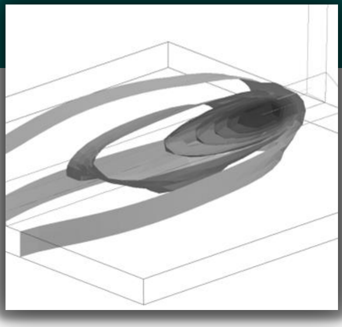
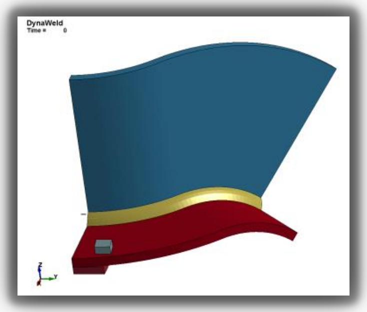




*BOUNDARY_THERMAL_WELD_TRAJECTORY

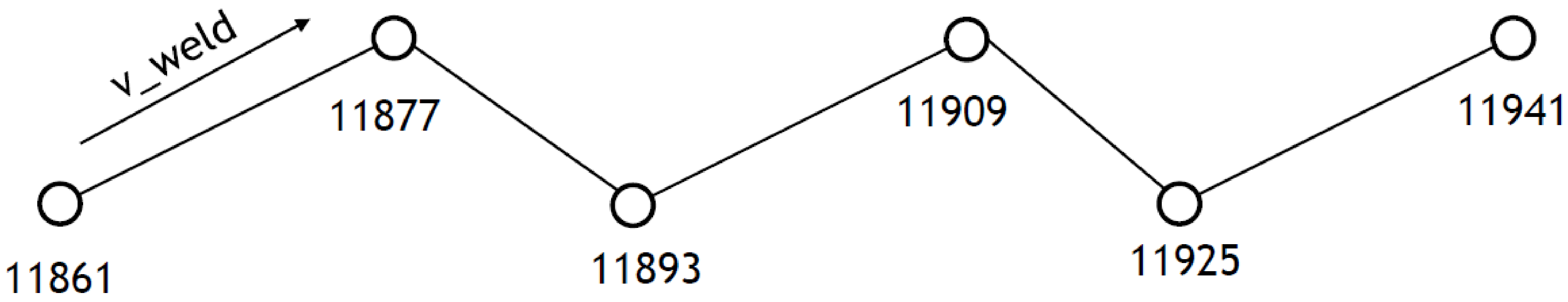
Dr.-Ing. Thomas Klöppel

DYNAmore GmbH

A new heat source - Approach

- Move the heat source movement to a new keyword.
- The heat source follows a prescribed velocity along a node path (*SET_NODE)
- The weldpath is continuously updated
- No need to include the mechanical solver

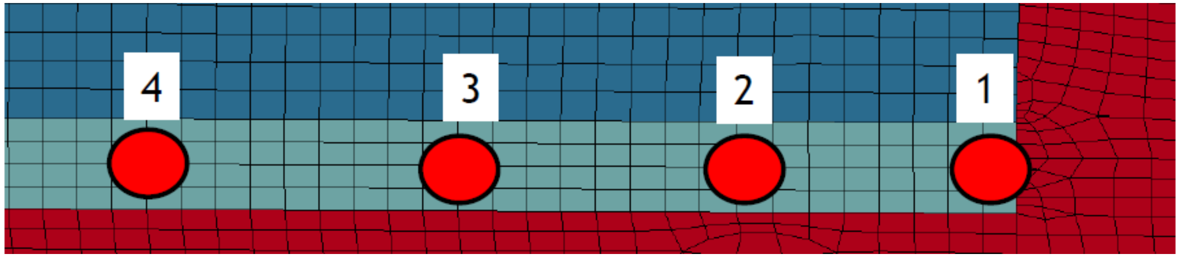
```
*SET_NODE_LIST
1
11861,11877,11893,11909,11925,11941
```



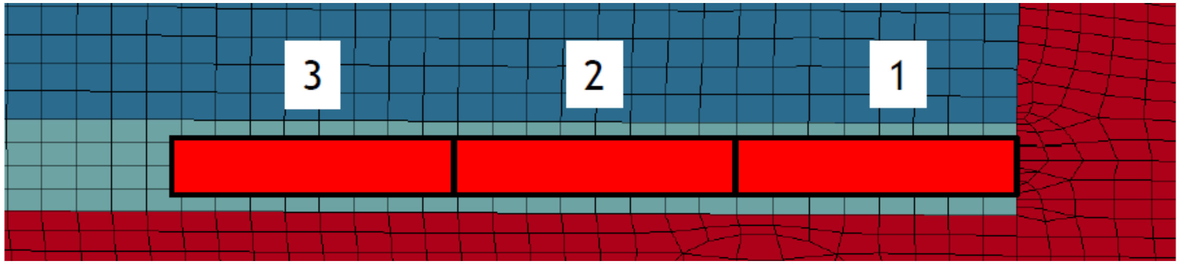
A new heat source - Approach

- Move the heat source movement to new keyword.
- The heat source follows a prescribed velocity along a nodepath
- The weldpath is continuously updated
- No need to include the mechanical solver
- Use “sub-timestep” for integration of heat source

Weld source evaluated at thermal timesteps



Weld source integrated between thermal time steps



*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- NSID1: Node set ID defining the trajectory
- VEL1: Velocity of weld source on trajectory
  - LT.0: |VEL1| is load curve ID for velocity vs. time
- SID2: Second set ID for weld beam direction
  - GT.0: S2ID is node set ID, beam is aimed from these reference nodes to trajectory
  - EQ.0: beam aiming direction is (Tx, Ty, Tz)
  - LT.0: SID2 is segment set ID, weld source is orthogonal to the segments
- VEL2: Velocity of reference point for SID2.GT.0
- NCYC: number of sub-cycling steps

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- IFORM: Geometry for energy rate density distribution
  - EQ.1. Goldak-type heat source
  - EQ.2. double ellipsoidal heata source with constant density
  - EQ.3. double conical heat source with constant density
  - EQ.4. conical heat source

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
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Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- LCID: Load curve ID for weld energy input rate vs. time
  - EQ.0: use constant multiplier value Q
- Q: Curve multiplier for weld energy input
  - LT.0: use absolute value and accurate integration of heat
- DISC: Resolution for accurate integration. Edge length for cubic integration cells
  - Default: 0.05*(weld source depth)

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
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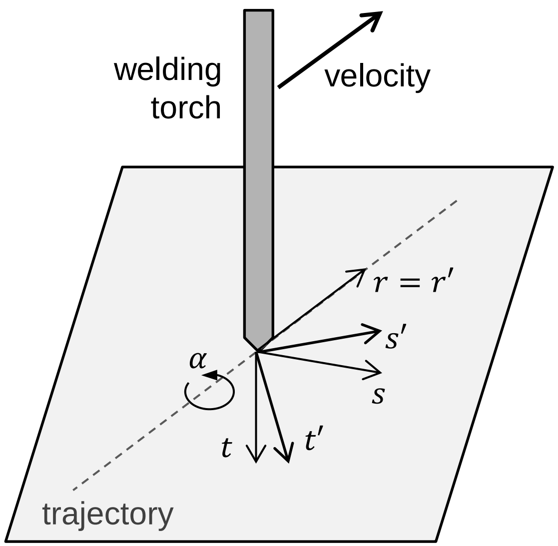
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

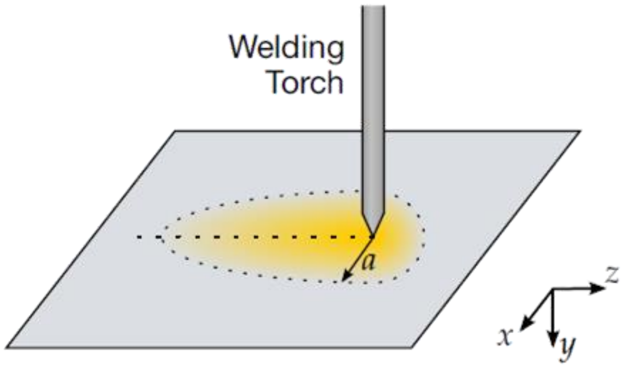
- LCROT: load curve defining the rotation (α in degree) of weld source around the trajectory as function of time.
- LCMOV: load curve for offset of weld source in depth (t') after rotation as funtion of time
- LCLAT: load curve for lateral offset (s') after rotation as function of time

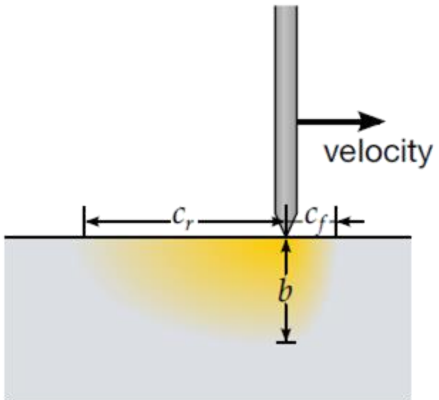


*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- For IFORM=1
  - P1: a
  - P2: b
  - P3: c_f
  - P4: c_r
  - P5: F_f
  - P6: F_r
  - P7: n



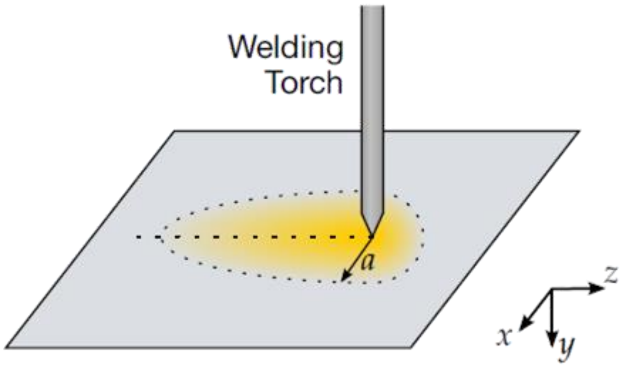


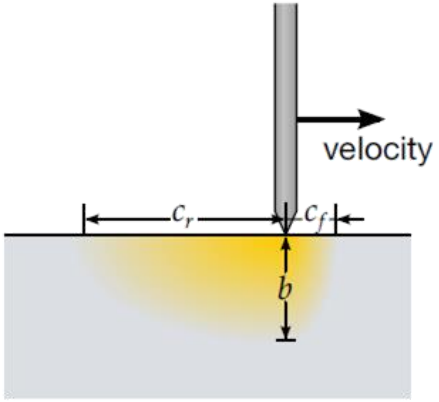
$$q = \frac{2n\sqrt{n}FQ}{\pi\sqrt{\pi}abc} \exp\left(\frac{-nx^2}{a^2}\right) \exp\left(\frac{-ny^2}{b^2}\right) \exp\left(\frac{-nz^2}{c^2}\right)$$

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- For IFORM=2
  - P1: a
  - P2: b
  - P3: c_f
  - P4: c_r
  - P5: F_f
  - P6: F_r



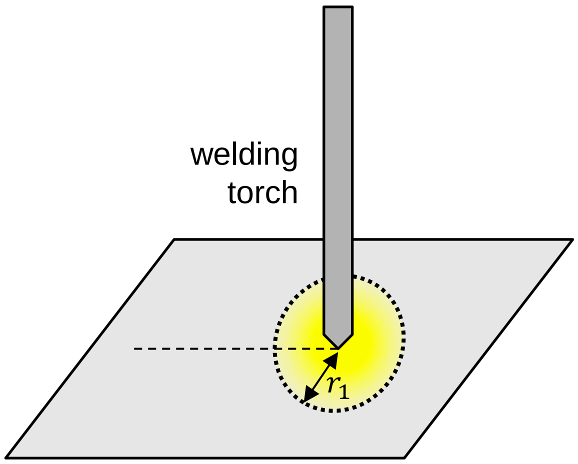


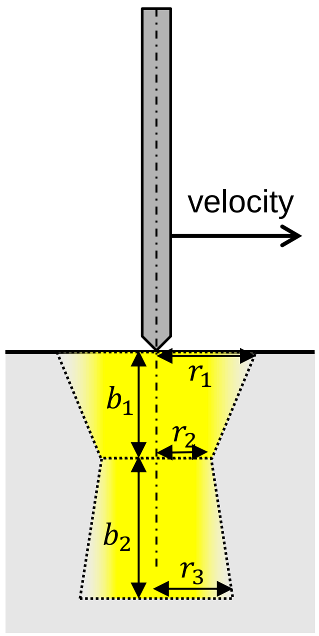
$$q = \frac{3F}{2\pi abc}$$

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- For IFORM=3
  - P1: r_1
  - P2: r_2
  - P3: r_3
  - P4: b_1
  - P5: b_2
  - P6: F_1
  - P7: F_2



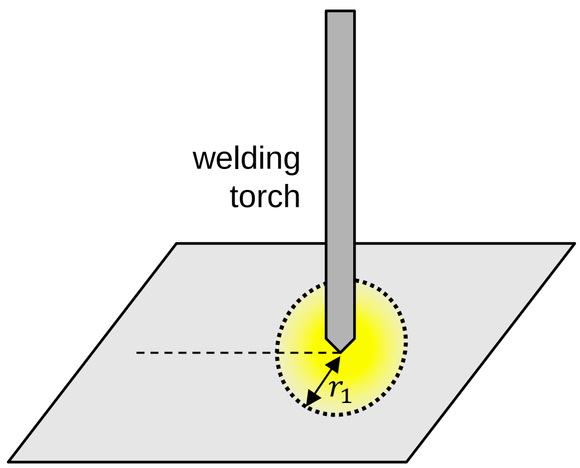


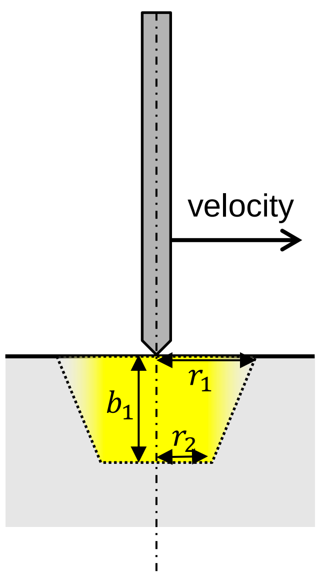
$$q = \frac{3F}{2\pi b(R^2 + r^2 + Rr)}$$

*BOUNDARY_THERMAL_WELD_TRAJECTORY

	1	2	3	4	5	6	7	8
Card 1	PID	PTYP	NSID1	VEL1	SID2	VEL2	NCYC	
Card 2	IFORM	LCID	Q	LCROT	LCMOV	LCLAT	DISC	
Card 3	P1	P2	P3	P4	P5	P6	P7	P8
Opt.	Tx	Ty	Tz					

- For IFORM=4
  - P1: r_1
  - P2: r_2
  - P3: b_1

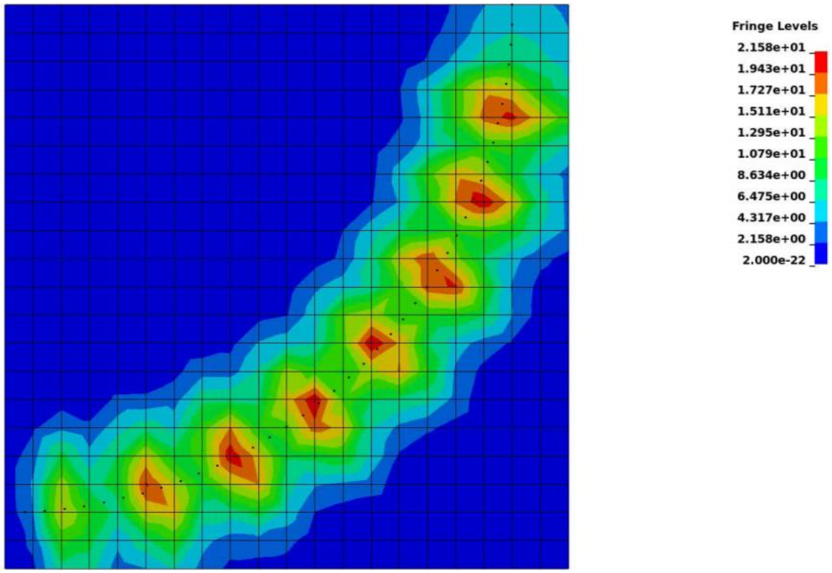




$$q = \frac{3}{\pi b(R^2 + r^2 + Rr)}$$

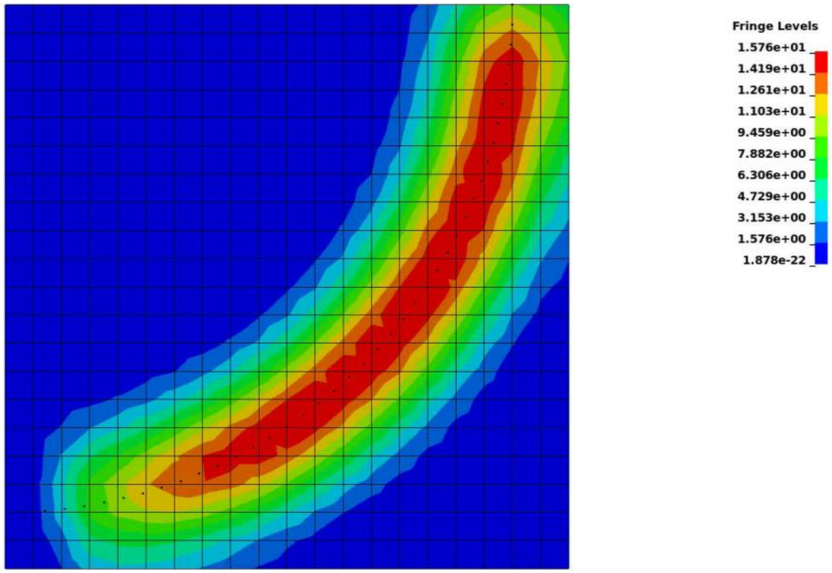
Example

- Welding on a circular trajectory
  - Thermal-only analysis with a large time step



temperature field, NCYC = 1

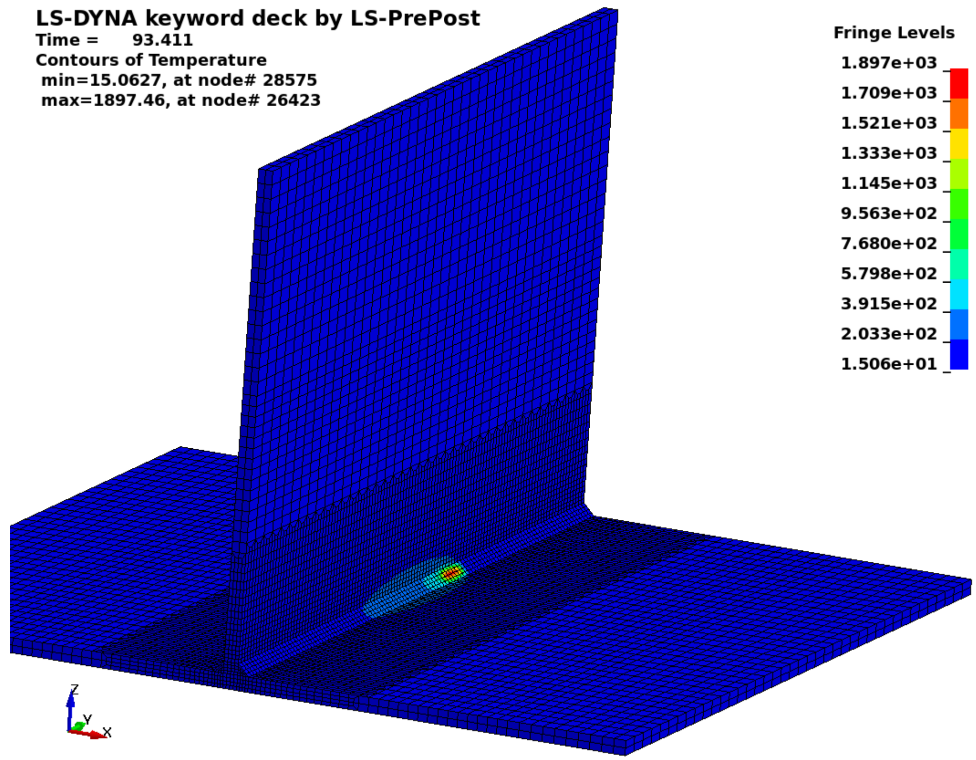
temperature field, NCYC = 10



Example

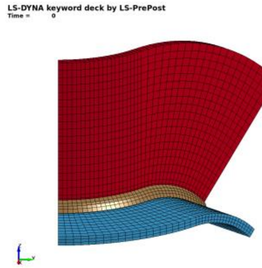
- Three-dimensional T-Joint
  - Thermal-only analysis with different values of NSUB
  - Testing DISC = 0.2175 (default) and DISC = 0.5, the difference in energy input and developing temperature field are insignificant.
- Simulation times:

NSUB	DISC=0.2175	DISC=0.5
1	20:17	12:47
2	21:02	10:43
3	23:58	08:47
4	39:23	11:28

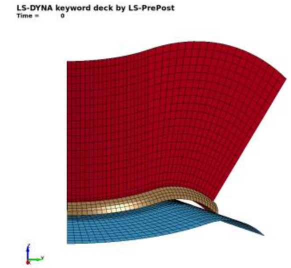


Example

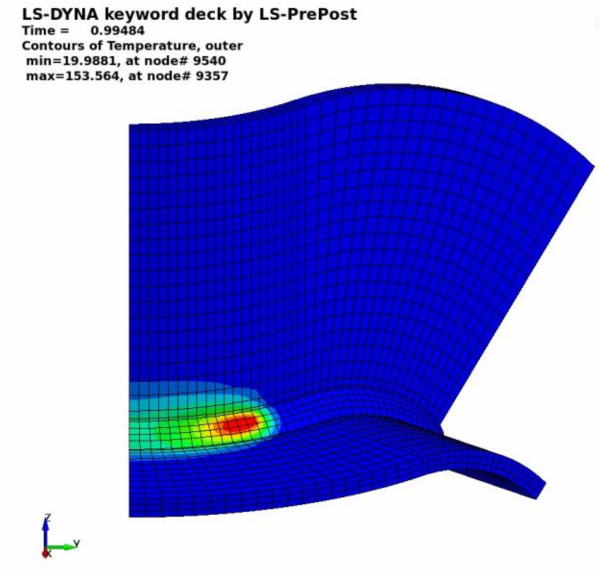
- New Keyword is also applicable to thermal thick shells
- Three-dimensional curved T-Joint, thermal-only analysis



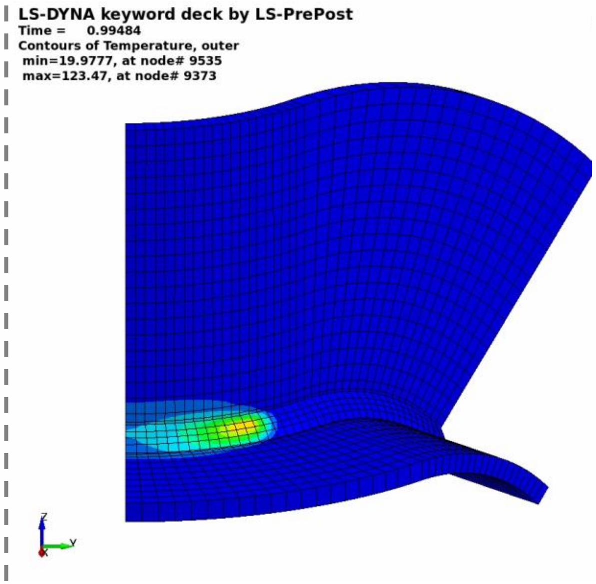
Solids



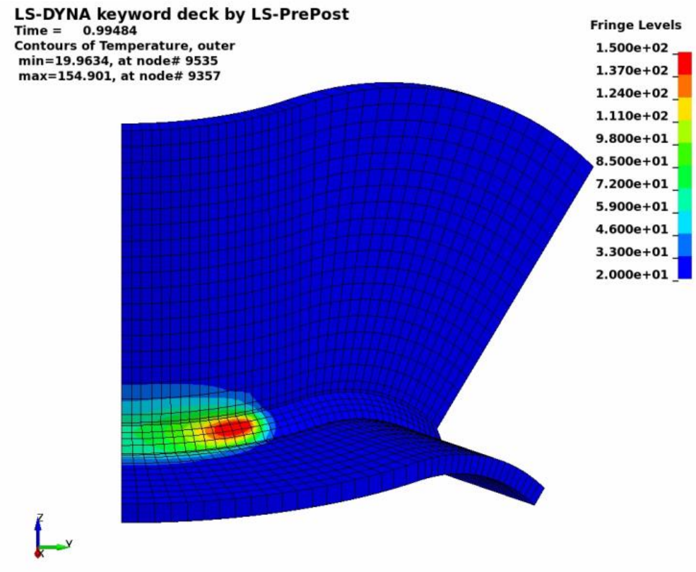
Solids and shells



BC on all solids



BC on solids only



BC on solids and shells