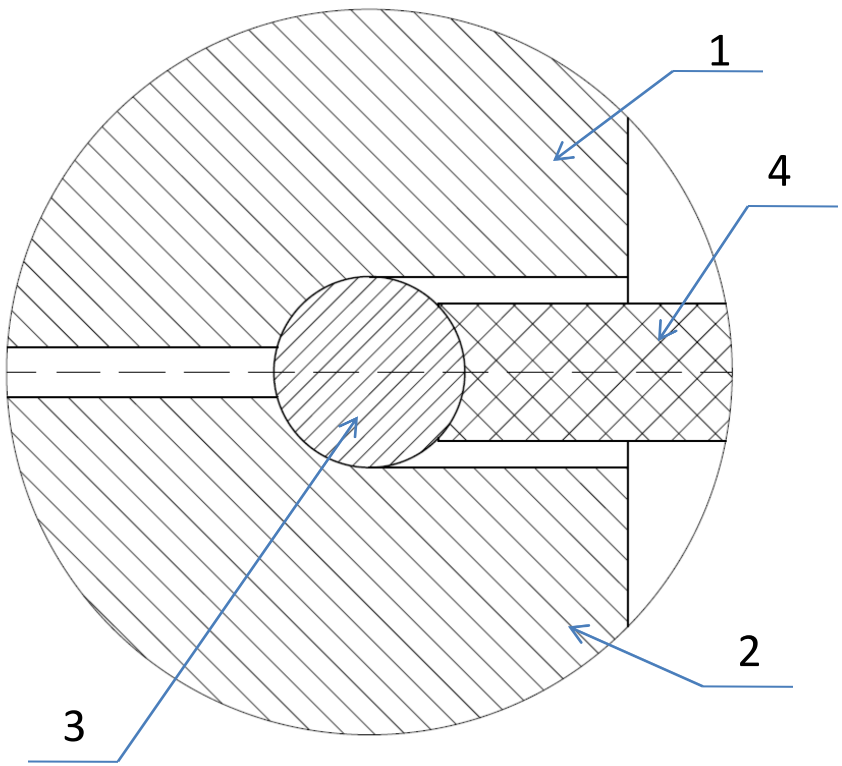


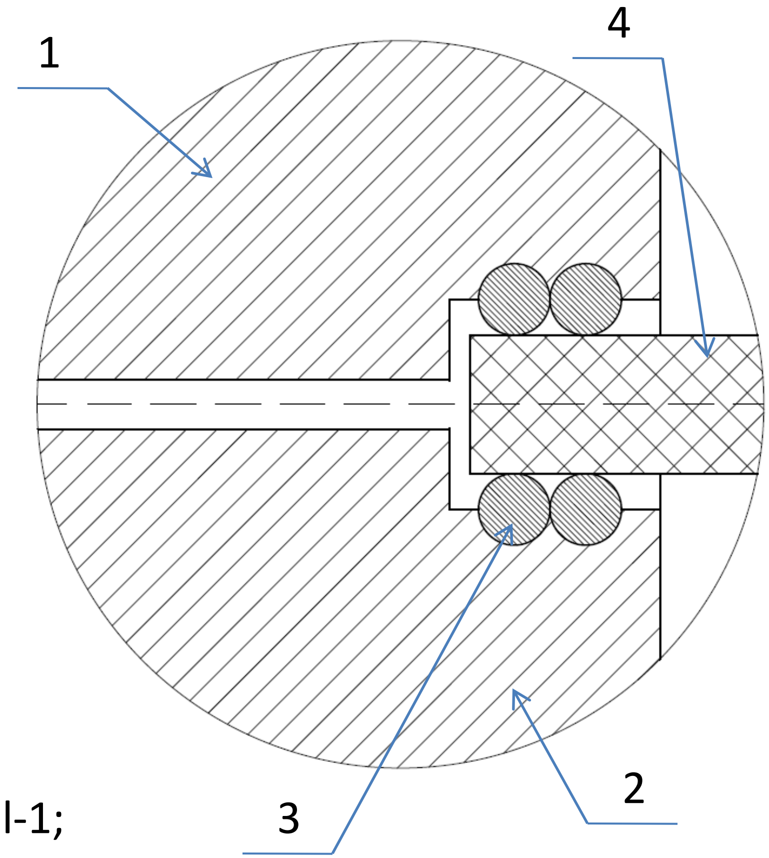
1. Metal – 1;
2. Metal-2;
3. Helicoflex;
4. Metal seal;
5. Ceramic.



Helicoflex-dictung

Sealing Ceramic to Metals with Metals

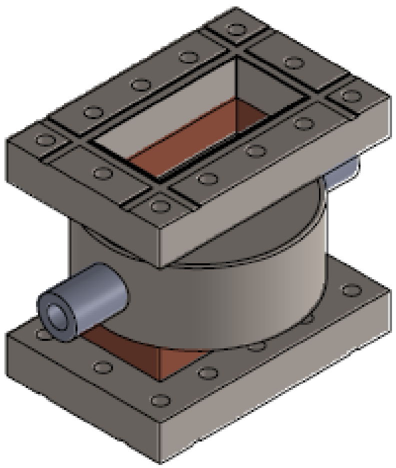


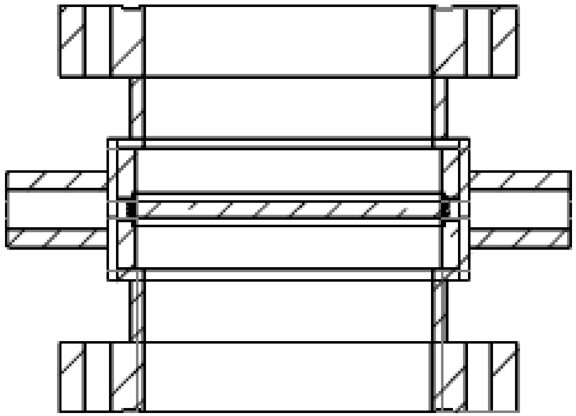


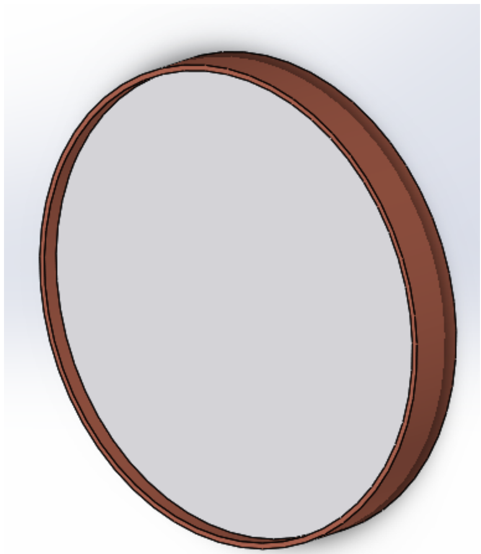
1. Metal-1;
2. Metal-2;
3. Sealed metal;
4. Ceramic.

Metals – Aluminum, Indium, Indium and SS combination, Aluminum and SS combination, Copper, Coper and SS combination, etc.

5.2. RF Windows - Brazing

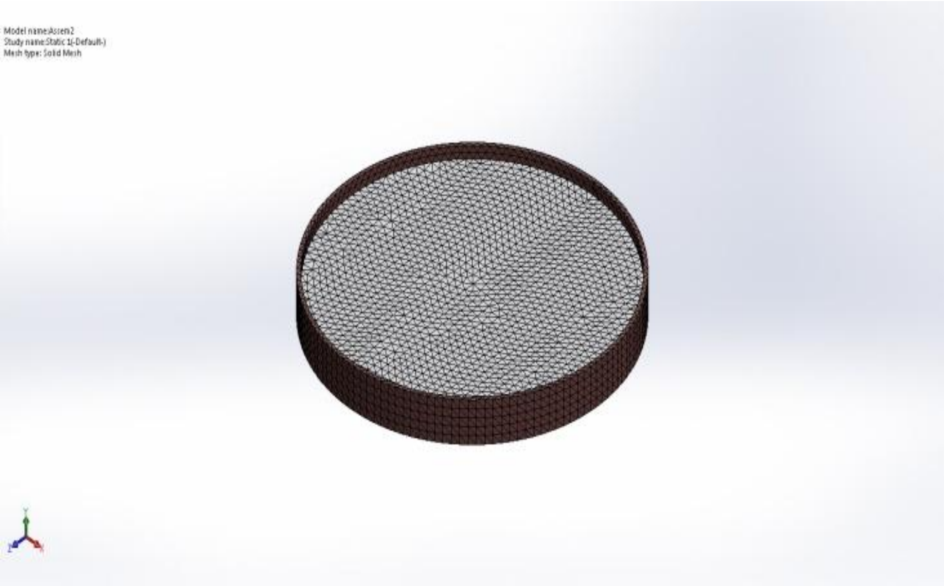




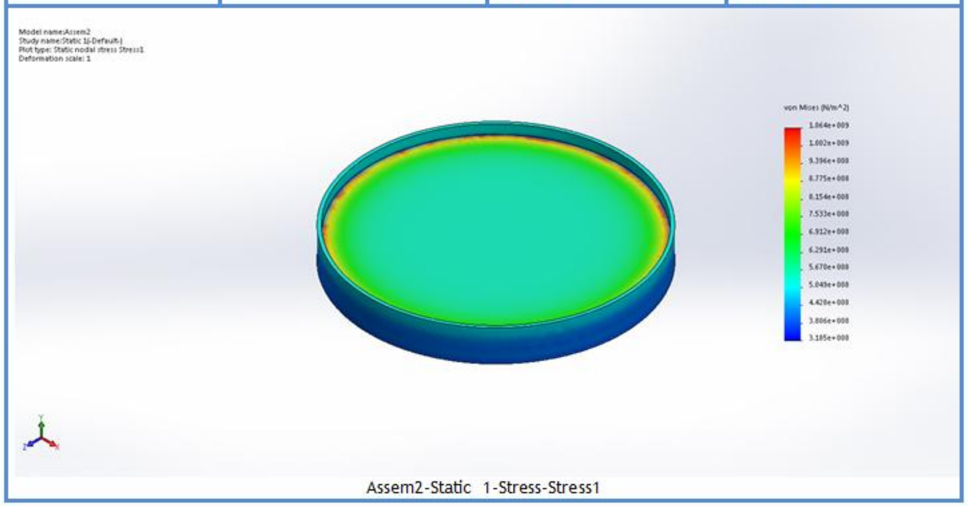


Cearmic/Copper joint

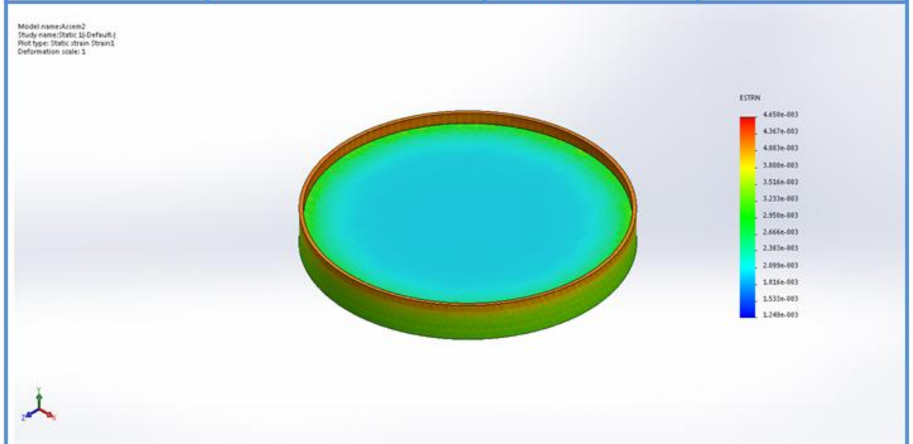
200 C



Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.18545e+008 N/m^2 Node: 12342	1.06379e+009 N/m^2 Node: 29547

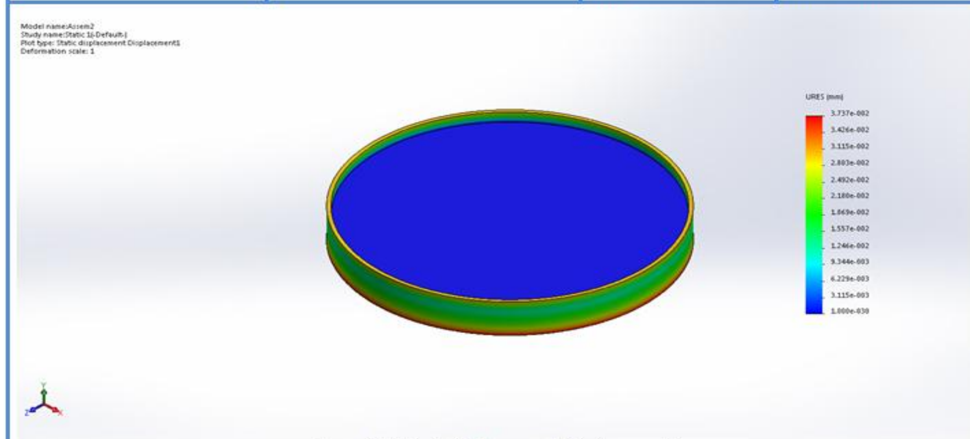


Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.00124927 Element: 6160	0.00464998 Element: 19615



Assem2-Static 1-Strain-Strain1

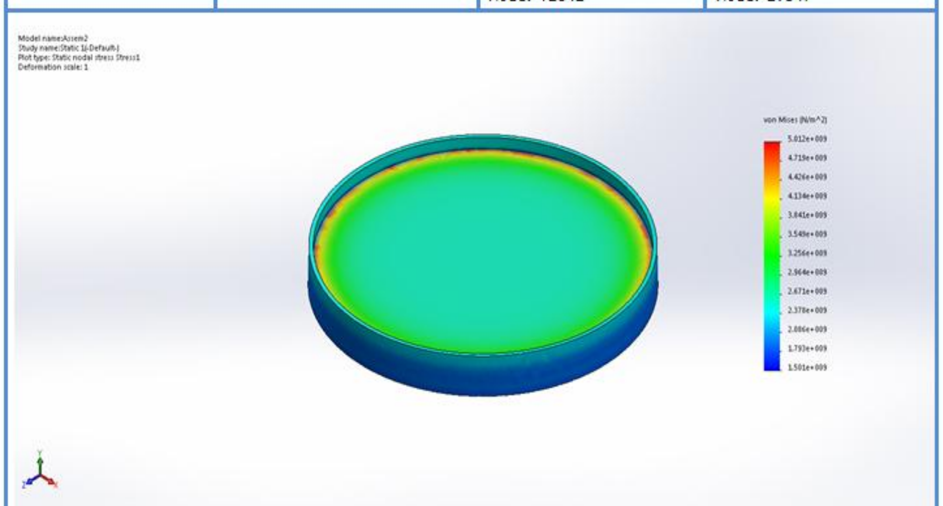
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.037374 mm Node: 31705



Assem2-Static 1-Displacement-Displacement1

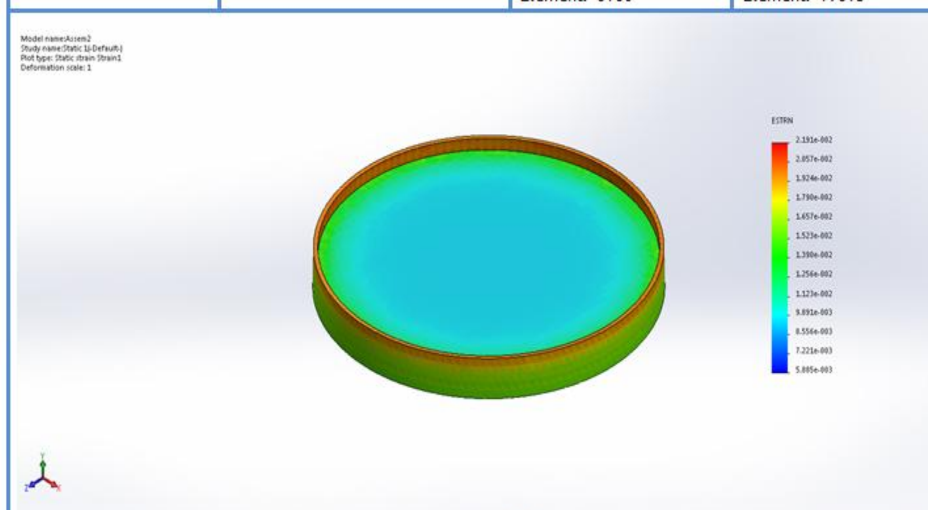
850 C

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.5007e+009 N/m^2 Node: 12342	5.01162e+009 N/m^2 Node: 29547

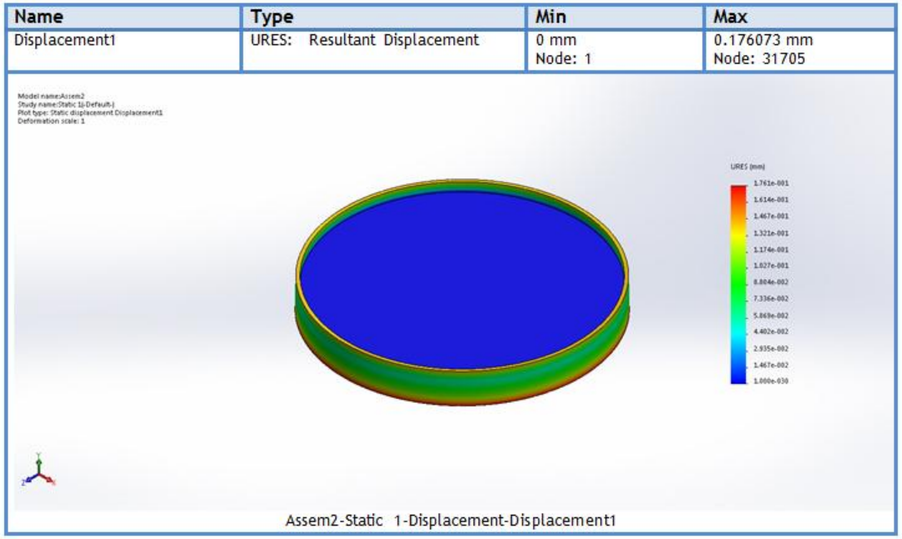


Assem2-Static 1-Stress-Stress1

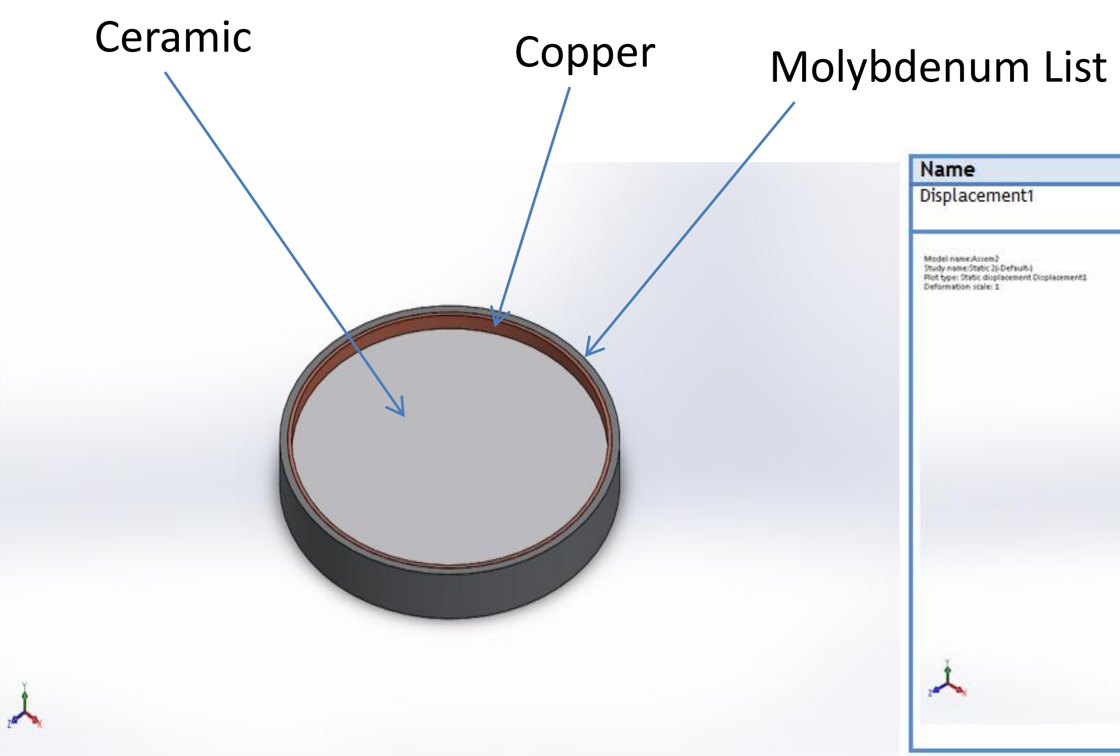
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.00588543 Element: 6160	0.0219066 Element: 19615

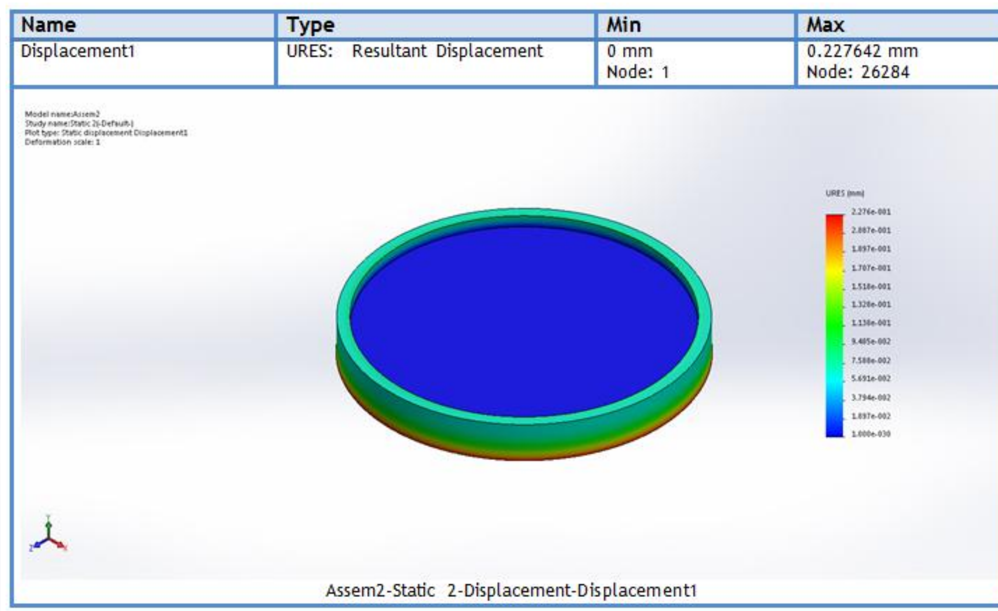


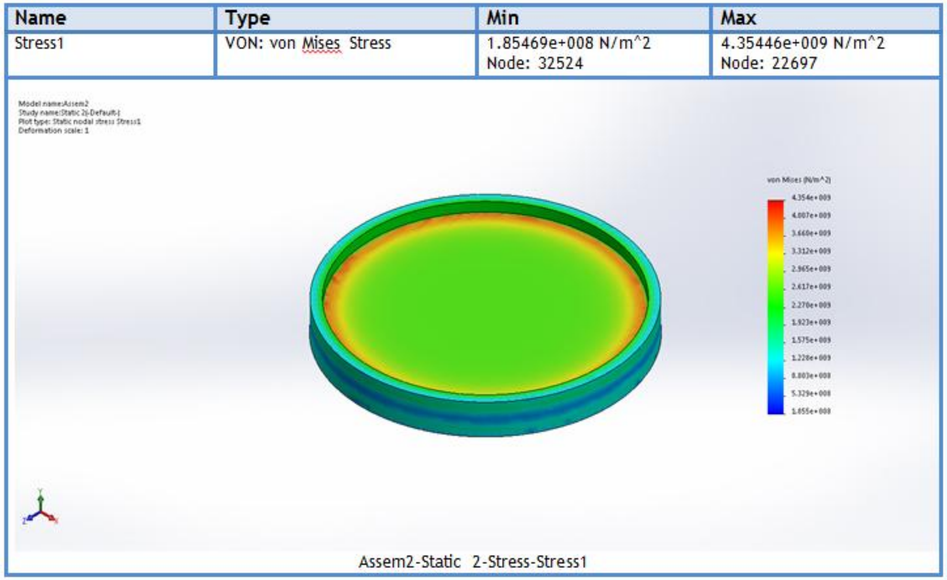
Assem2-Static 1-Strain-Strain1

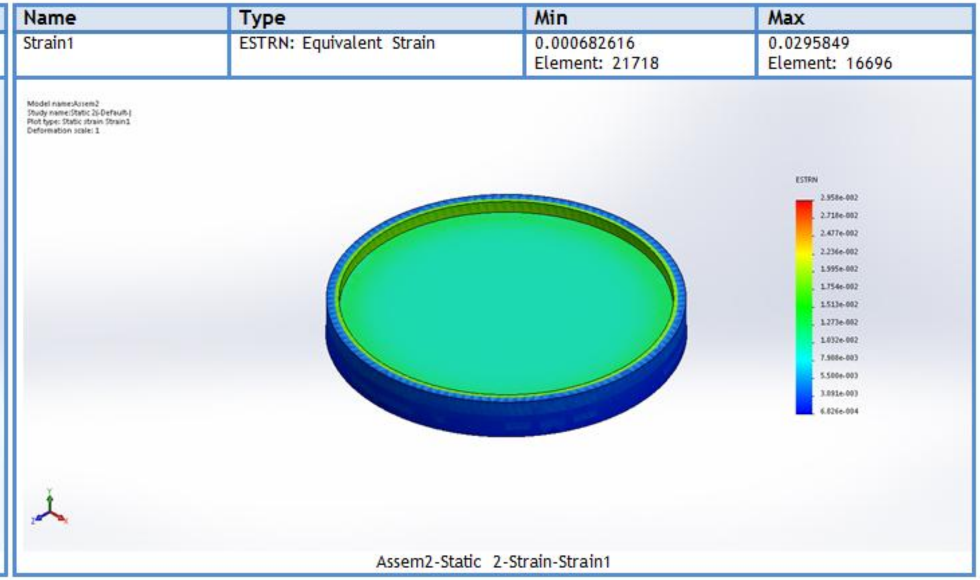

Name
Type
Min
Max
Displacement1
URES: Resultant Displacement
0 mm
Node: 1
0.176073 mm
Node: 31705
Assem2-Static 1-Displacement-Displacement1

850 C

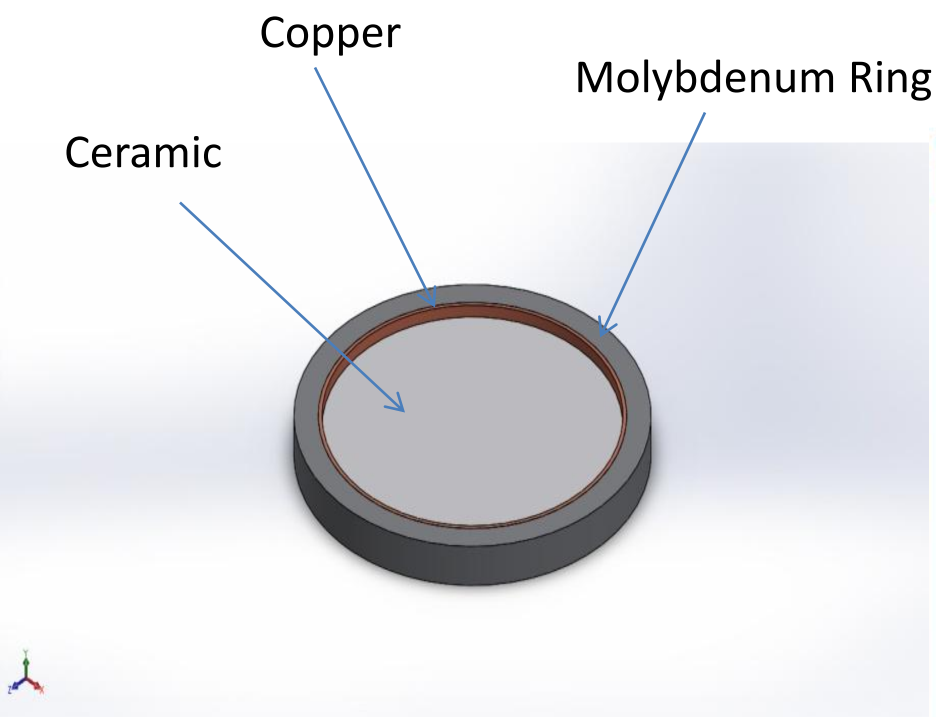

Ceramic
Copper
Molybdenum List

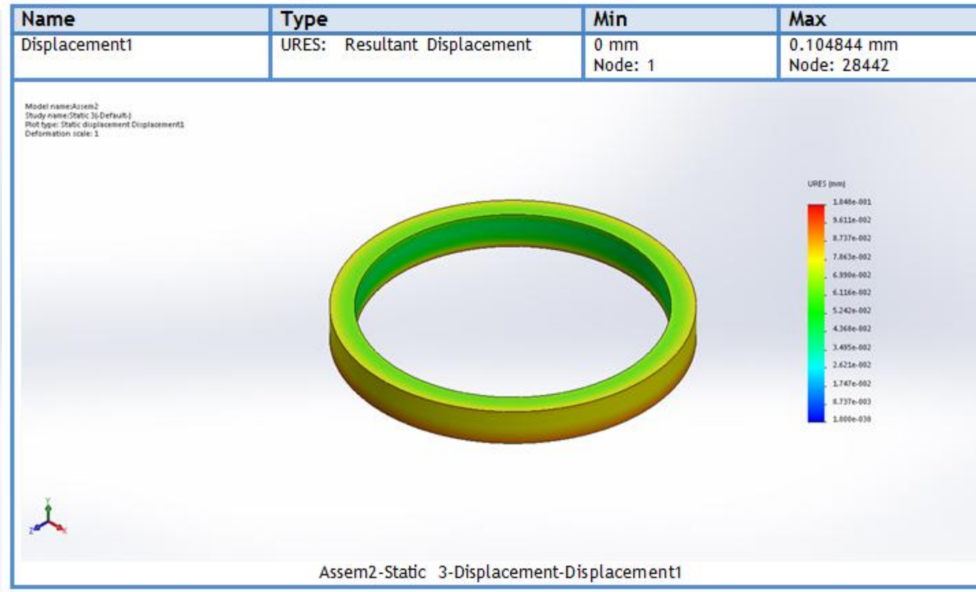

Name
Type
Min
Max
Displacement1
URES: Resultant Displacement
0 mm
Node: 1
0.227642 mm
Node: 26284
Assem2-Static 2-Displacement-Displacement1


Name
Type
Min
Max
Stress1
VON: von Mises Stress
1.85469e+008 N/m^2
Node: 32524
4.35446e+009 N/m^2
Node: 22697
Assem2-Static 2-Stress-Stress1

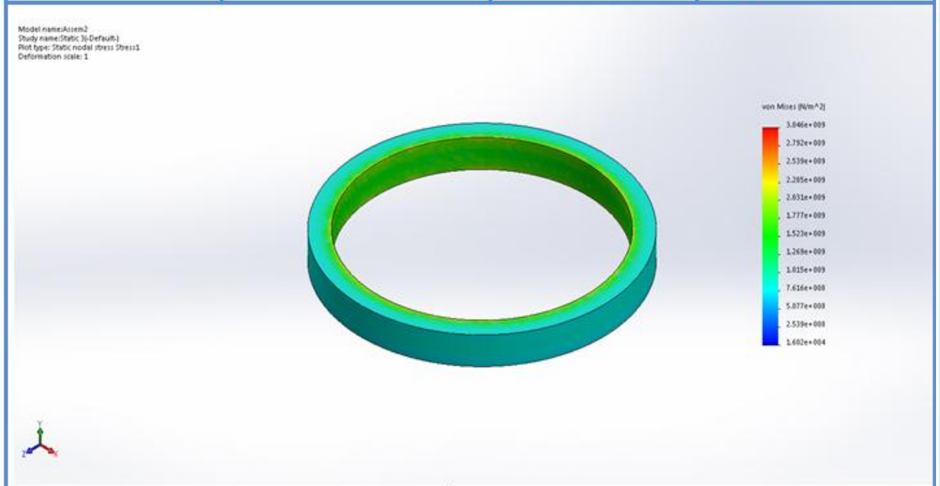

Name
Type
Min
Max
Strain1
ESTRN: Equivalent Strain
0.000682616
Element: 21718
0.0295849
Element: 16696
Assem2-Static 2-Strain-Strain1

850 C


Copper
Molybdenum Ring
Ceramic

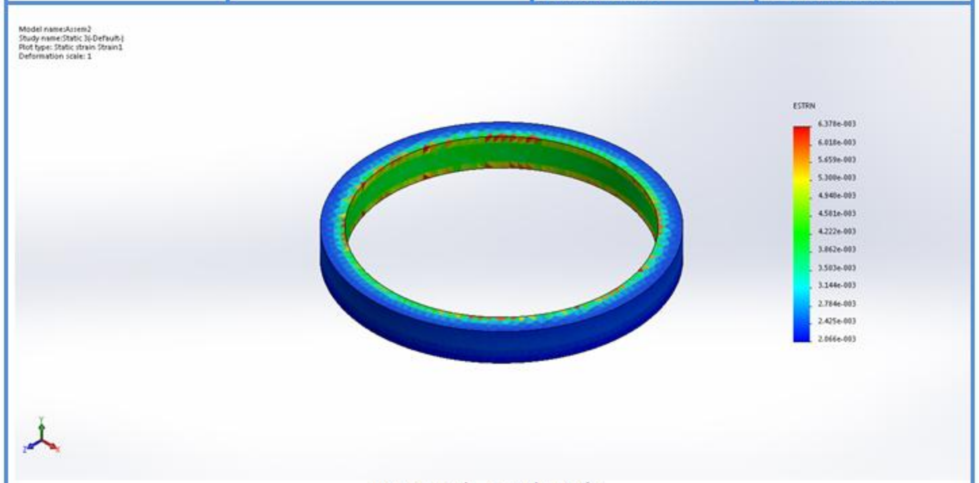

Name
Type
Min
Max
Displacement1
URES: Resultant Displacement
0 mm
Node: 1
0.104844 mm
Node: 28442
Assem2-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	16017.4 N/m^2 Node: 20938	3.04621e+009 N/m^2 Node: 22168



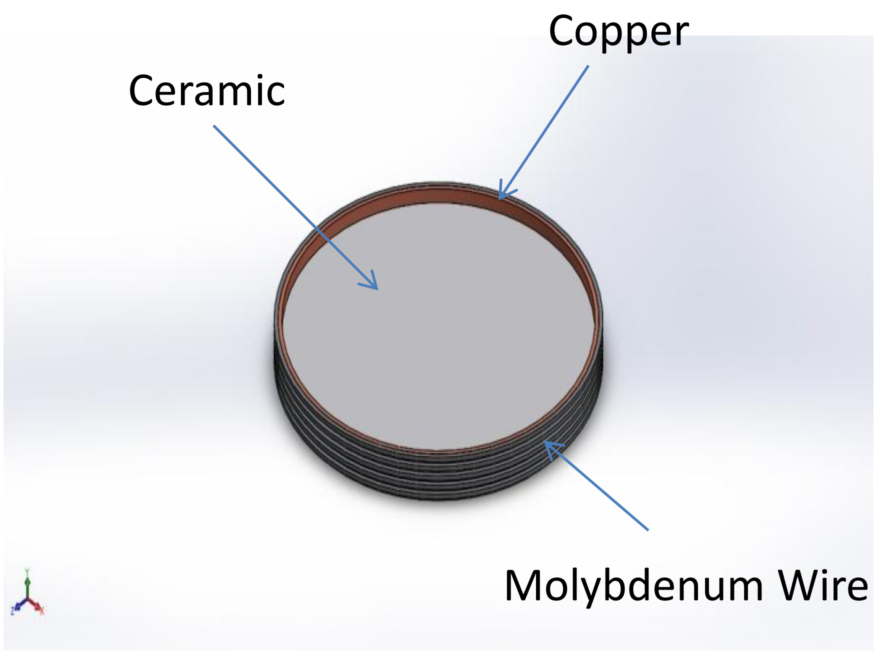
Assem2-Static 3-Stress-Stress1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.82597e-008 Element: 1420	0.027085 Element: 14483

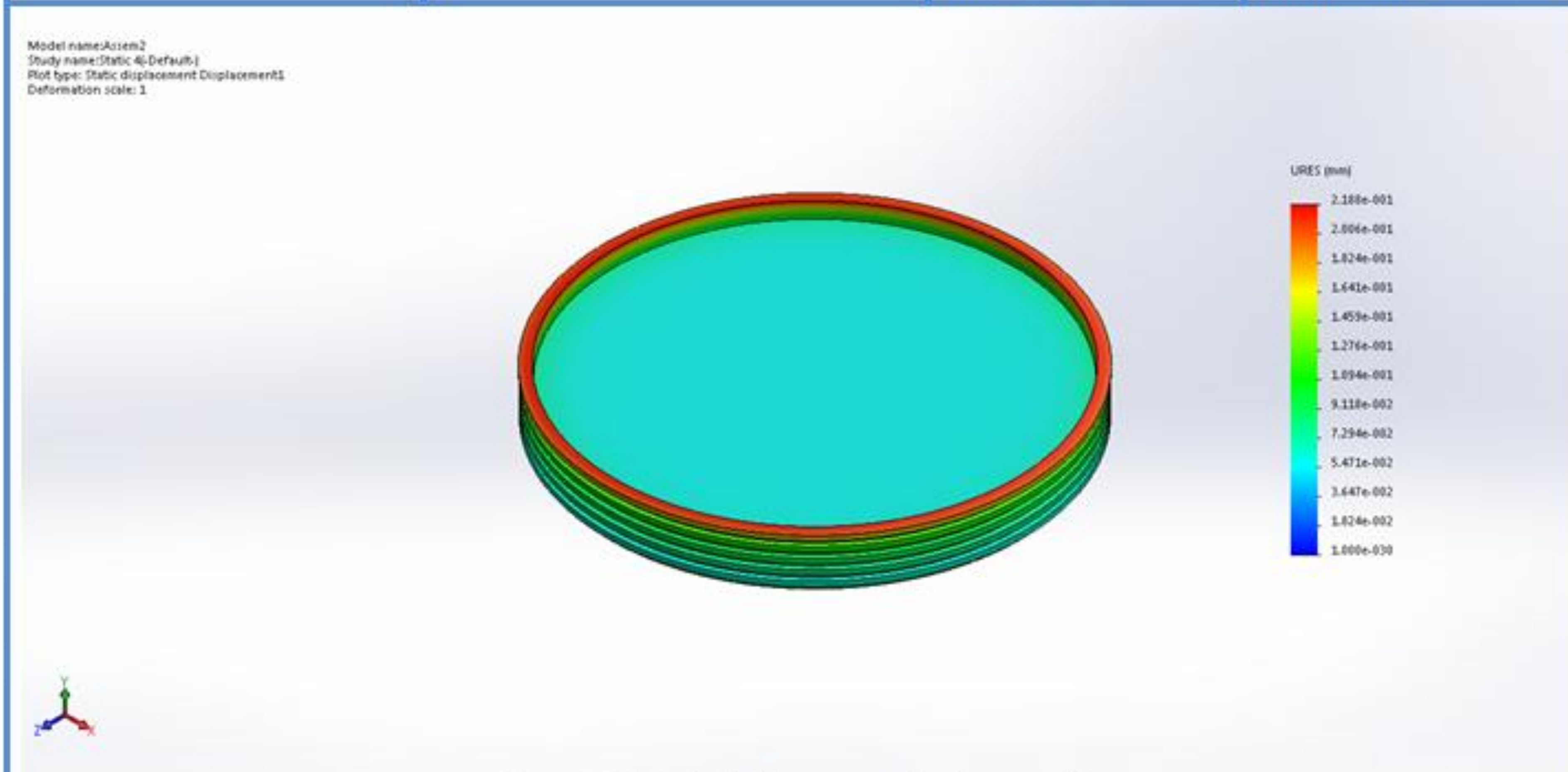


Assem2-Static 3-Strain-Strain1

850 C

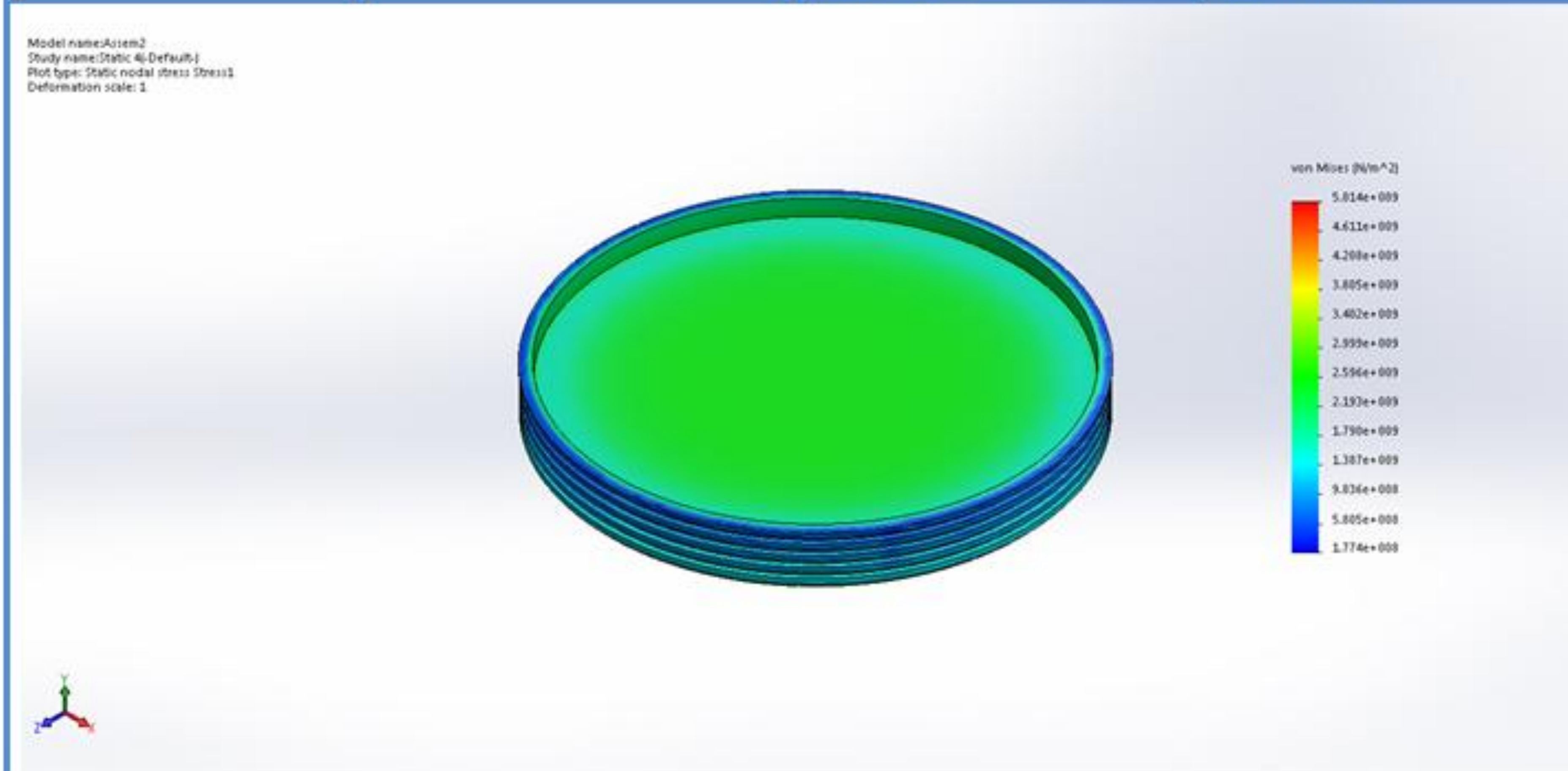


Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 49	0.218824 mm Node: 39858



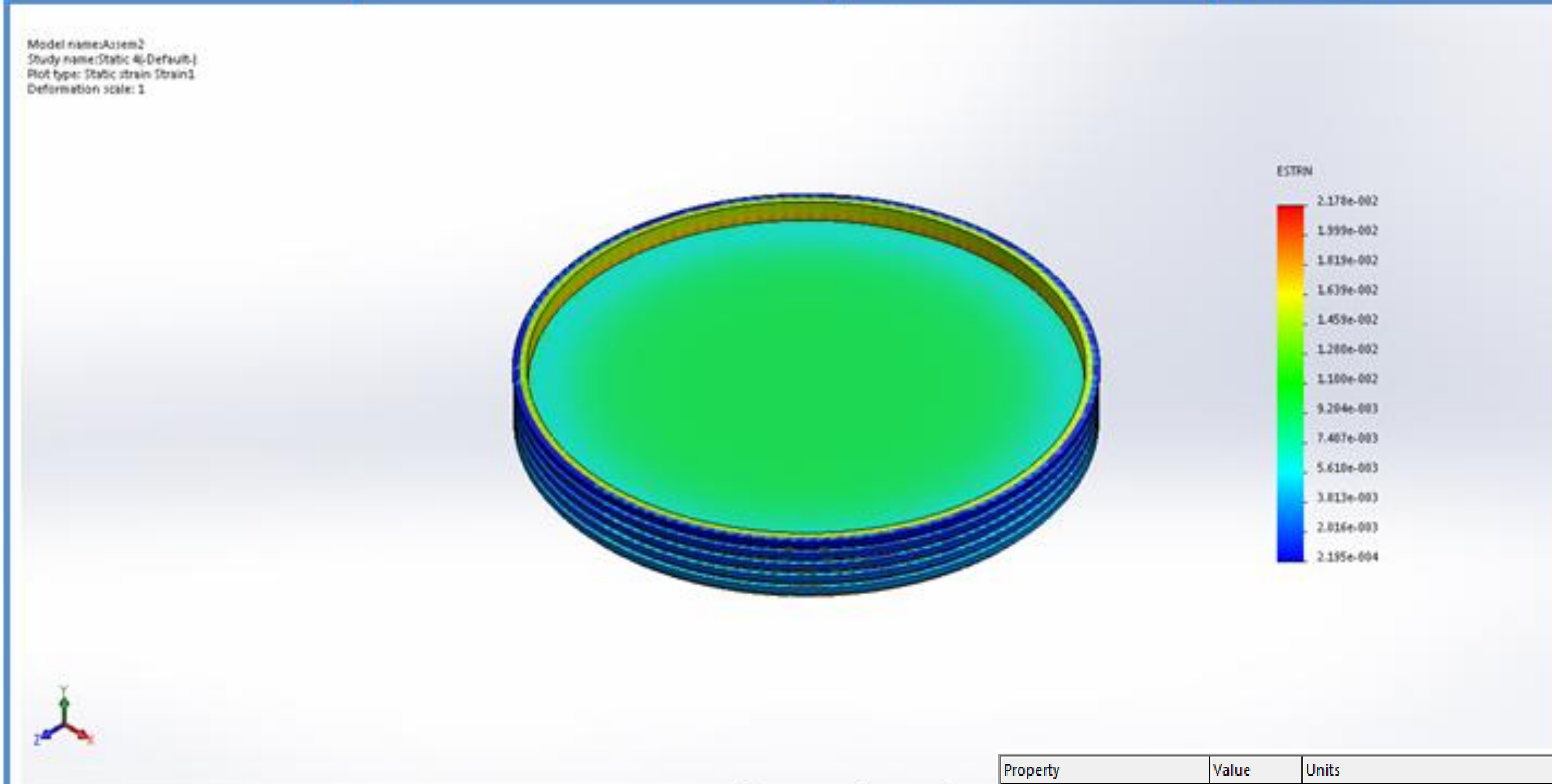
Assem2-Static 4-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.77419e+008 N/m^2 Node: 52354	5.01443e+009 N/m^2 Node: 36848



Assem2-Static 4-Stress-Stress1

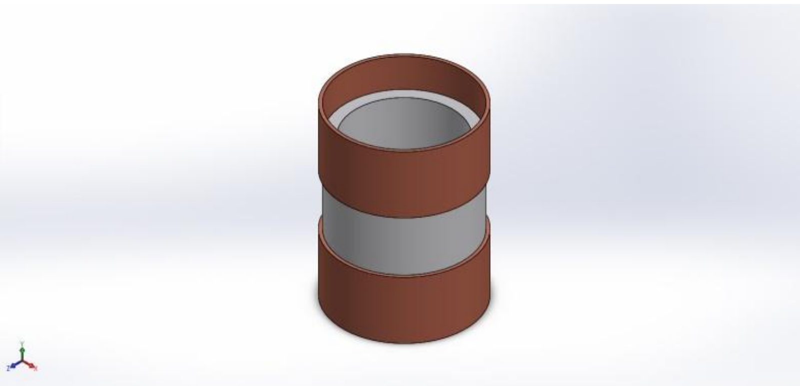
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000219472 Element: 30824	0.0217822 Element: 30042



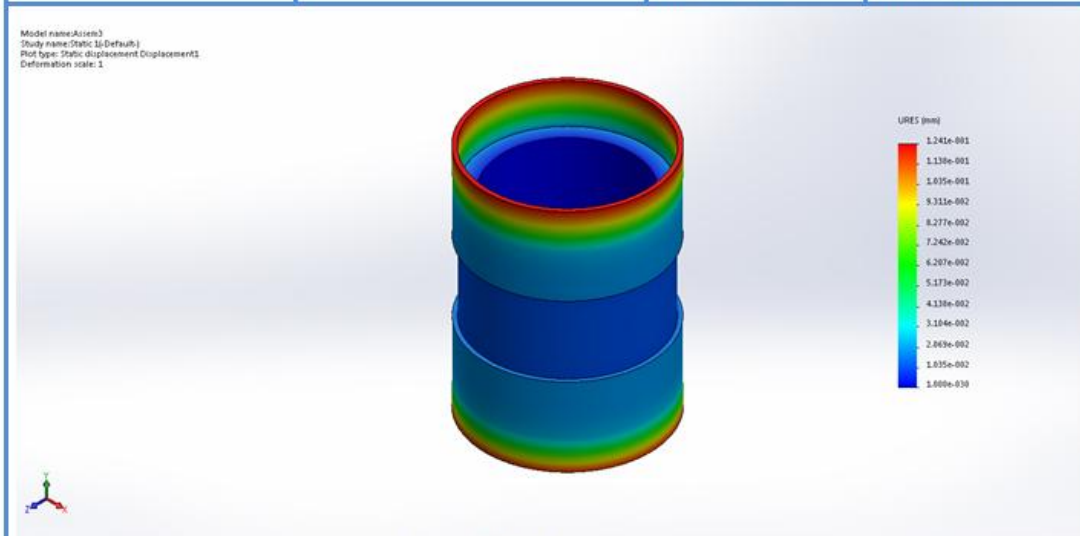
Assem2-Static 4-Strain-Strain1

Property	Value	Units
Elastic Modulus	2.2059e+011	N/m^2
Poisson's Ratio	0.22	N/A
Shear Modulus	9.0407e+010	N/m^2
Mass Density	2300	kg/m^3
Tensile Strength	172340000	N/m^2
Compressive Strength	551490000	N/m^2
Yield Strength		N/m^2
Thermal Expansion Coefficient	1.08e-005	/K
Thermal Conductivity	1.4949	W/(m·K)
Specific Heat	877.96	J/(kg·K)
Material Damping Ratio		N/A

200 ^{0}C

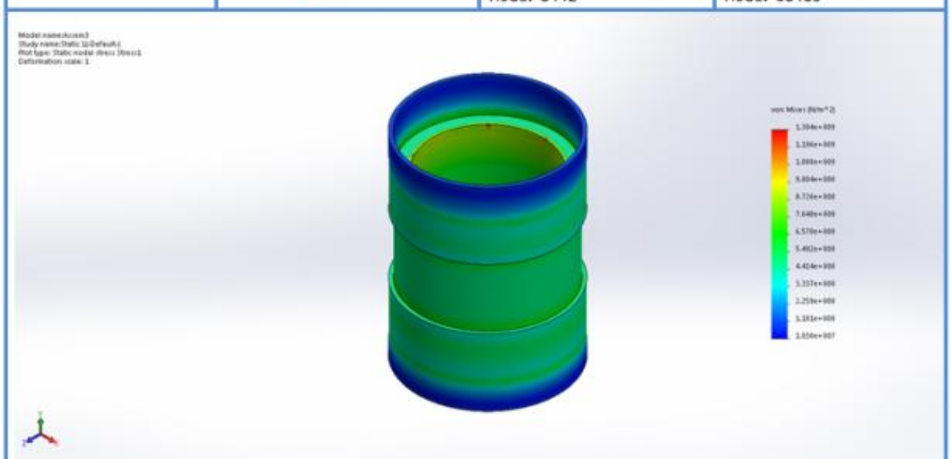


Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 22046	0.124149 mm Node: 10702



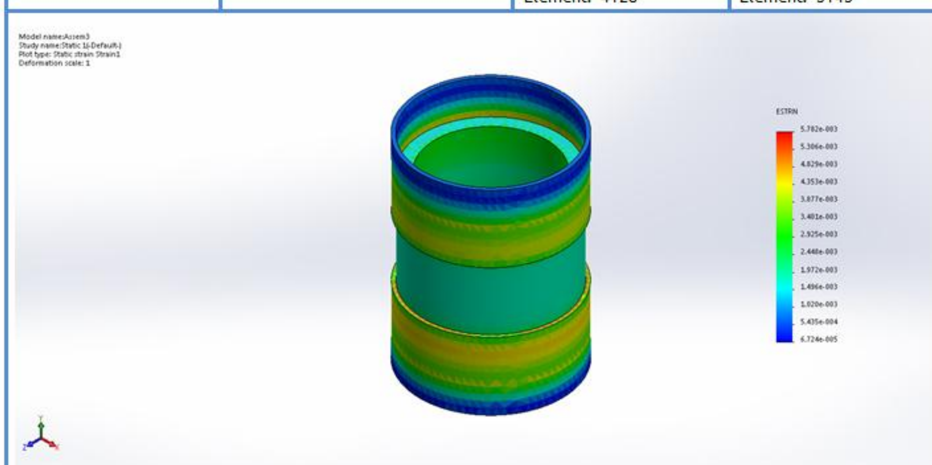
Assem3-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.03002e+007 N/m^2 Node: 8442	1.30373e+009 N/m^2 Node: 38485



Assem3-Static 1-Stress-Stress1

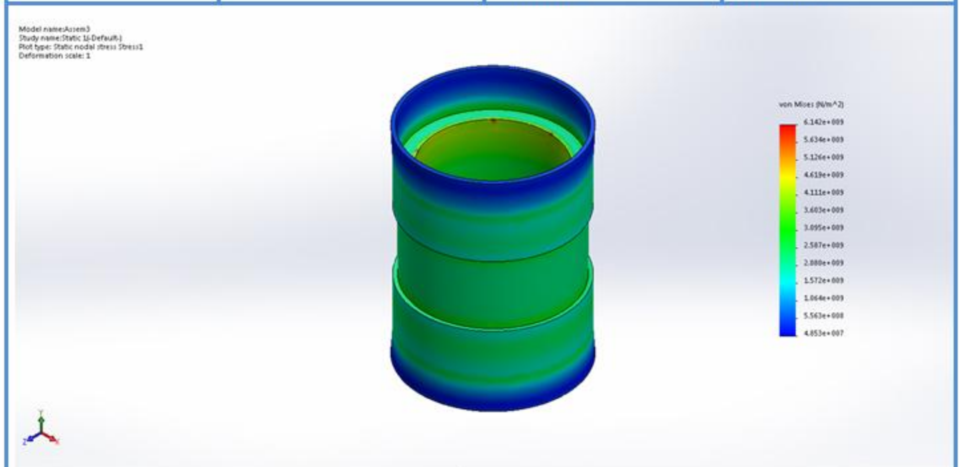
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.72377e-005 Element: 4128	0.00578179 Element: 5145



Assem3-Static 1-Strain-Strain1

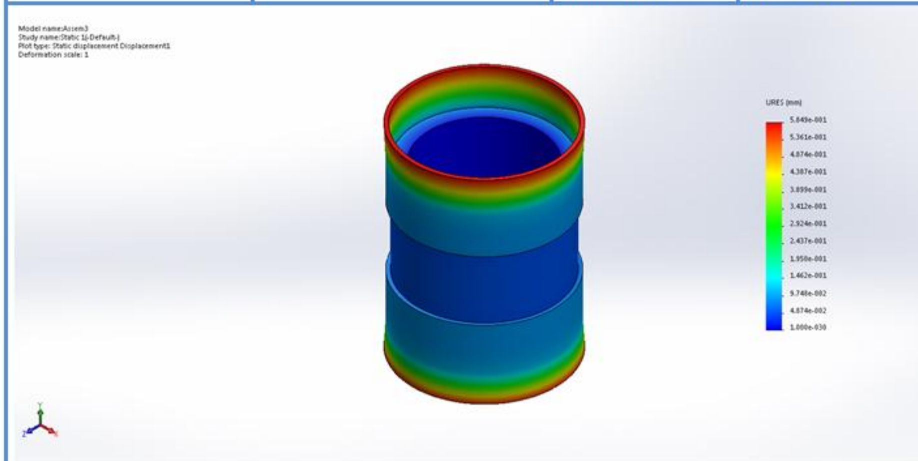
850 ^{0}C

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.85253e+007 N/m^2 Node: 8442	6.14199e+009 N/m^2 Node: 38485



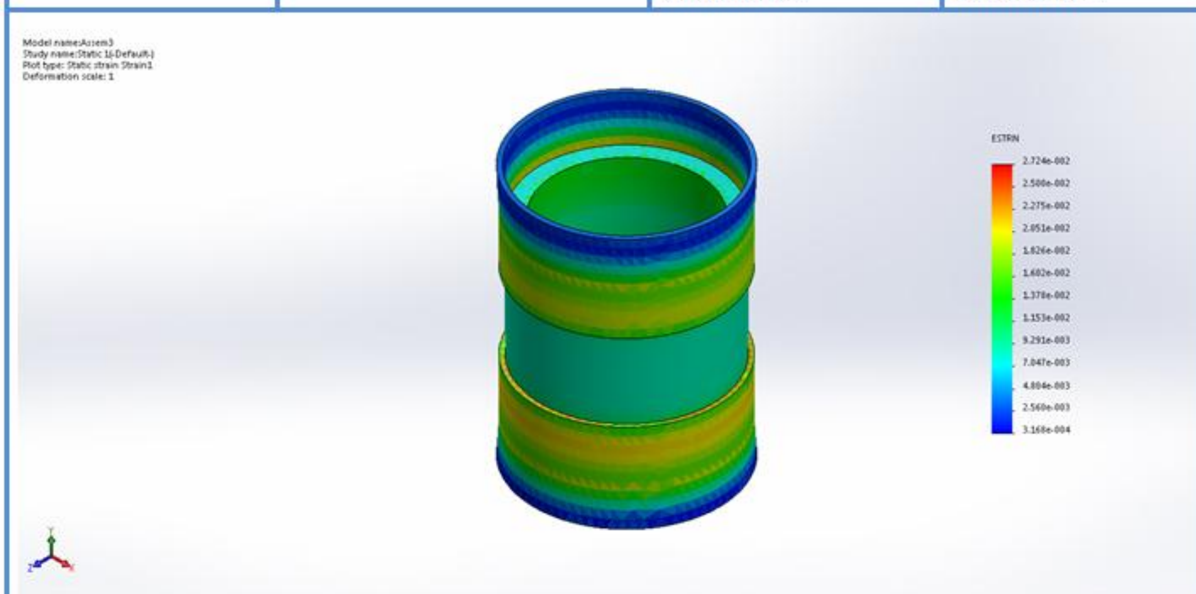
Assem3-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 22046	0.584879 mm Node: 10702



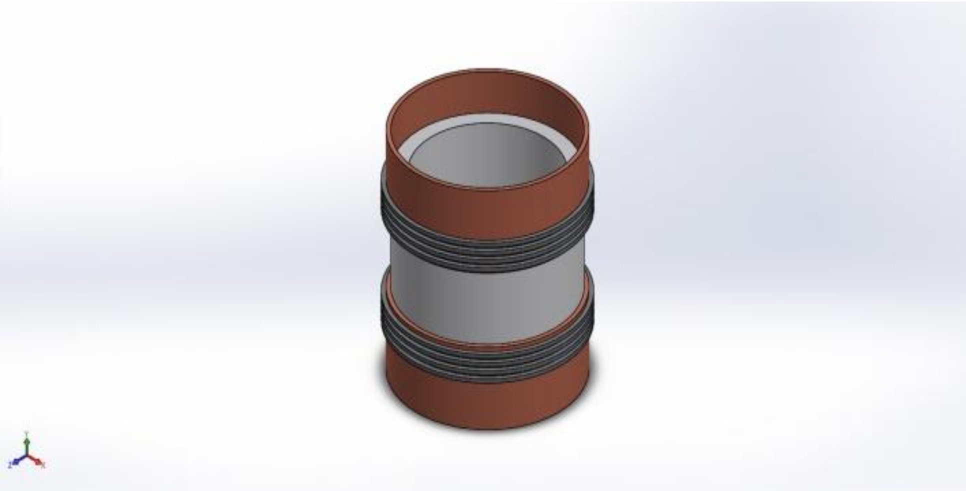
Assem3-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000316764 Element: 4128	0.0272386 Element: 5145

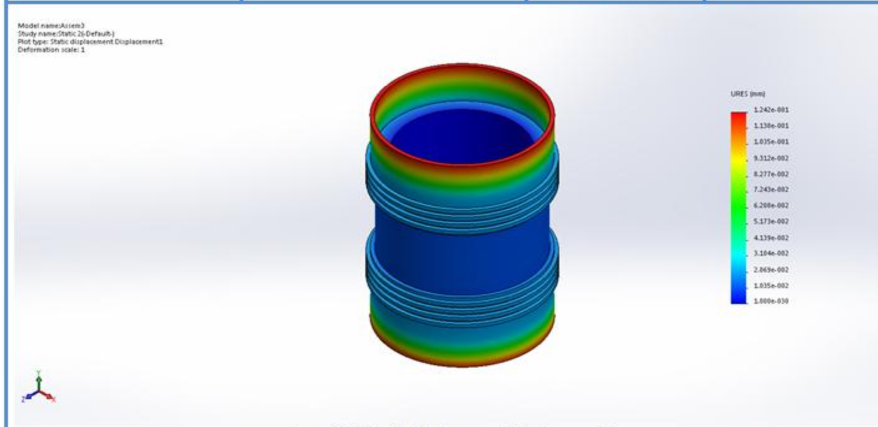


Assem3-Static 1-Strain-Strain1

200 ^{0}C

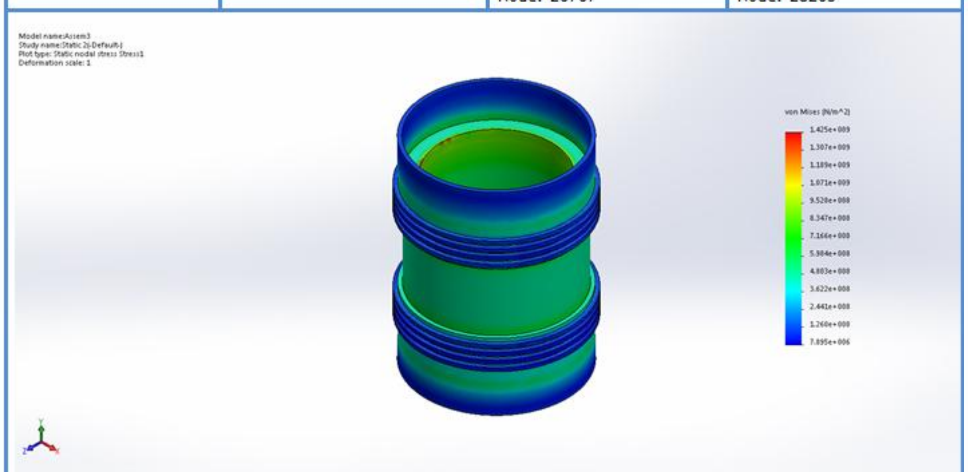


Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 27826	0.124158 mm Node: 11718



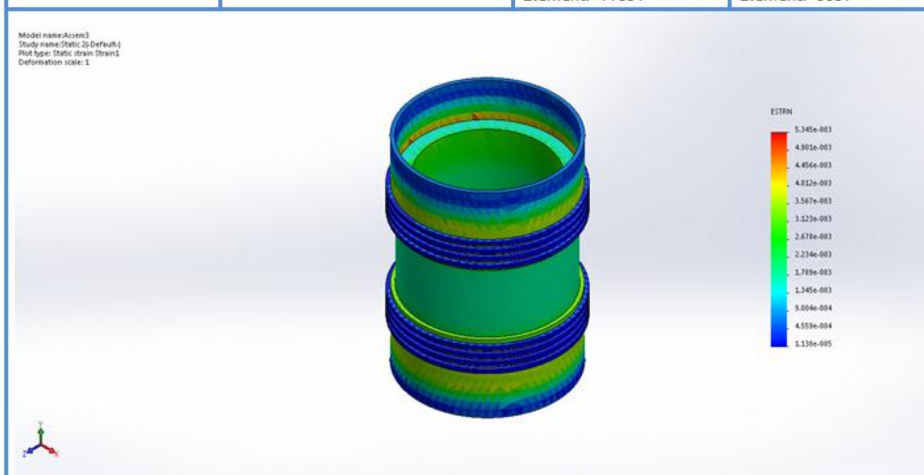
Assem3-Static 2-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7.89506e+006 N/m^2 Node: 26767	1.42521e+009 N/m^2 Node: 28265



Assem3-Static 2-Stress-Stress1

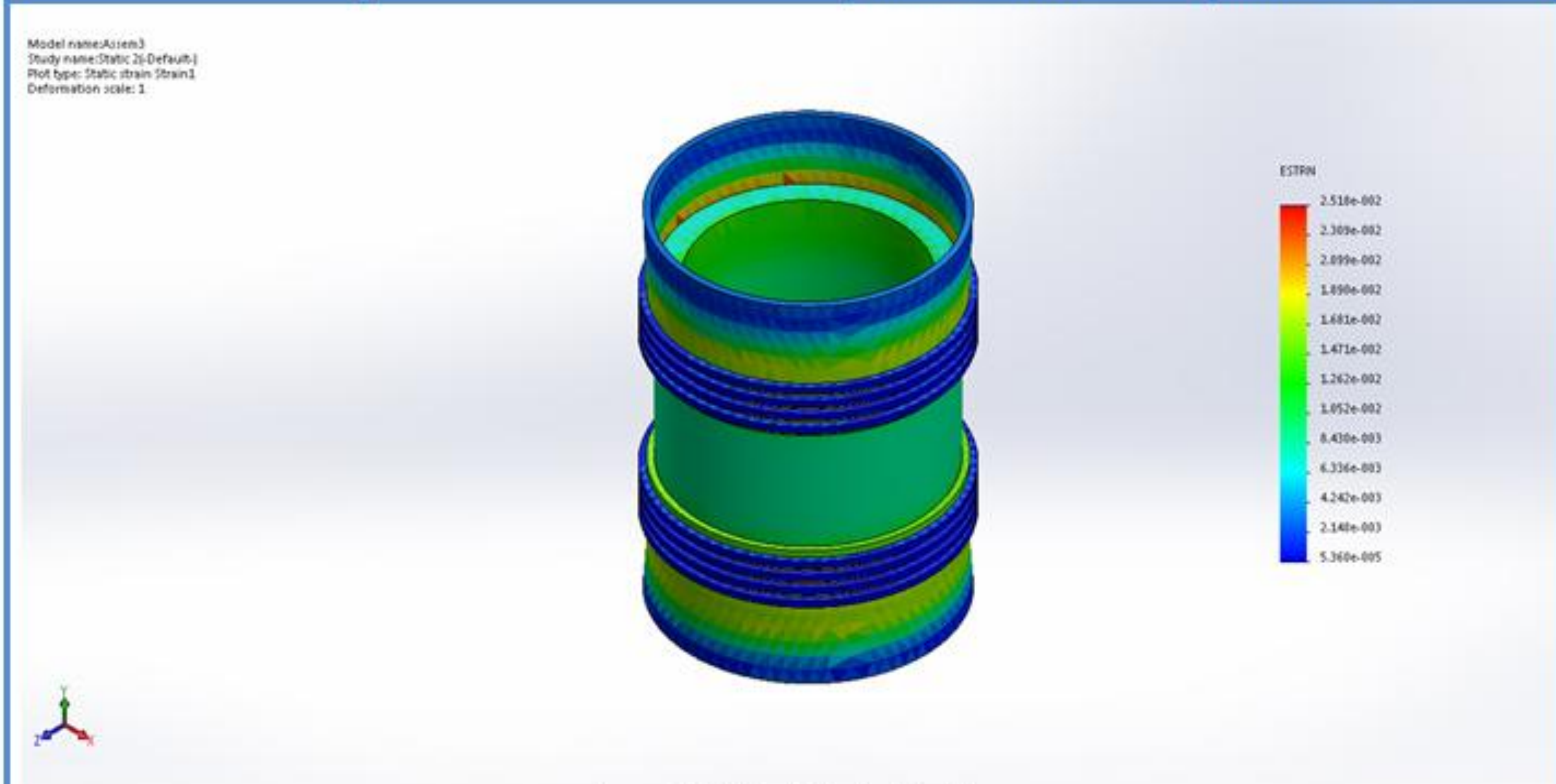
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.13783e-005 Element: 11851	0.0053454 Element: 3359



Assem3-Static 2-Strain-Strain1

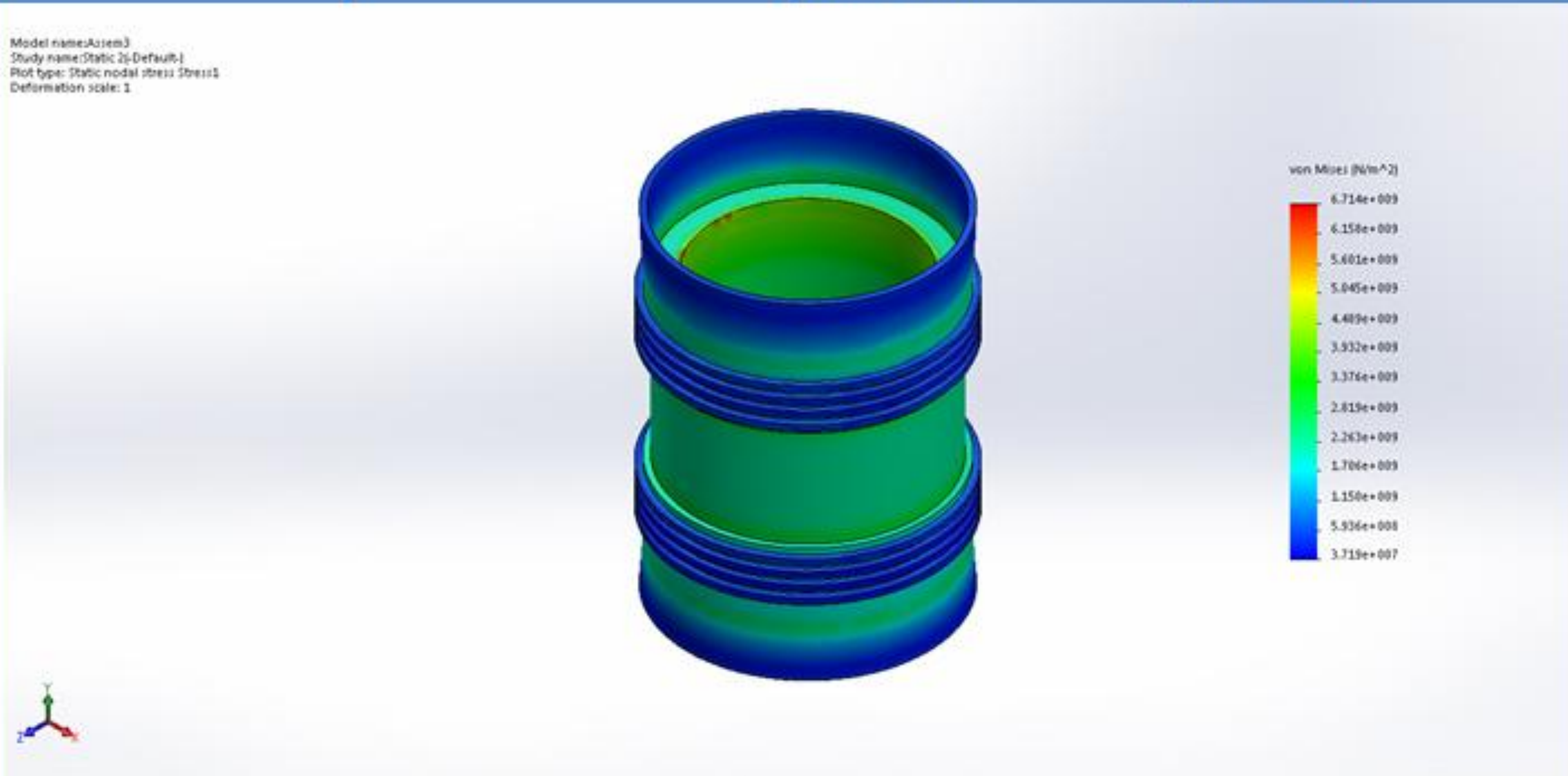
850 ^{0}C

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.36045e-005 Element: 11851	0.0251827 Element: 3359



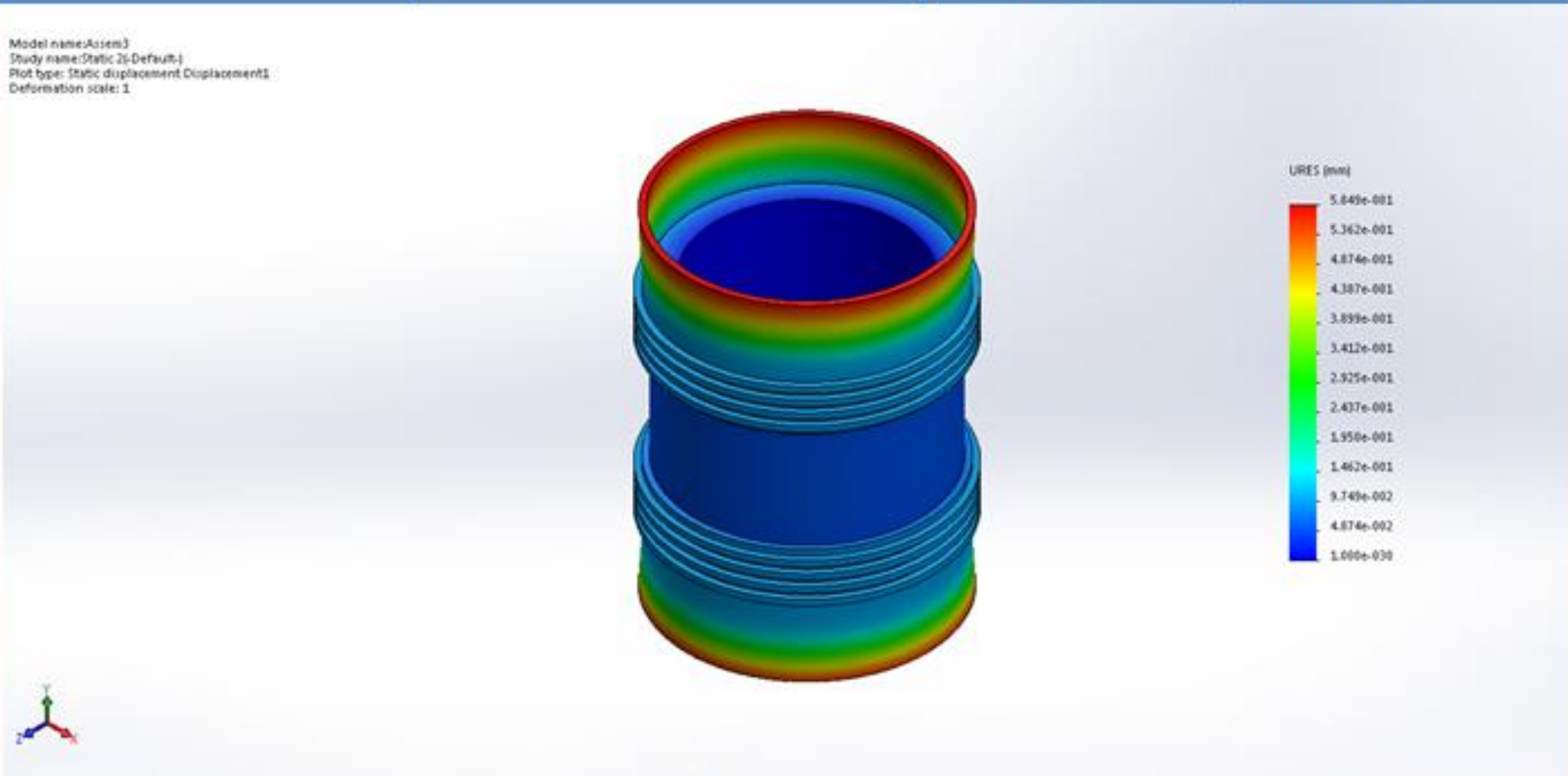
Assem3-Static 2-Strain-Strain1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.71945e+007 N/m^2 Node: 26767	6.71431e+009 N/m^2 Node: 28265

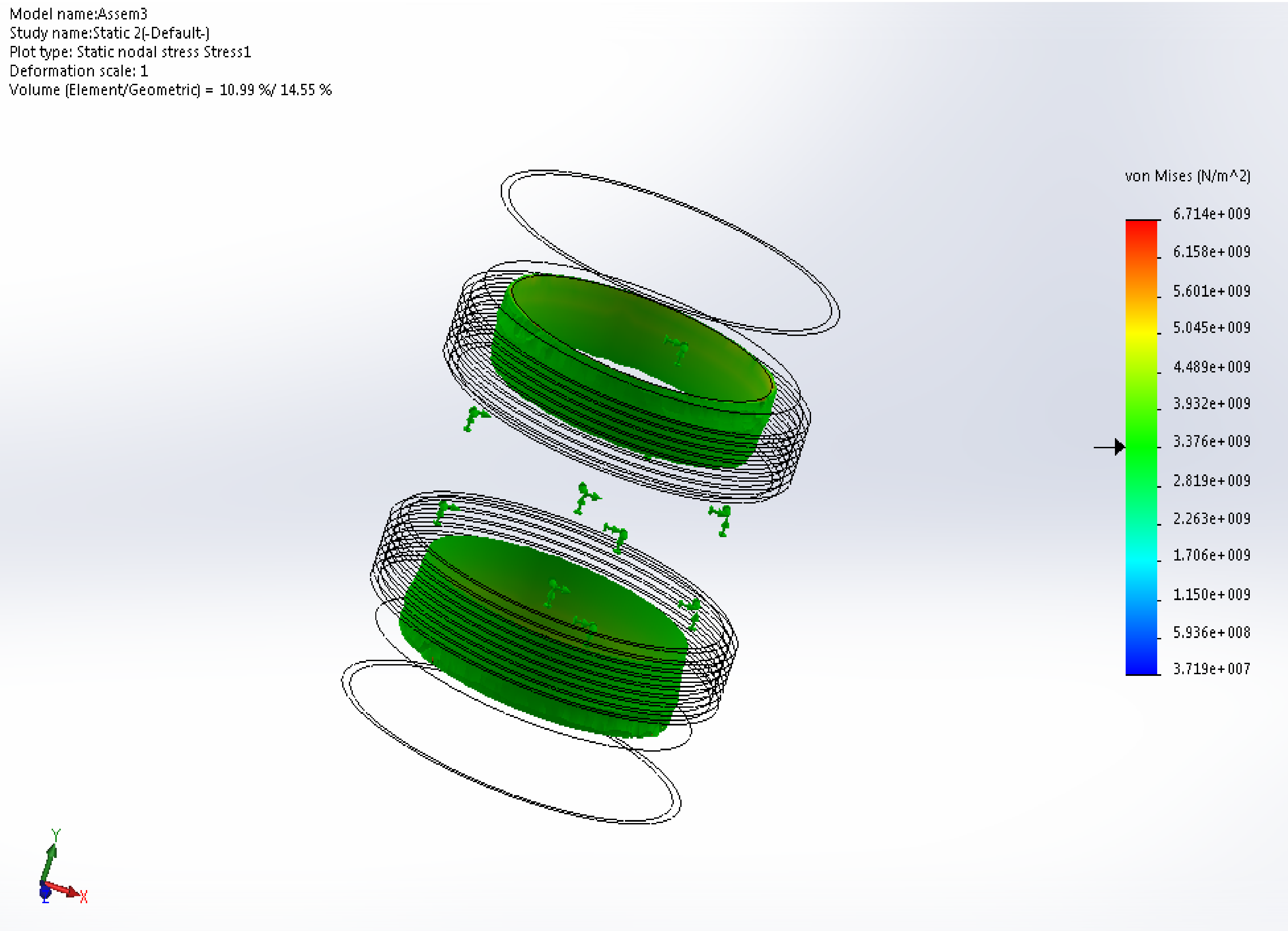


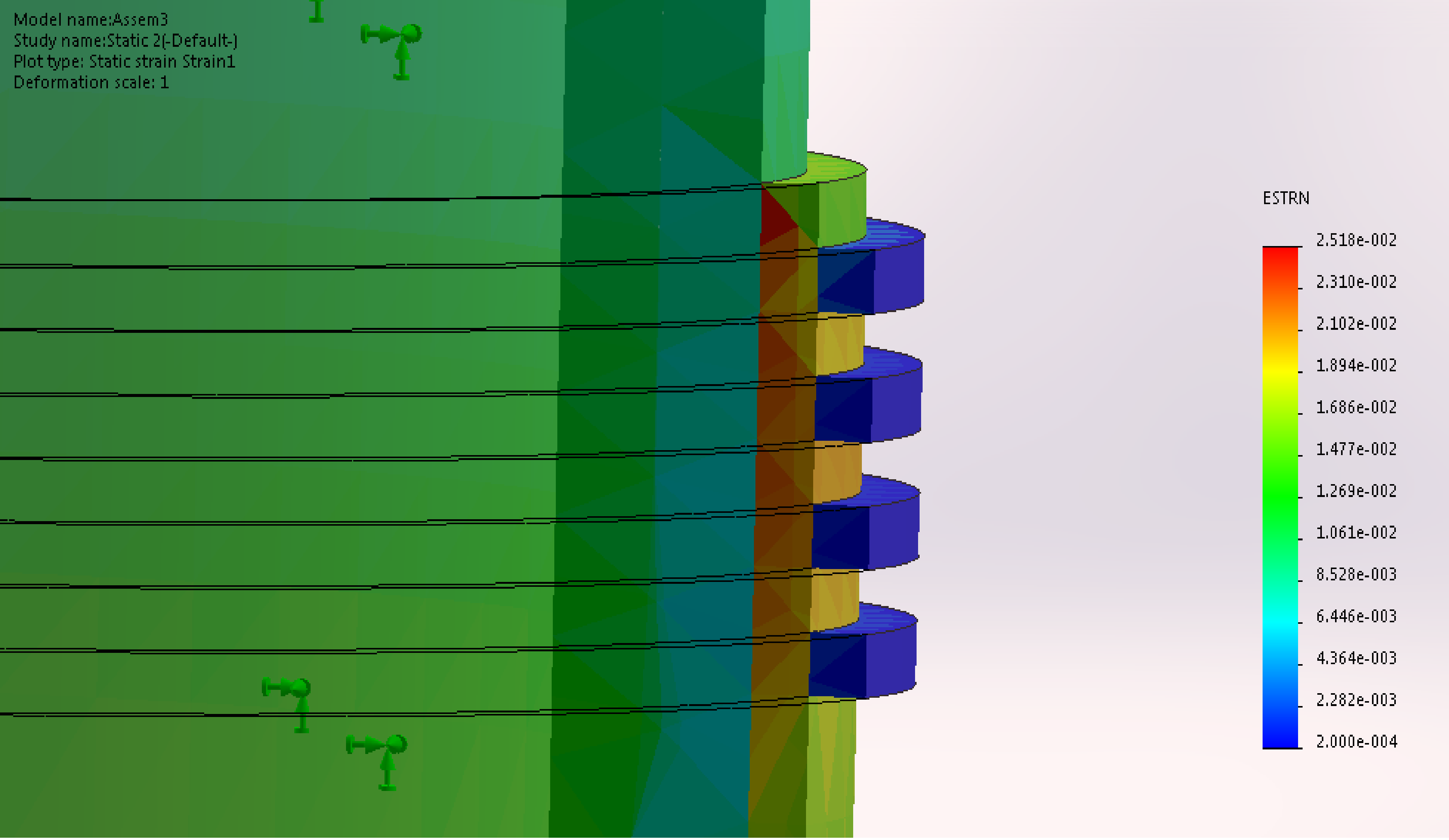
Assem3-Static 2-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 27826	0.584921 mm Node: 11718

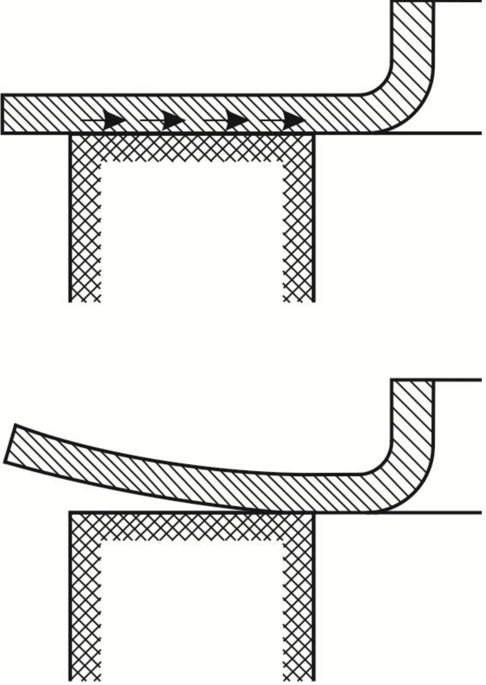


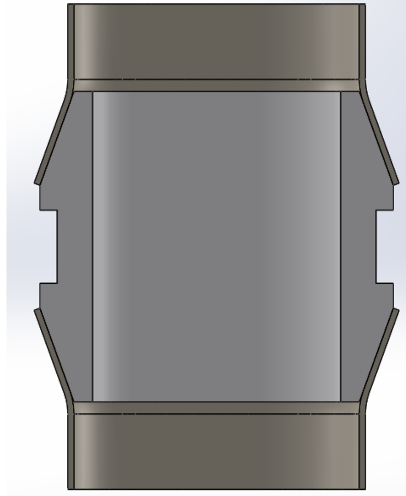
Assem3-Static 2-Displacement-Displacement1

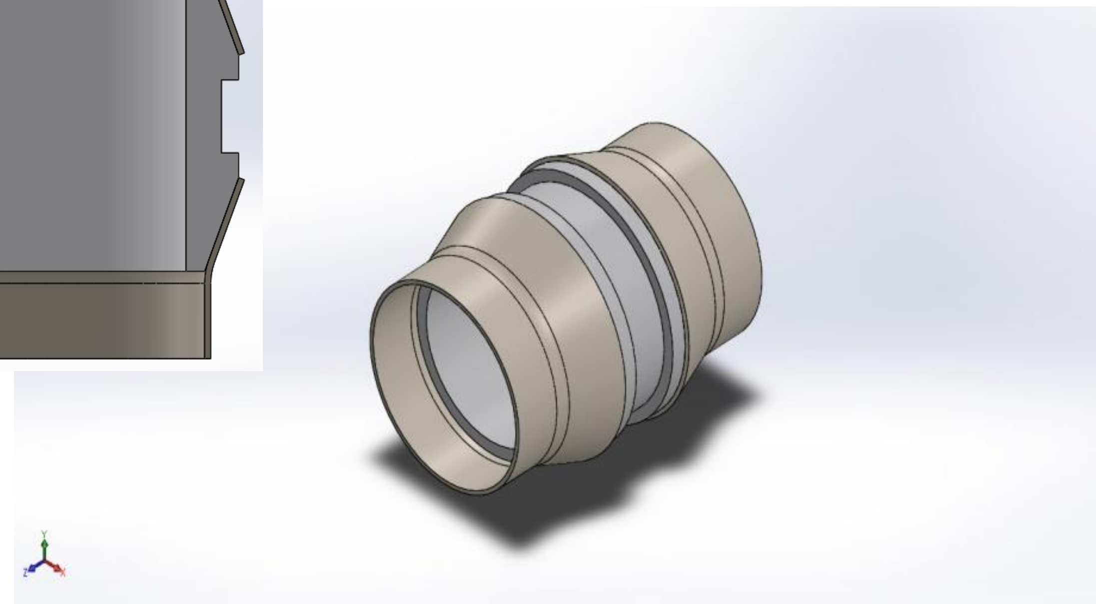

Model name:Assem3
Study name:Static 2(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
Volume (Element/Geometric) = 10.99 %/ 14.55 %
von Mises (N/m^2)
6.714e+009
6.158e+009
5.601e+009
5.045e+009
4.489e+009
3.932e+009
3.376e+009
2.819e+009
2.263e+009
1.706e+009
1.150e+009
5.936e+008
3.719e+007
Y
X


Model name:Assem3
Study name:Static 2(-Default-)
Plot type: Static strain Strain1
Deformation scale: 1
ESTRN
2.518e-002
2.310e-002
2.102e-002
1.894e-002
1.686e-002
1.477e-002
1.269e-002
1.061e-002
8.528e-003
6.446e-003
4.364e-003
2.282e-003
2.000e-004

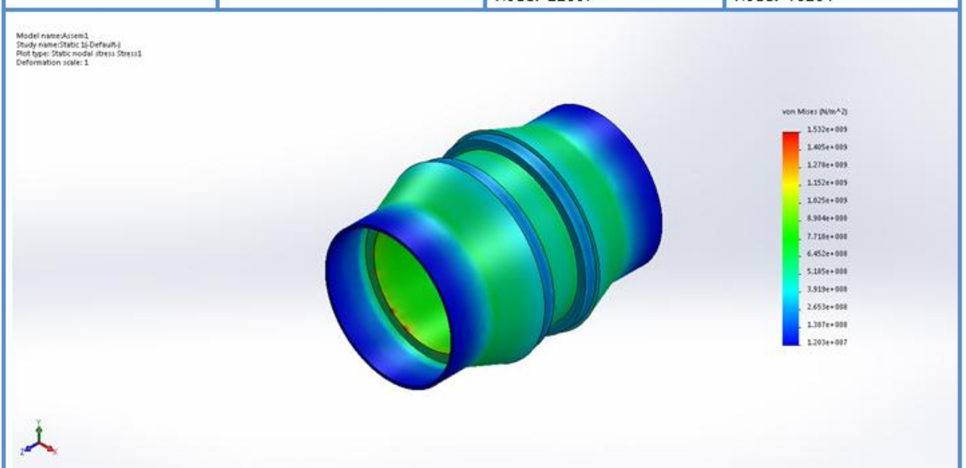
At 200 ^{0}C





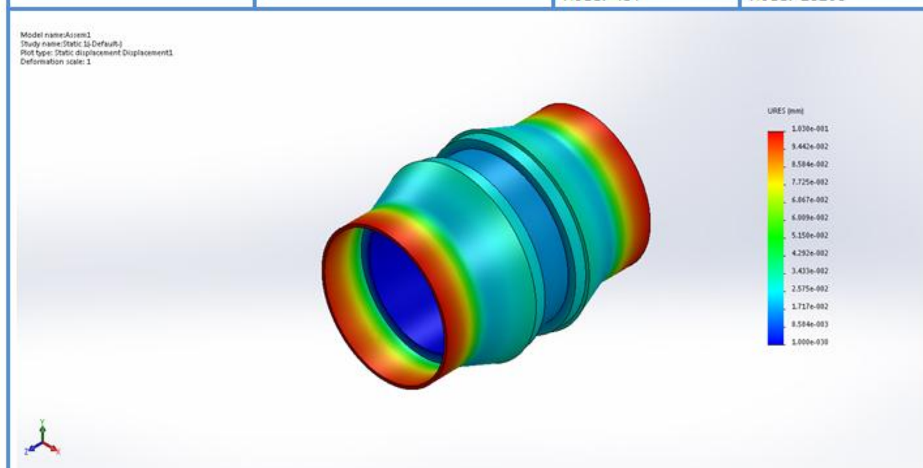


Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.20277e+007 N/m^2 Node: 22607	1.53156e+009 N/m^2 Node: 16264



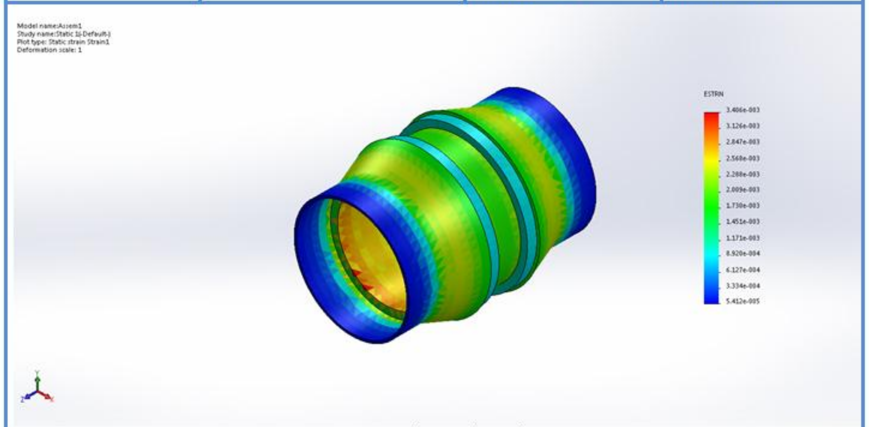
Assem1-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 451	0.103004 mm Node: 23203



Assem1-Static 1-Displacement-Displacement1

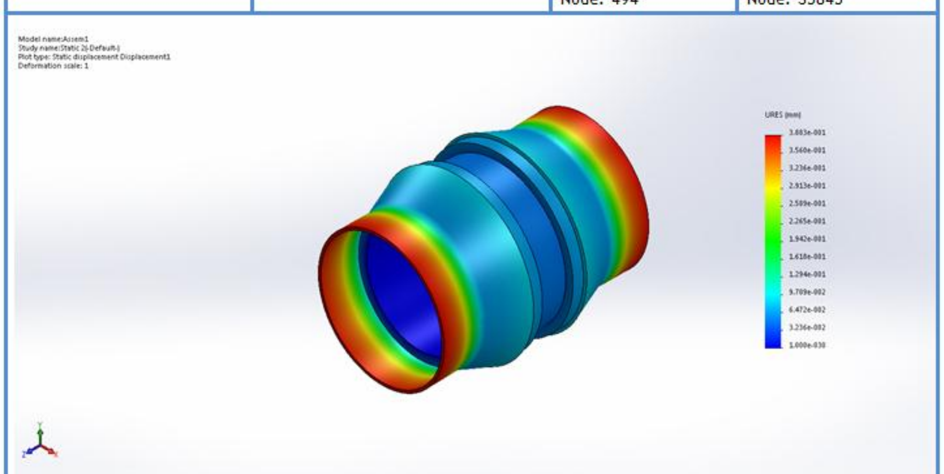
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.41168e-005 Element: 16178	0.00340559 Element: 10260



Assem1-Static 1-Strain-Strain1

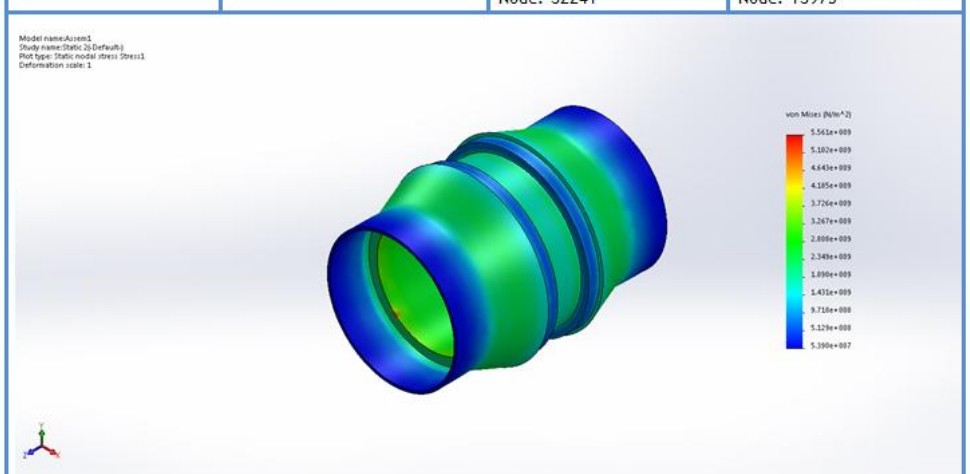
Mo-monel 850 ^{0}C

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 494	0.388341 mm Node: 35845



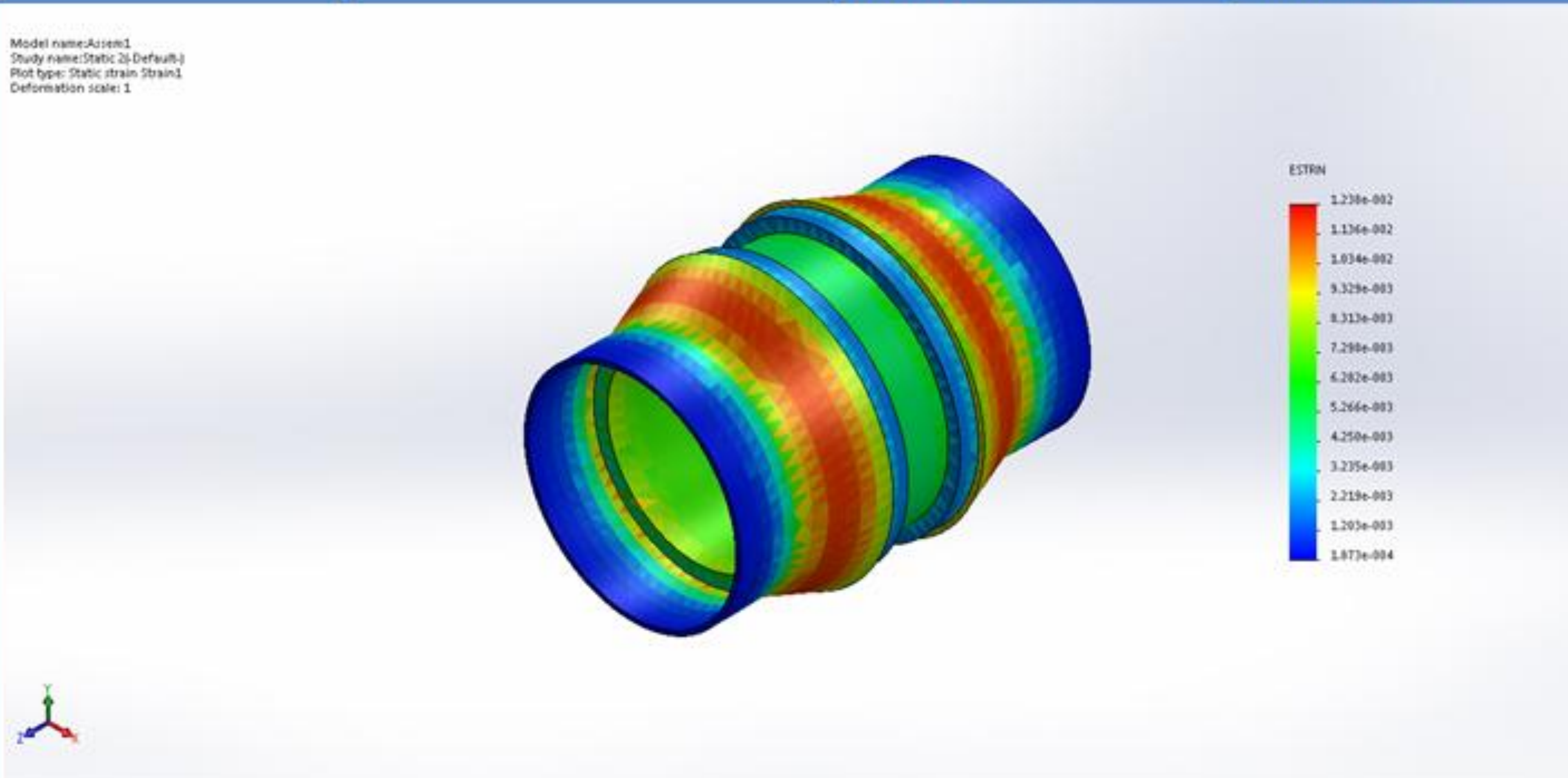
Assem1-Static 2-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	5.39037e+007 N/m^2 Node: 32241	5.56137e+009 N/m^2 Node: 13975



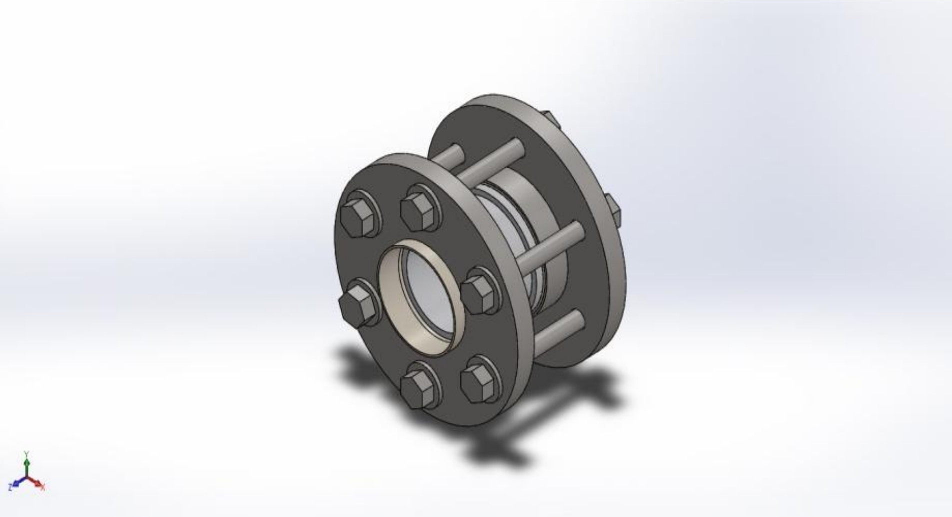
Assem1-Static 2-Stress-Stress1

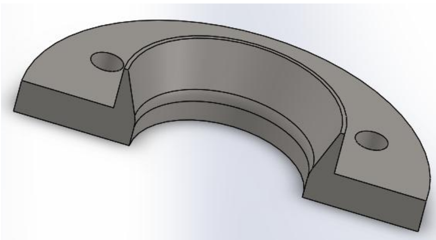
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000187349 Element: 23507	0.0123764 Element: 16576



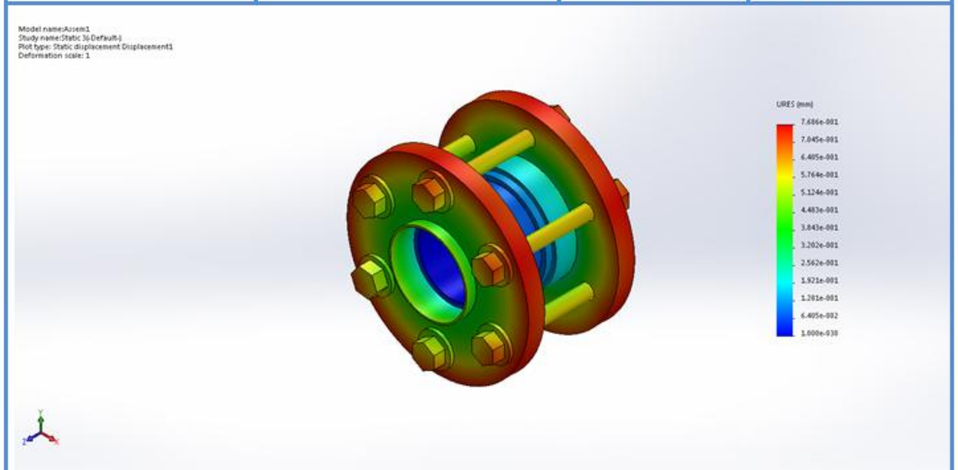
Assem1-Static 2-Strain-Strain1

200 ^{0}C



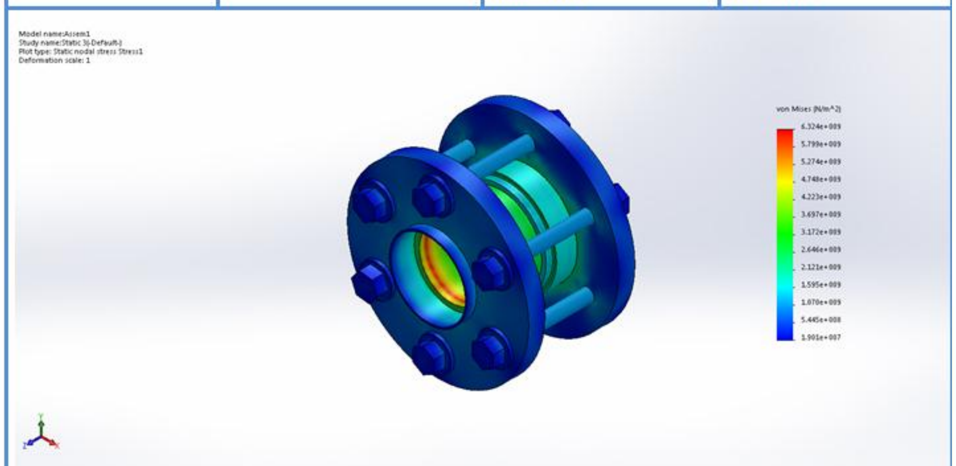


Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 241	0.768588 mm Node: 25247



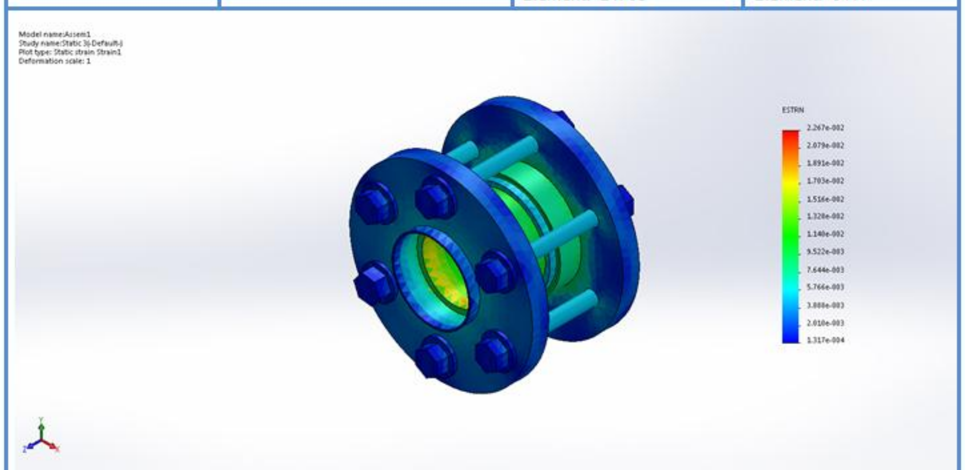
Assem1-Static 3-Displacement-Displacement1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.90094e+007 N/m^2 Node: 41862	6.32446e+009 N/m^2 Node: 444



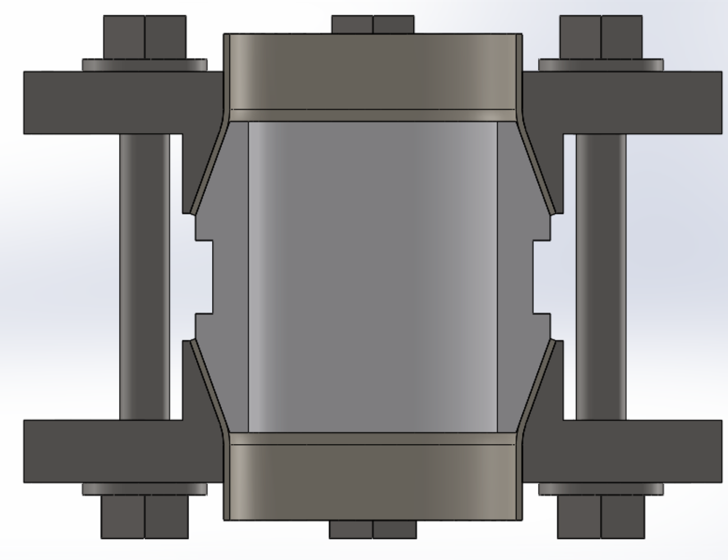
Assem1-Static 3-Stress-Stress1

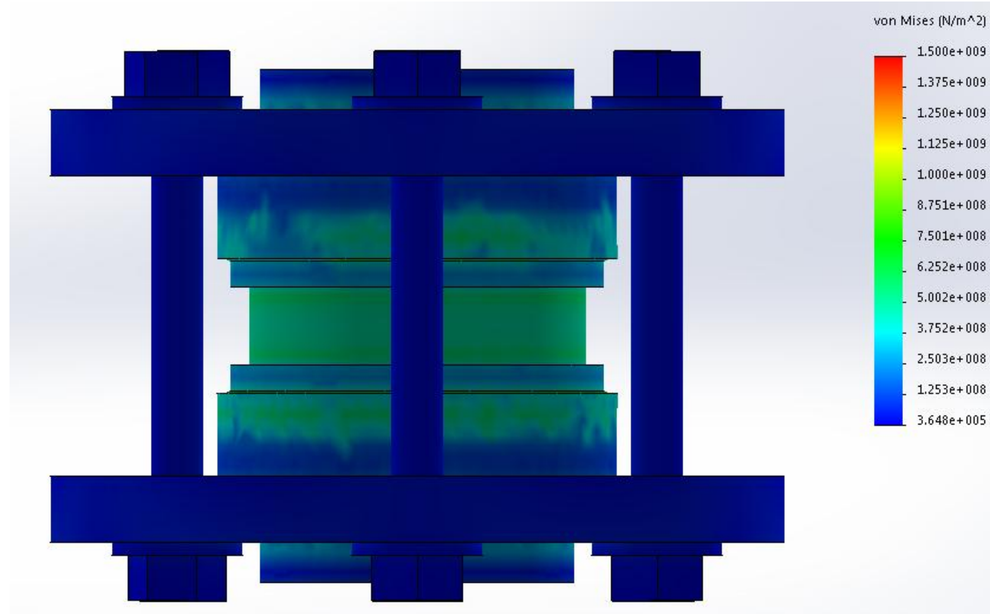
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000131692 Element: 24708	0.0226678 Element: 6417

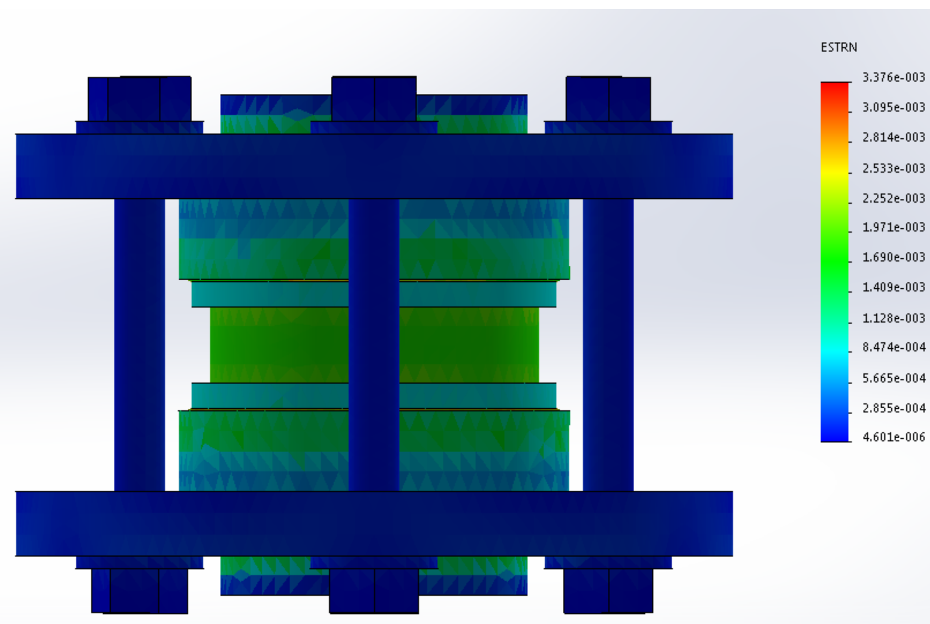


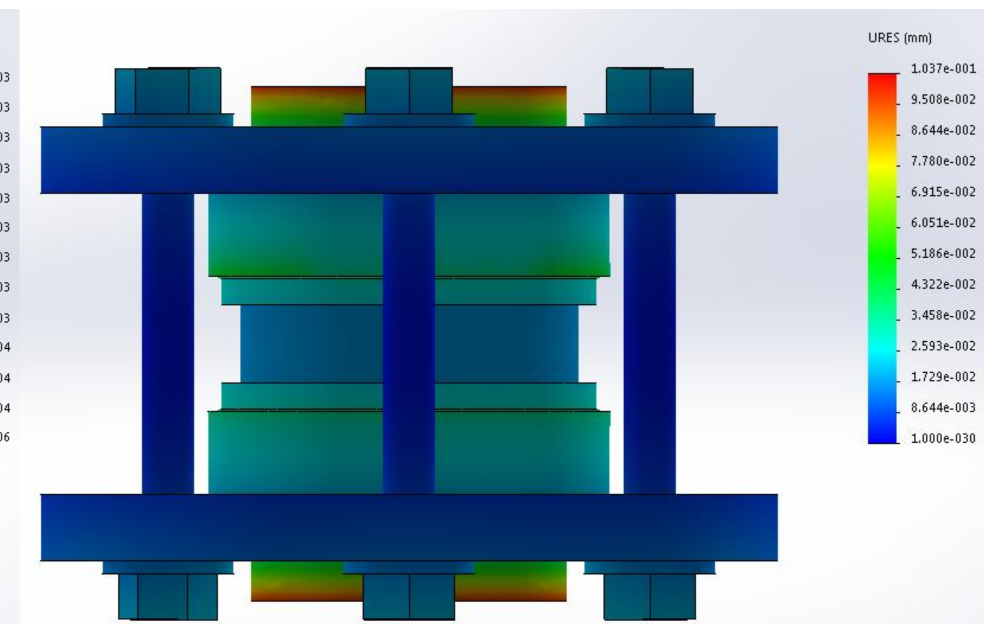
Assem1-Static 3-Strain-Strain1

200 ^{0}C

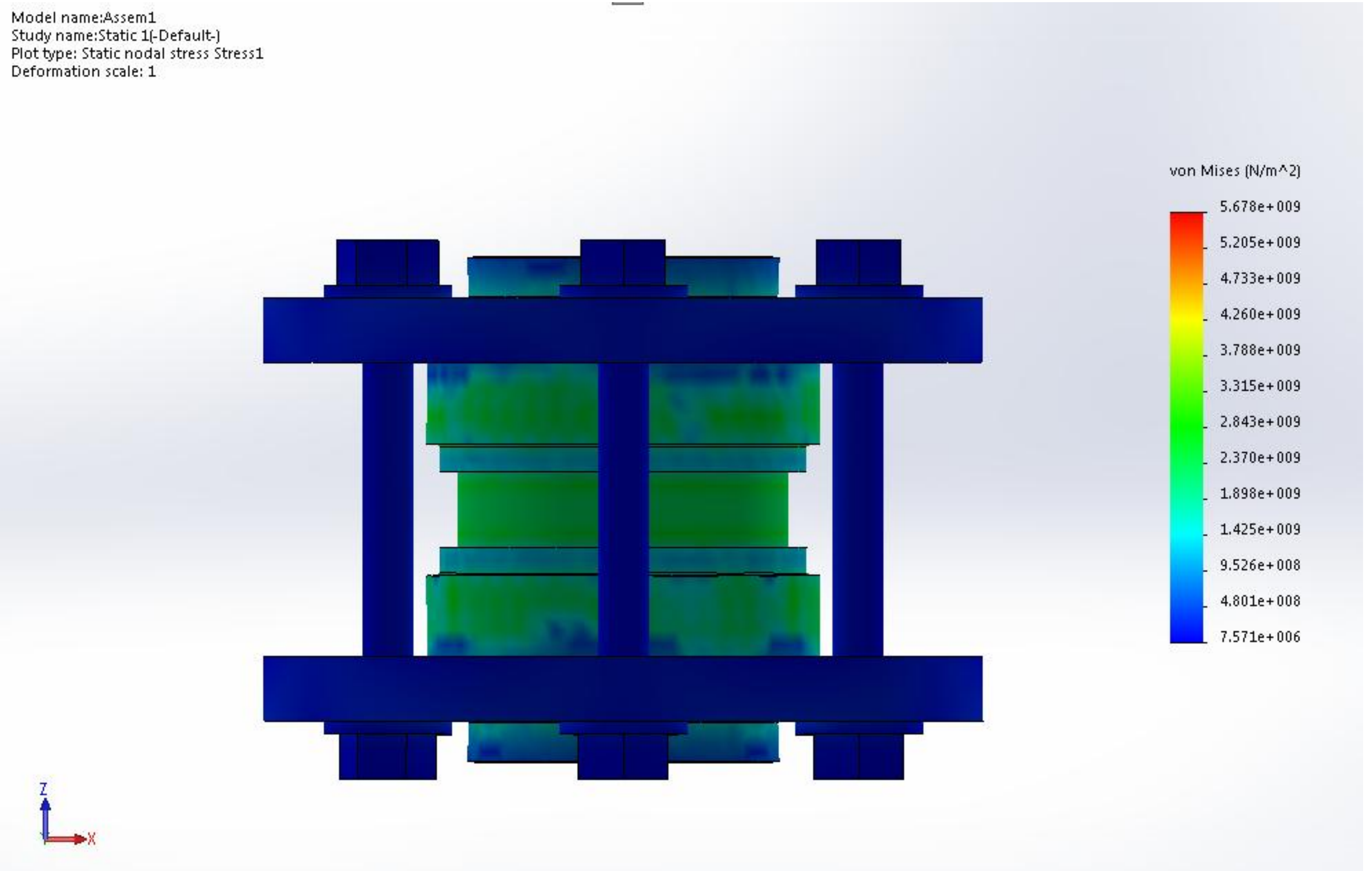



von Mises (N/m^2)
1.500e+009
1.375e+009
1.250e+009
1.125e+009
1.000e+009
8.751e+008
7.501e+008
6.252e+008
5.002e+008
3.752e+008
2.503e+008
1.253e+008
3.648e+005

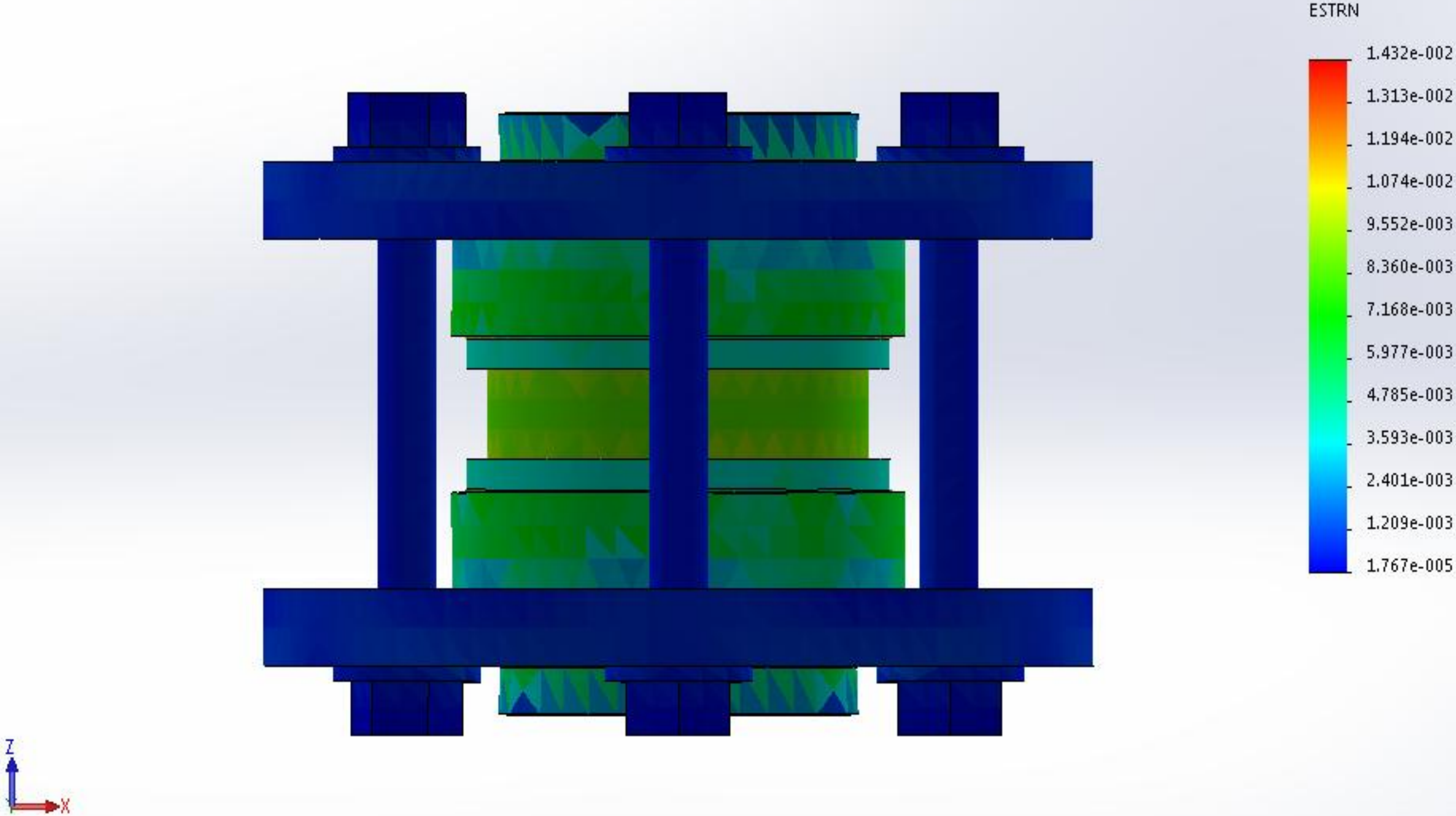

ESTRN
3.376e-003
3.095e-003
2.814e-003
2.533e-003
2.252e-003
1.971e-003
1.690e-003
1.409e-003
1.128e-003
8.474e-004
5.665e-004
2.855e-004
4.601e-006


URES (mm)
1.037e-001
9.508e-002
8.644e-002
7.780e-002
6.915e-002
6.051e-002
5.186e-002
4.322e-002
3.458e-002
2.593e-002
1.729e-002
8.644e-003
1.000e-030

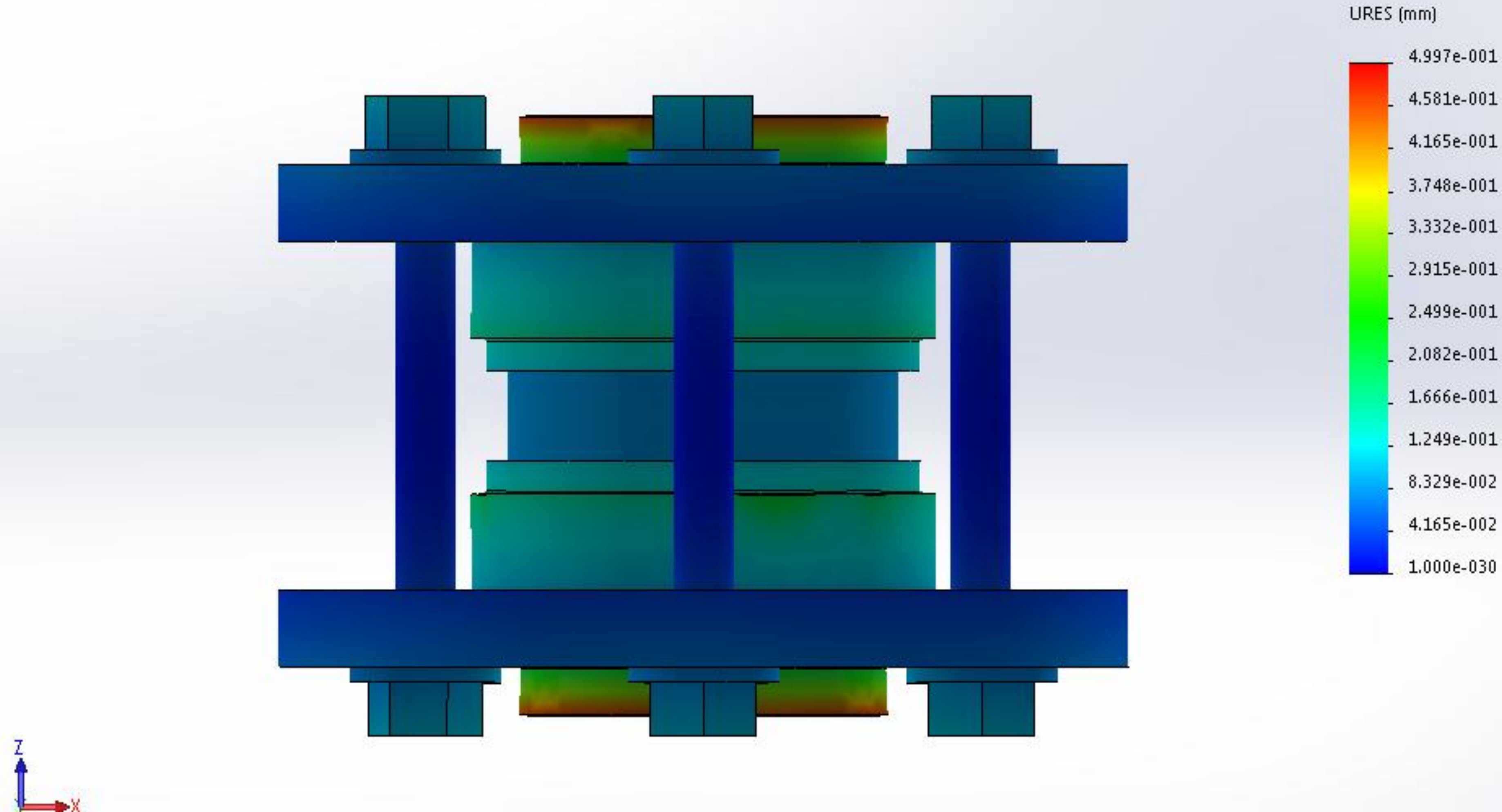
850 ^{0}C


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1
von Mises (N/m^2)
5.678e+009
5.205e+009
4.733e+009
4.260e+009
3.788e+009
3.315e+009
2.843e+009
2.370e+009
1.898e+009
1.425e+009
9.526e+008
4.801e+008
7.571e+006
Z
X

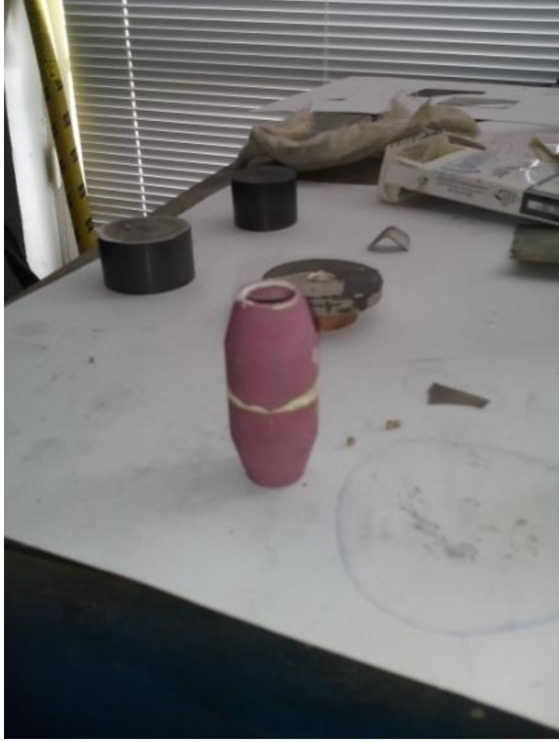
Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static strain Strain1
Deformation scale: 1



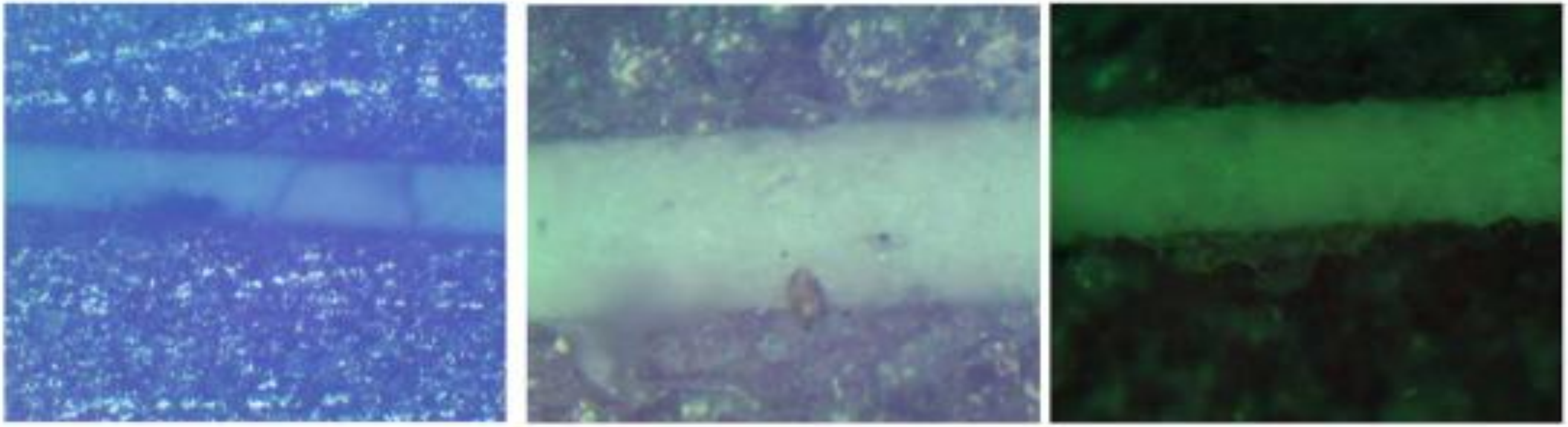
Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 1



4.4. Metal-ceramic bonding based on silicate adhesive.

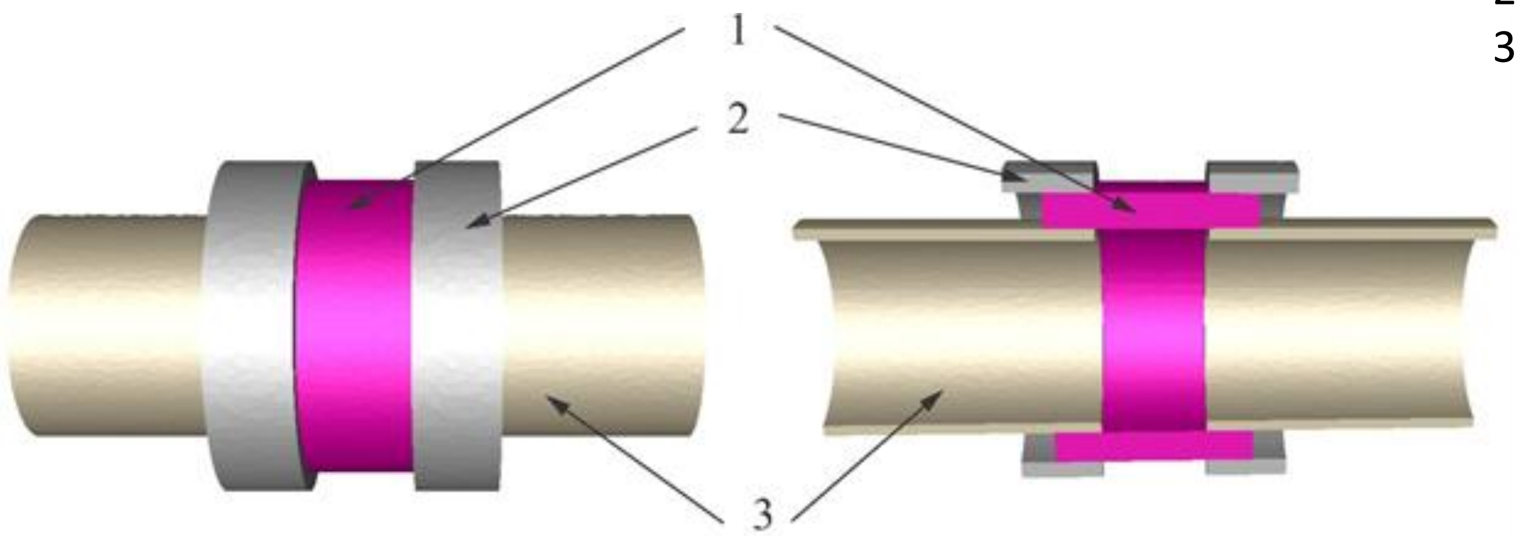


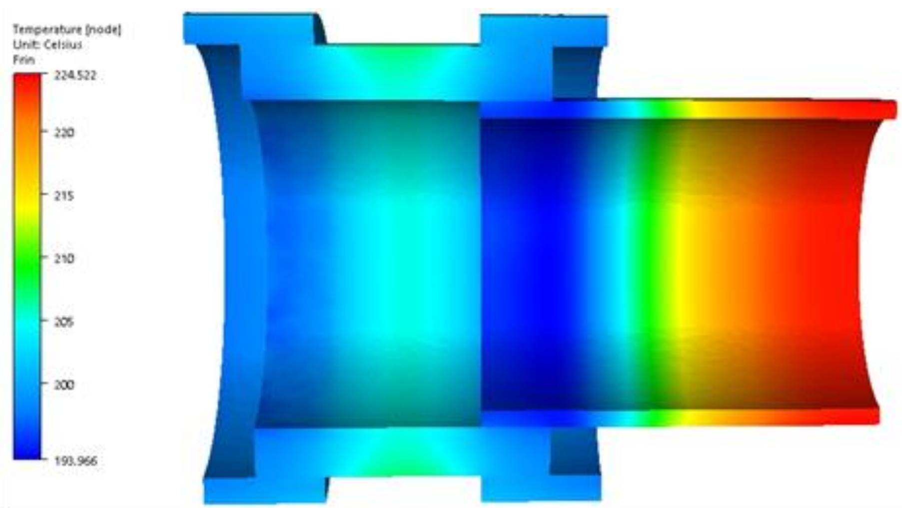
Disadvantages
-Low mechanical strength,
-Low working temperature,
-Short lifetime,

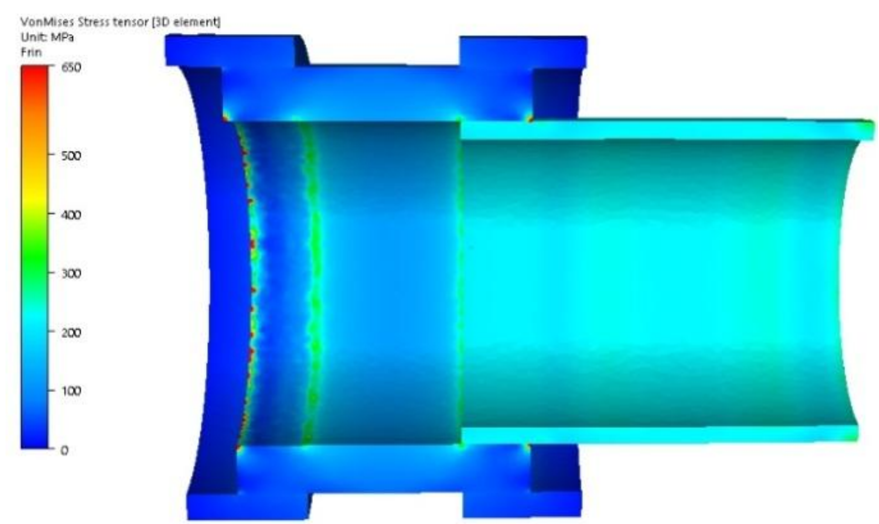


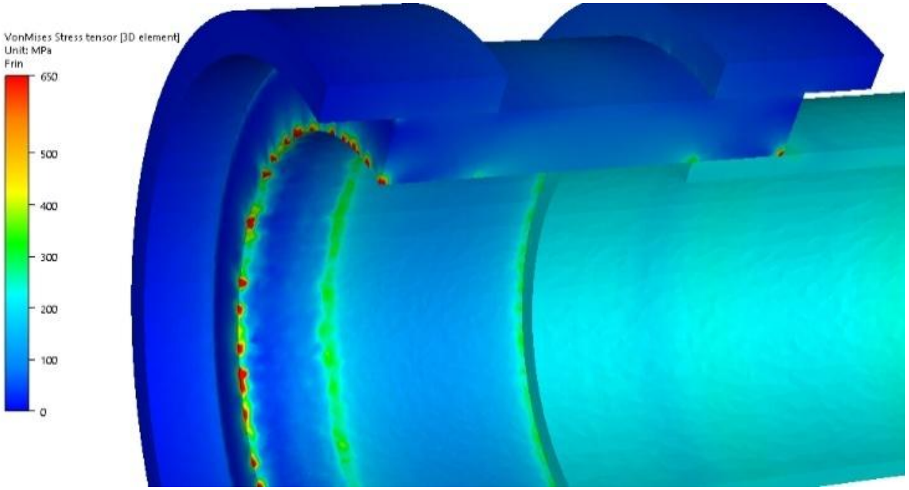
Optimal Bakeout Temperature simulation.

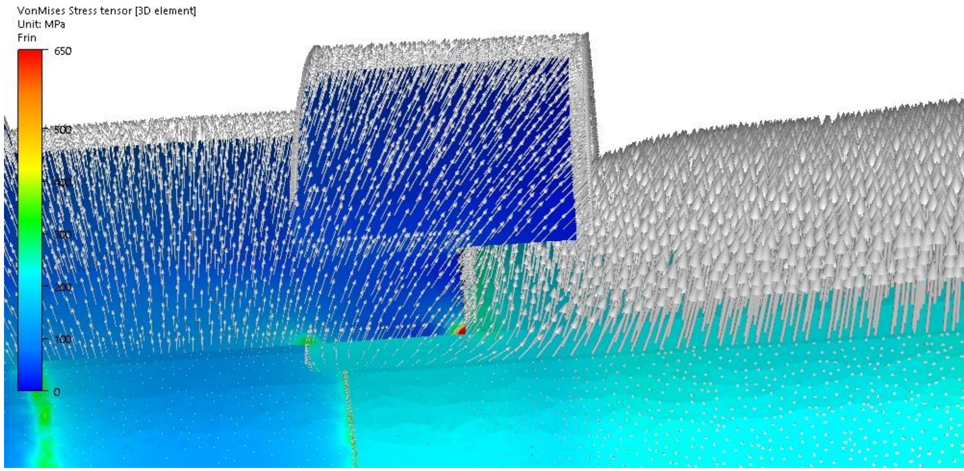
1. Ceramic,
2. Kovar,
3. Stainless steel.

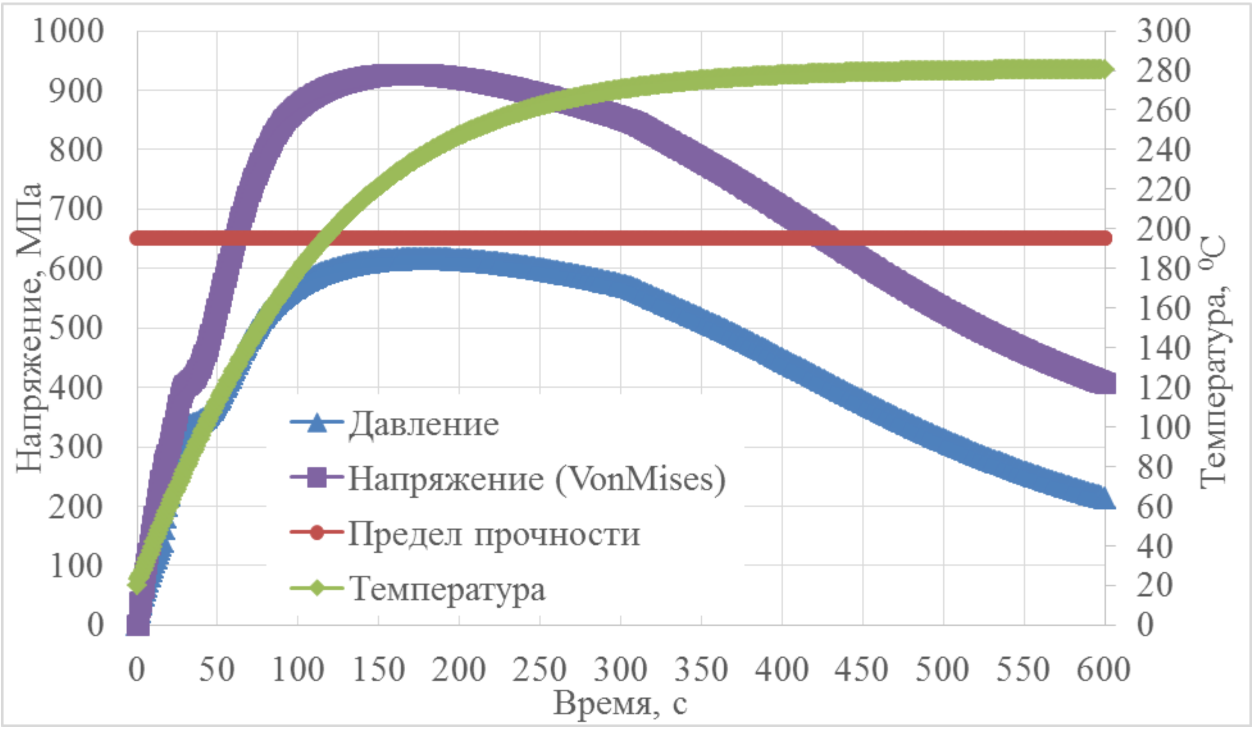




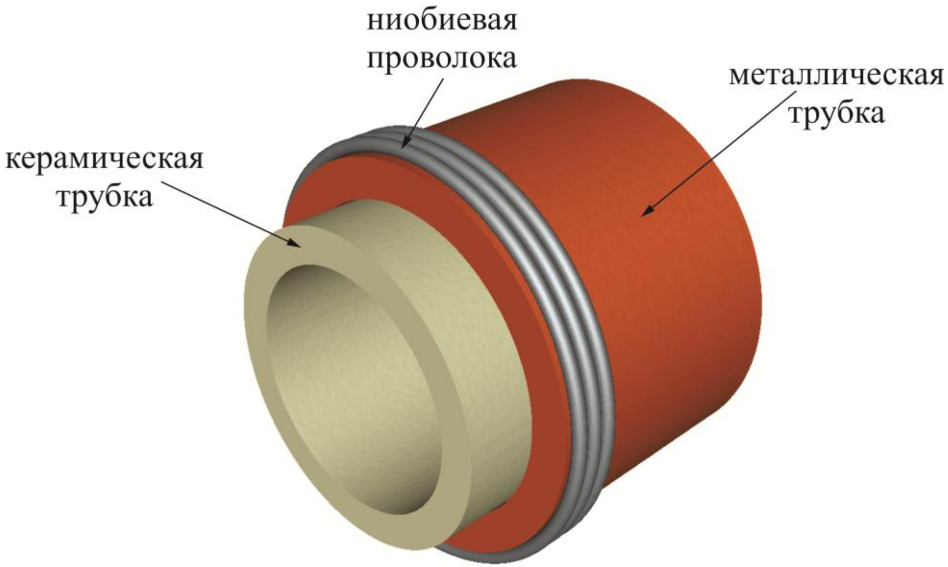


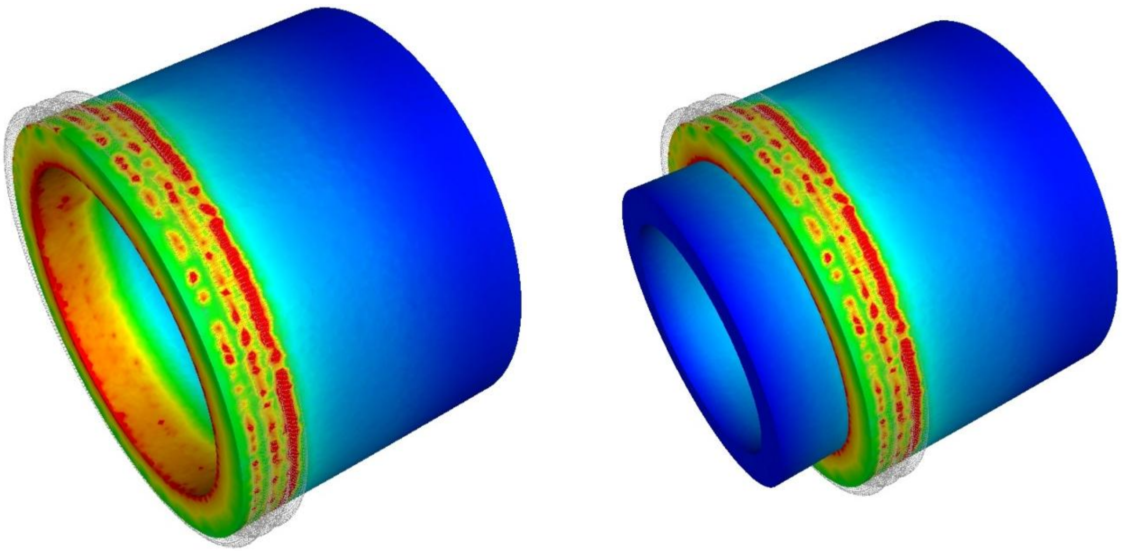


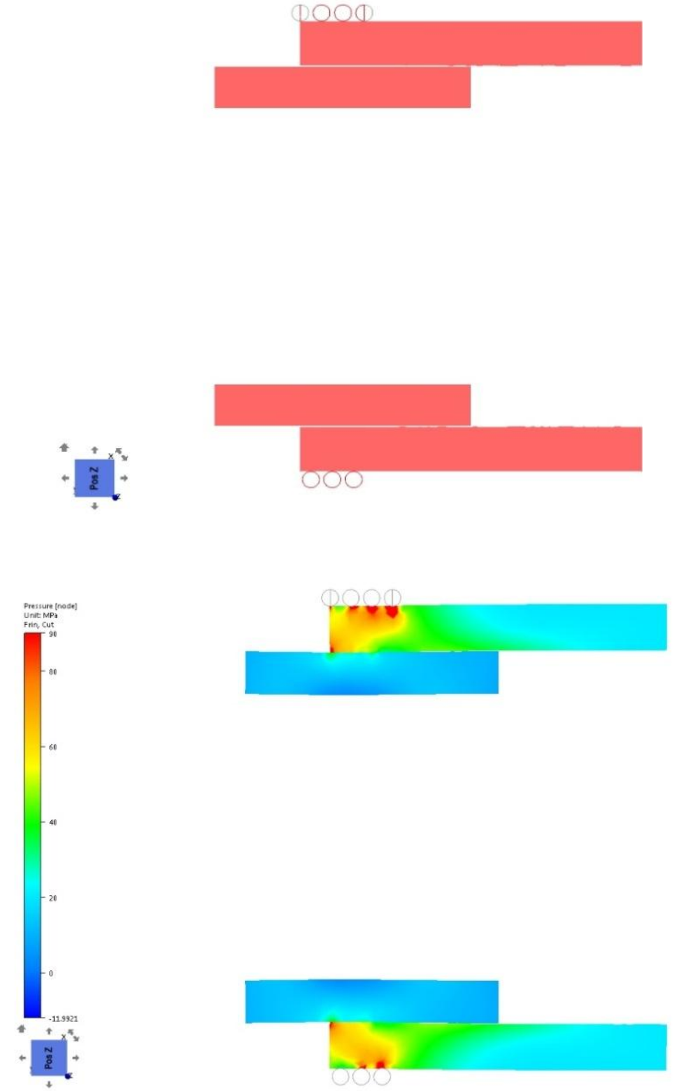


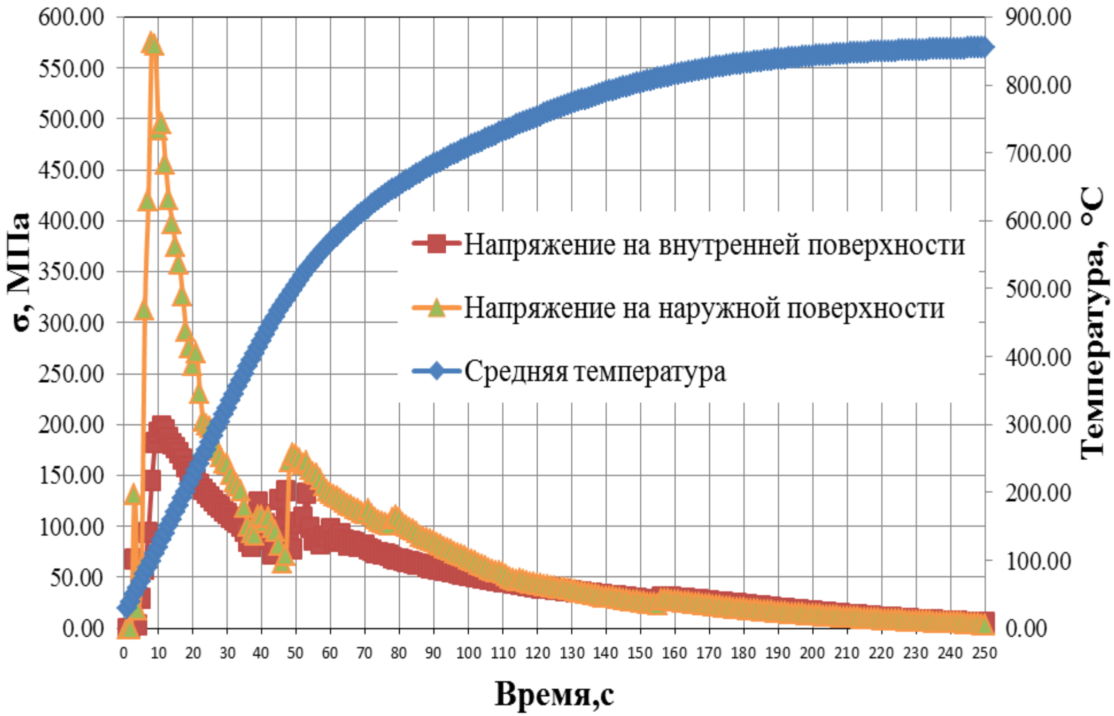


Bakeout temperature - 134 ^{0}C

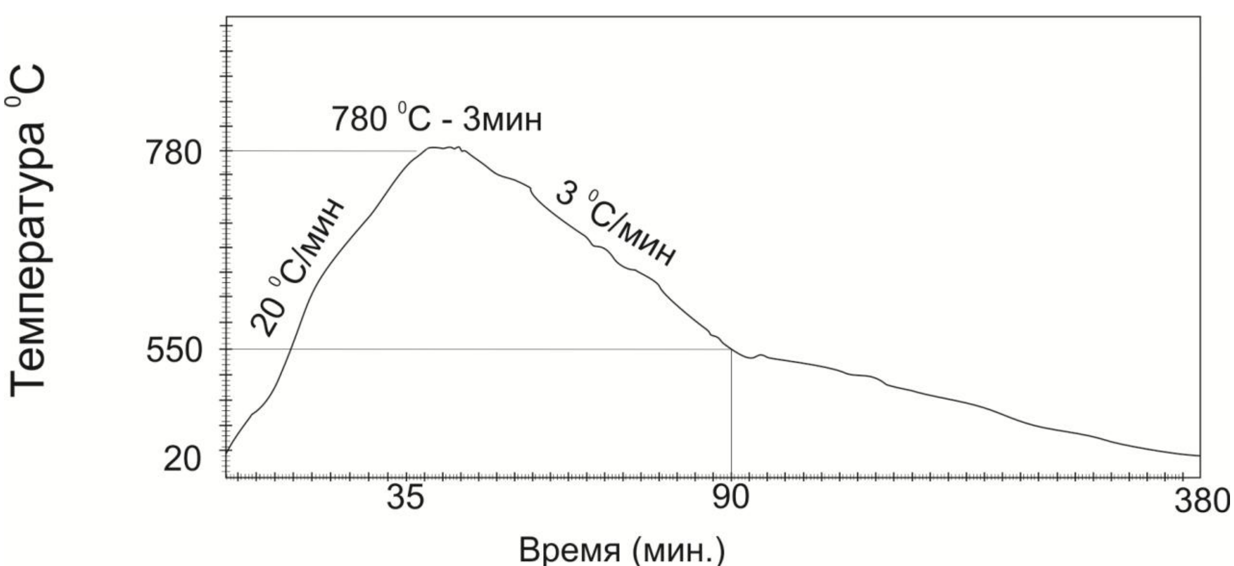

ниобиевая
проволока
металлическая
трубка
керамическая
трубка







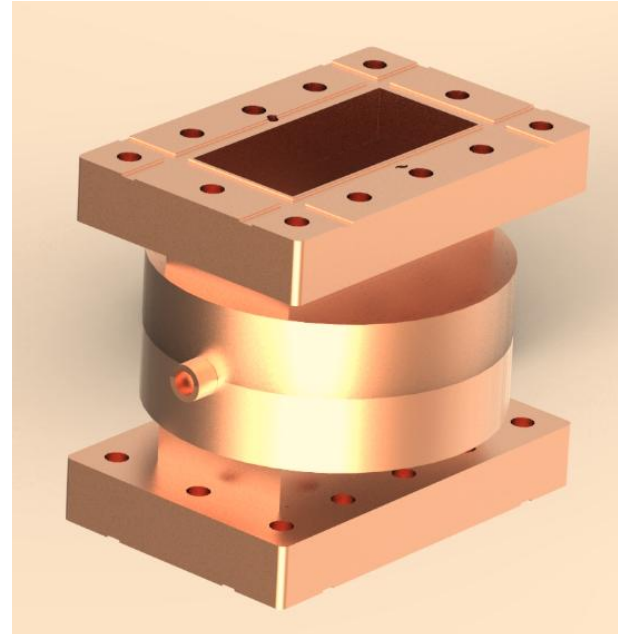
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
σ, МПа
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Температура, °C
Напряжение на внутренней поверхности
Напряжение на наружной поверхности
Средняя температура
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
Время,с

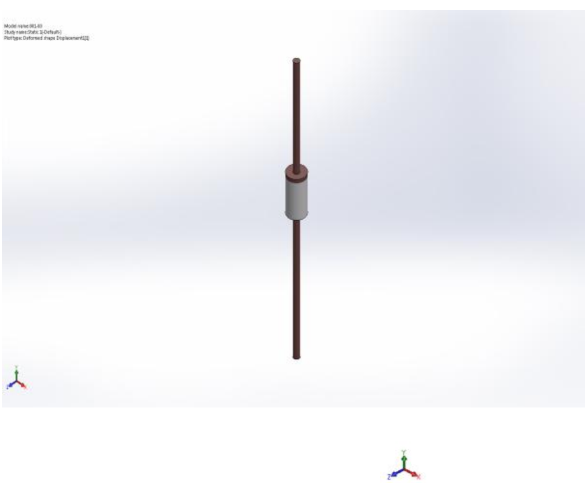


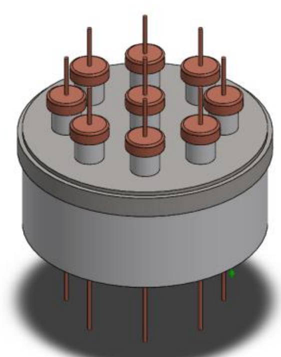
Температура °C
780
550
20
780 °C - 3мин
20 °C/мин
3 °C/мин
35
90
380
Время (мин.)

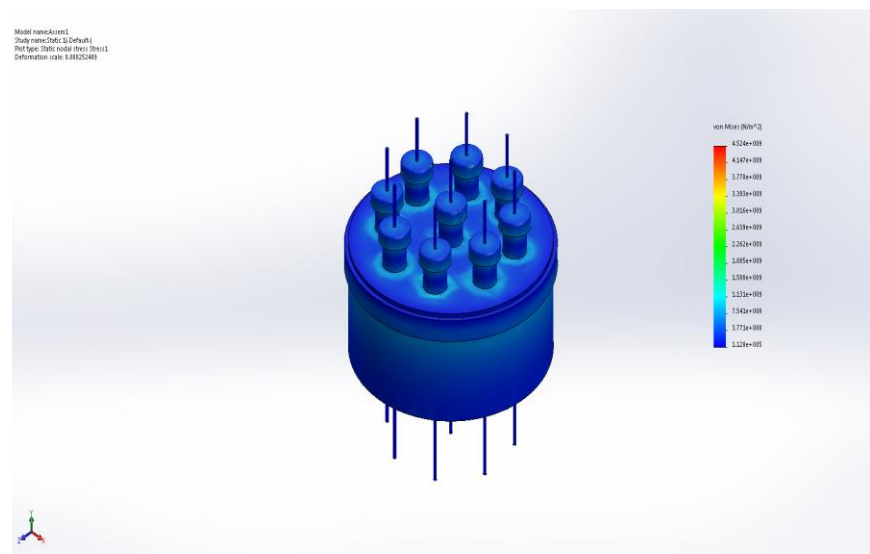
Ceramic/metal Joints in Accelerator Technology

1. Insulators,
2. Feedthroughs,
3. Chambers,
4. Kicker magnet chamber,
5. Beam line windows,
6. RF windows,









Conclusions

- Materials and existing technologies for vacuum tight metal/ceramic junctions were reviewed,
- Materials for vacuum tight ceramic joints were selected,
- Alumina ceramics were metallized,
- Alumina ceramic with stainless steel and copper were brazed,
- New brazing methods for vacuum tight ceramic/metal joints were developed,
- Ceramic/metal joints based FEA method were simulated,

Publications

- V.V. Vardanyan, BRAZING TECHNOLOGIES OF CERAMIC TO METALS FOR UHV SYSTEMS OF CHARGED PARTICLE ACCELERATORS, MECHANICAL ENGINEERING AND METALLURGY, Yerevan, 2017, Under process
- В.В. Варданян, В.Ш. Авагян, В.А. Даниелян, В.С. Дехтярев, Т.А. Мкртчян, А.С. Симонян, ‘’ Новий метод соединения керамики с металлом’’, МАШИНОСТРОЕНИЕ И МЕТАЛЛУРГИЯ, УДК 655.344.022.72., Engineering Academy of Armenia, Volume 13, Number 4, Yerevan 2016, с 446 - 451
- V.V. Vardanyan, V. Sh. Avagyan,''ADVANCED METAL-CERAMIC BONDING TECHNOLOGIES FOR PARTICLE ACCELERATORS'', ISBN 978-9939-1-0238-2, УДК 544:06, ББК 24.5, Book of Abstracts, IV International Conference. “CURRENT PROBLEMS OF CHEMICAL PHYSICS”, 5-9 October 2015, Yerevan, Armenia, P. 208-209.
- V. Vardanyan, V. Avagyan,''Investigation and design of metal to ceramic bonding technologies for particle accelerator's vacuum RF window'', International Conference ''ADVANCED MATERIALS AND TECHNOLOGIES'' 21-23 October, Tbilisi, Georgia, Dedicated to the 70th anniversary of foundation of Ilia Vekua Sukhumi Institute of Physics and Technology, P. 230 – 235.
- V.V. Vardanyan, V.Sh. Avagyan, “COMPEARING OF METAL-CERAMIC BONDING METHODS FOR ULTRA HIGH VACUUM”, ISSN 1829-0043, PROCEEDINGS OF ENGINEERING ACADEMY OF ARMENIA (PEAA). 2015, V.12,N.1, Yerevan, Armenia, P 192-195,
- V. Avagyan, A. Gevorgyan, V. Vardanyan et.al, “Precise cooling system for elektro-magnetic equipment” Proceedings of engineering Academy of Armenia, volume 10, N 3, 2013, pp.537-541.

- V. Vardanyan, G. Amatuni, V. Avagyan, B. Grigoryan, et al., “Distributed Cooling System for the AREAL Test Facility” Proceedings of IPAC2014, pp., 4010-4012, Dresden, Germany 2014.
- V. Vardanyan, V. Avagyan, A. Gevorgyan, T. Mkrtchyan, et al., “Cooling Systems for Advanced Vacuum Electron Sources”Proceedings of IVESCICEE-2014, Saint-Petersburg, Russia, June 30-July04, 2014, ISBN 978-1-4799-5770-5, p 260-261.

- Vardan Shavarsh Avagyan, Vahagn Vanik Vardanyan, ’’Diffusion brazing methods of difficult geometry dissimilar detail’’, Patent, Intellectual Property Agency of Armenia, AM201453 , N 2883 A, 2014.

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- Mechanical Workshop Staff – Gevorg Sargsyan, Aramayis Aleksanyan, Norayr Sargsyan, Avetis Simonayn

Thank You for Your Attention