LCWS12

Seamless ILC Cavity Fabrication: Forming Process Development by Numerical Simulation

Presented by **John Buttles**

jbuttles@baileytool.com

Yuyuan Wang, Woong Ho Bang, Steve Ingersoll, John Buttles

Bailey Tool & Mfg.

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General Outline

1. ***Bailey Tool (BTM) Introduction***
2. ***Discussion***
3. ***BTM forming process***
4. ***Spin-necking FEA models***
5. ***Spin-necking as metal forming challenge***
6. ***FEA results: spin-necking & hydroforming***
7. ***Conclusions and work in progress***

1. Bailey Tool (BTM) Introduction

1. **BTM is a product development company in the Dallas area with roots in automotive metalforming manufacturing.**

2. **We began our HEP work by providing a machine and process proposal to FNAL in March of 2011 for ILC 9-cell seamless cavity production.**

3. **We have advanced our work in HEP through cavity production, magnet structure and superconductor work for local research institutions such as UTA and TAMU.**

4. **We continue to support SRF accelerator structure and detector in collaboration with University and National Lab customers.**

2. Discussion
— Fabrication Methods

1. Current: 9-cell ILC cavities are produced by press forming half-cells + electron beam (EB) welding — costly, weld defects.

2. A seamless multi-cell cavity reduces welding dramatically, decreasing cost and improving quality. A holy grail for high volume LINAC projects — producing seamless cavity tubes??

3. The current baseline seamless production method for the ILC cavity: established by W. Singer at DESY: swaging preform + hydroforming from seamless tube.

4. BTM has independently developed a spin-necking and hydroform process for optimal ILC seamless cavity fabrication. Thinning is reduced in this process which may reduce defects in the finished cavity.

3. ILC 9-cell BTM Forming Process

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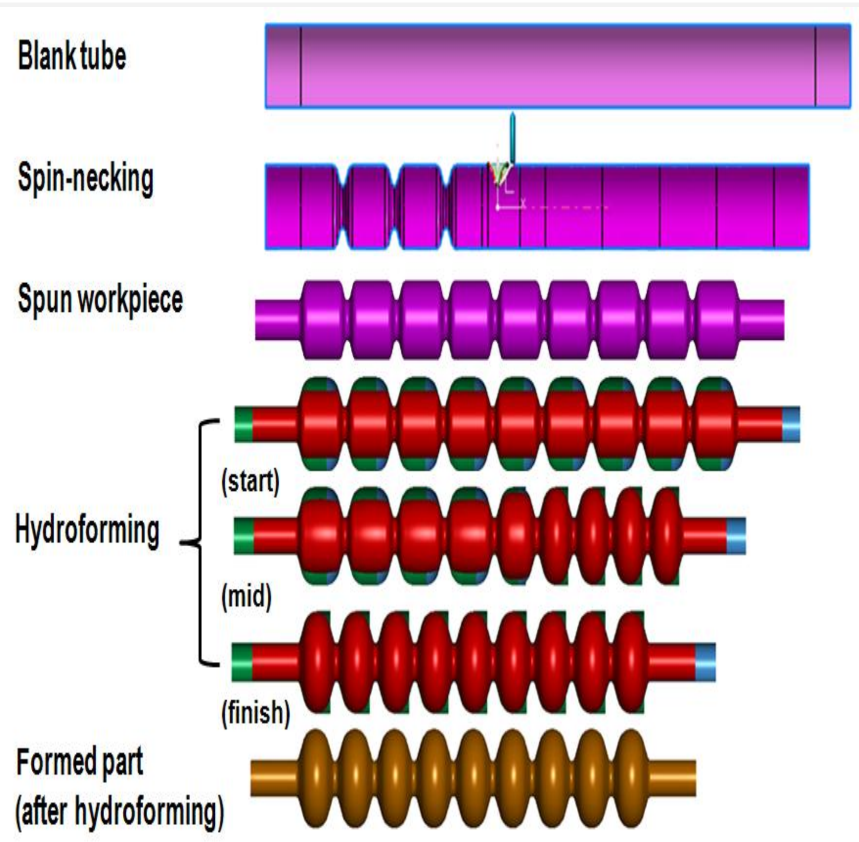

SRF Cavity: ILC 9-cell

Process: high-volume production

Blank: seamless tube (~Dia.150mm)

⇩

Spin-necking (preform)

⇩

Tube hydroforming (expansion)

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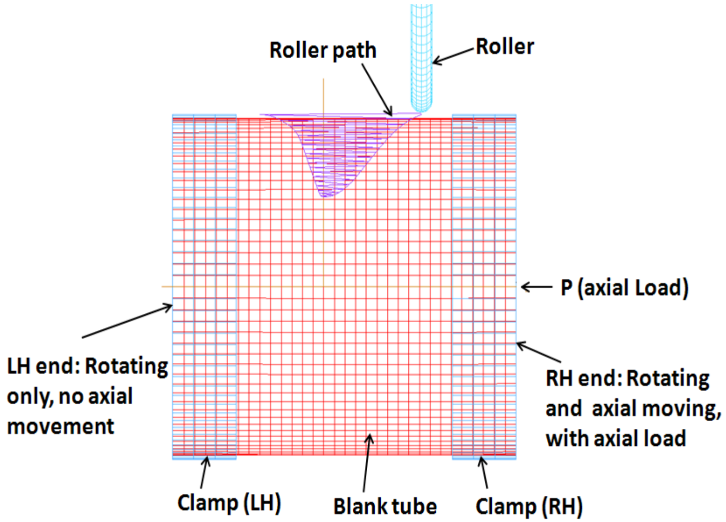
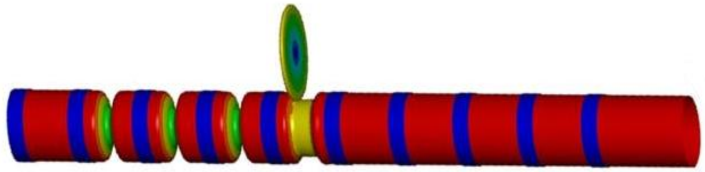
[**Calibration** (hydroforming 2)]

Challenges: complicated spin-necking FEA process modeling.

4. Spin-necking FEA Modeling



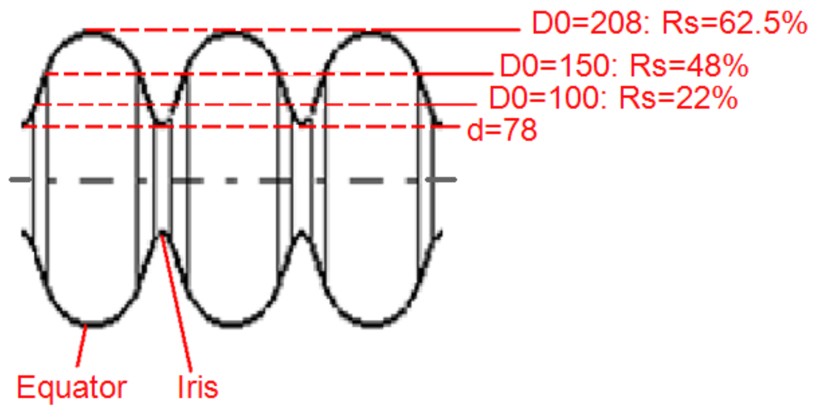
a. Spin-necking model—for one full cell



b. Spin-necking model—for nine-cells

Blank tube: t0 = 3.0mm; D0: 150, 100 & 208mm.
Axial load P: varied as required
Element: shell, & solid
Feeding rate and scale times: iterative
Mandrel: none for full cell; simple for end cell
Material: Cu, Nb; elasto-plastic material model
Part designs: full cell, end cell & nine cell
Roller geometry: varied diameter & section shapes
Roller path: varied feeding & forming force, depending on feed rate, roller geometry & workpiece profile
Rotating method: various methods – tube stationary, tube rotating
Other conditions and parameters: boundary condition, contacts, control parameters, friction, etc.
Software employed: LS-Dyna, Dynaform

5. Spin-necking Forming Challenge



Question: what starting tube OD is optimal from material forming standpoint ?

- **100mm tube OD** -- beneficial due to low 22% reduction but hydroforming from this size results in excessive tube expansion
- **208mm tube OD** -- utilizes 63% reduction which is severe from a material forming standpoint
- **150mm tube OD** -- 48% reduction – good balance for the forming process

SOLUTION: BTM spin-necking process and tooling geometry mitigates problems associated with severe deformation. U.S. Patent application 13652871 applied for.

6.1 FEA Results: BTM Spin-necking

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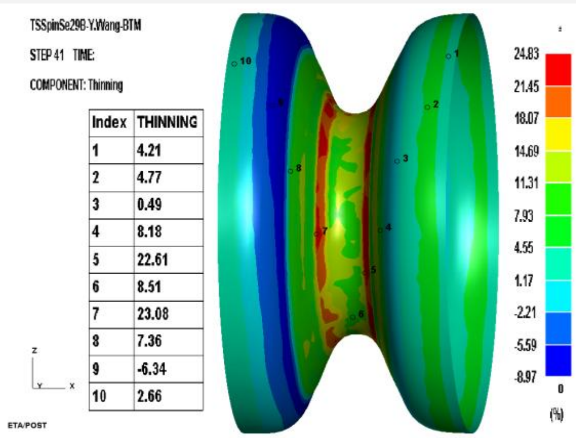
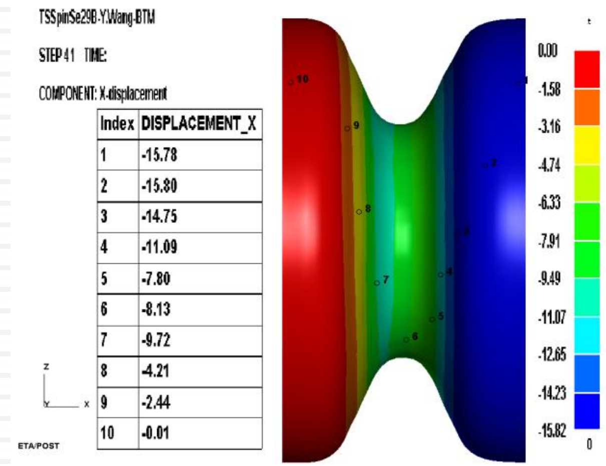
D0=150mm, BTM Spin-necking & the Rollers (rollers not shown)



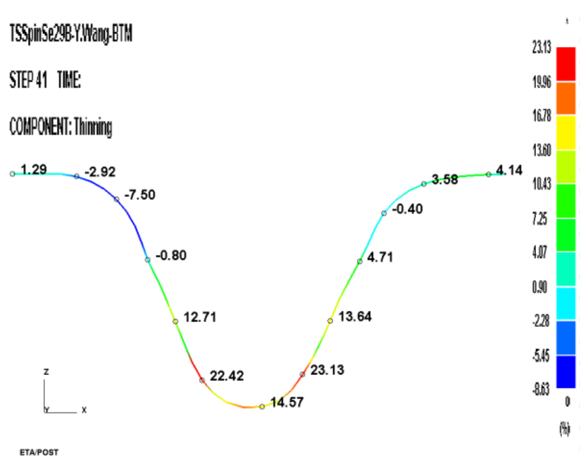
Index	THINNING
1	4.21
2	4.77
3	0.49
4	8.18
5	22.61
6	8.51
7	23.08
8	7.36
9	-6.34
10	2.66

a. Thinning (thickness reduction): Max 24.8%

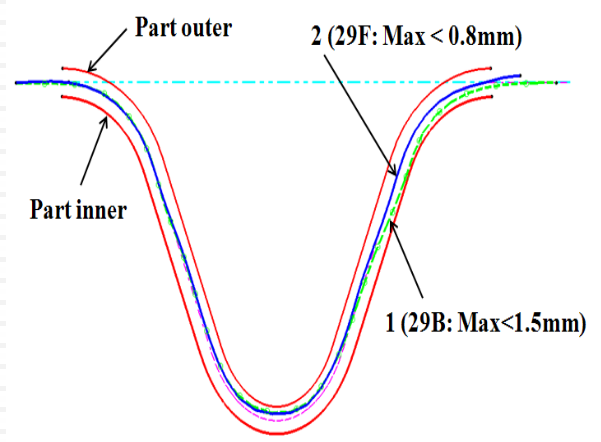


Index	DISPLACEMENT_X
1	-15.78
2	-15.80
3	-14.75
4	-11.09
5	-7.80
6	-8.13
7	-9.72
8	-4.21
9	-2.44
10	-0.01

c. Axial X displacement (Max=15.8mm)



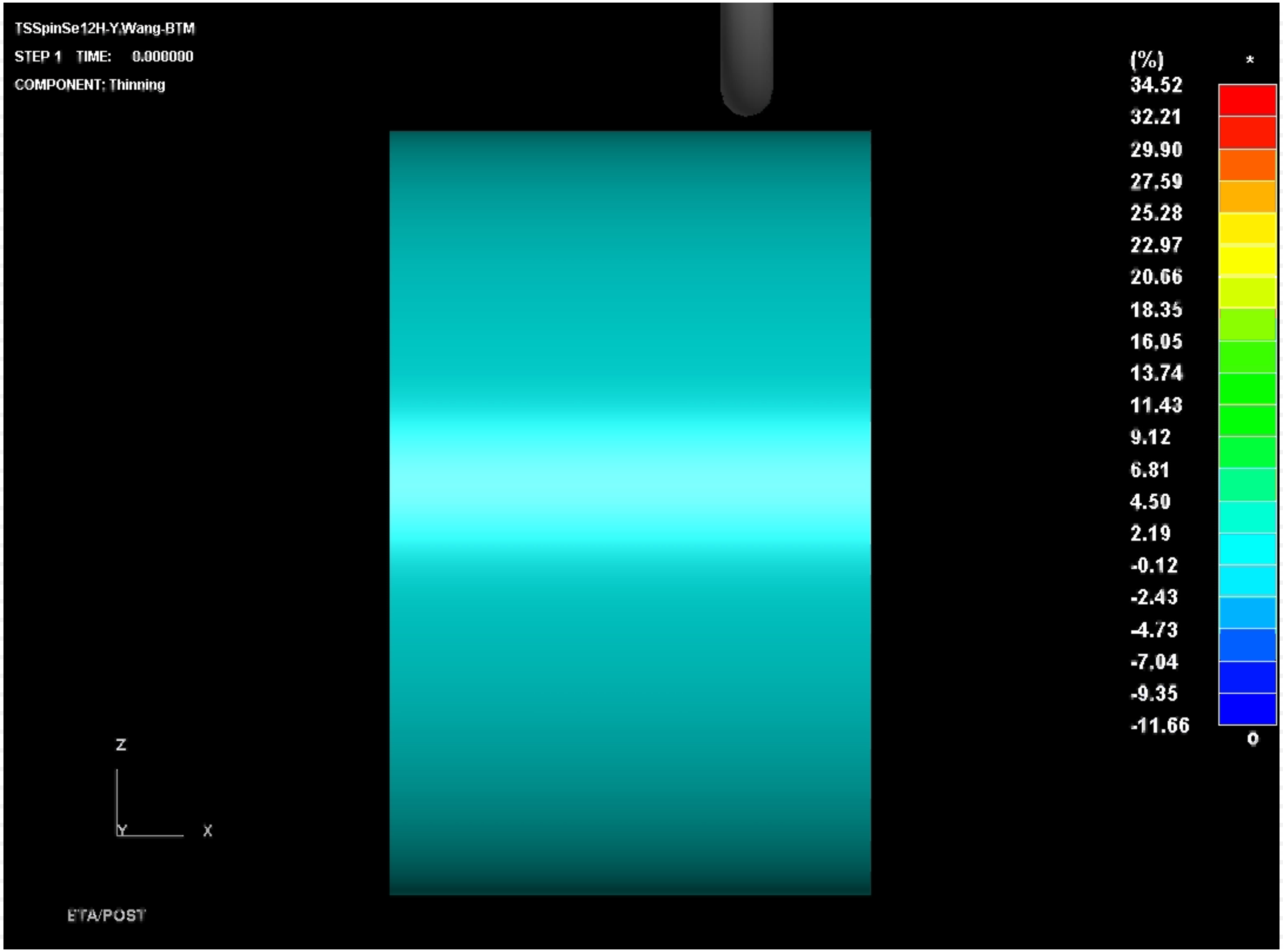
b. Thinning (thickness reduction) on spun section



d. Spun profiles (Curve 2: Max <0.8mm)

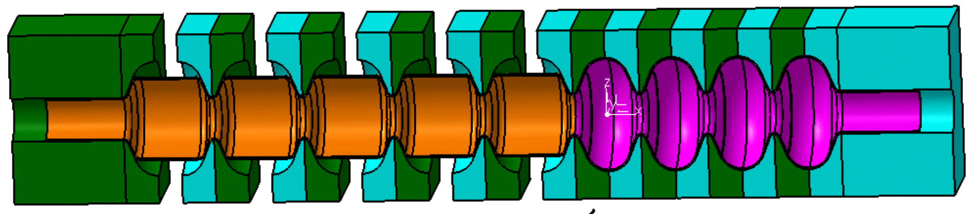
6.2 FEA Results: Spin-necking Avi.

D0 = 150mm, Spin-necking using Conventional Simple Roller

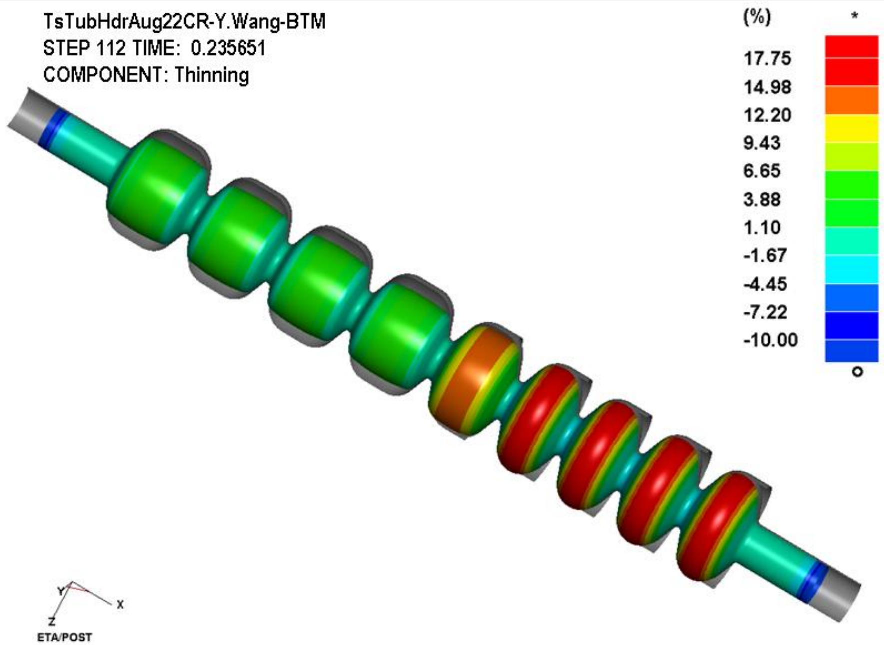


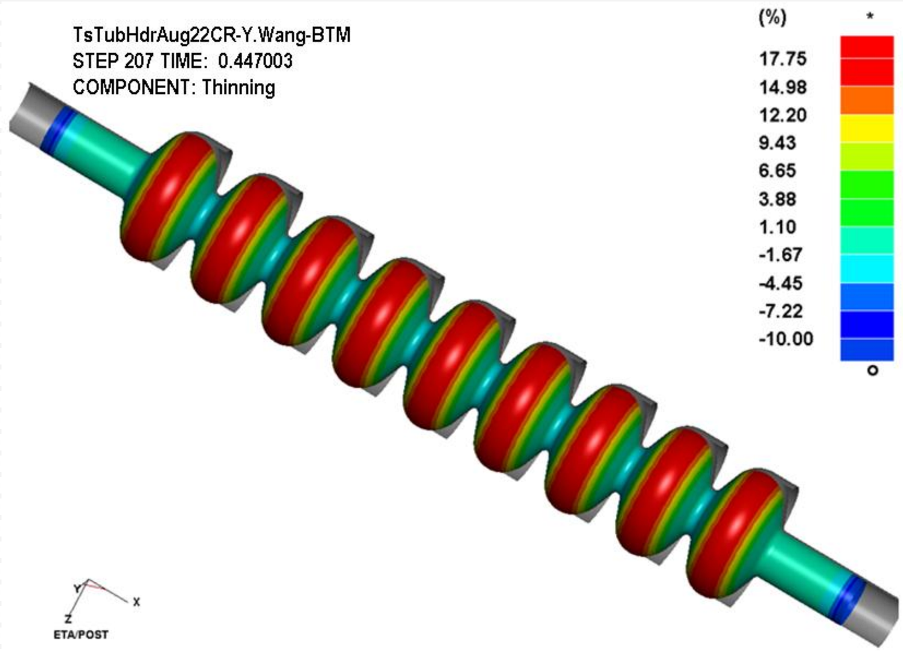
6.3 FEA Results: Hydroforming

t0 = 3.0mm, Zero Stress-strain in Blank



Hydroforming die cavities

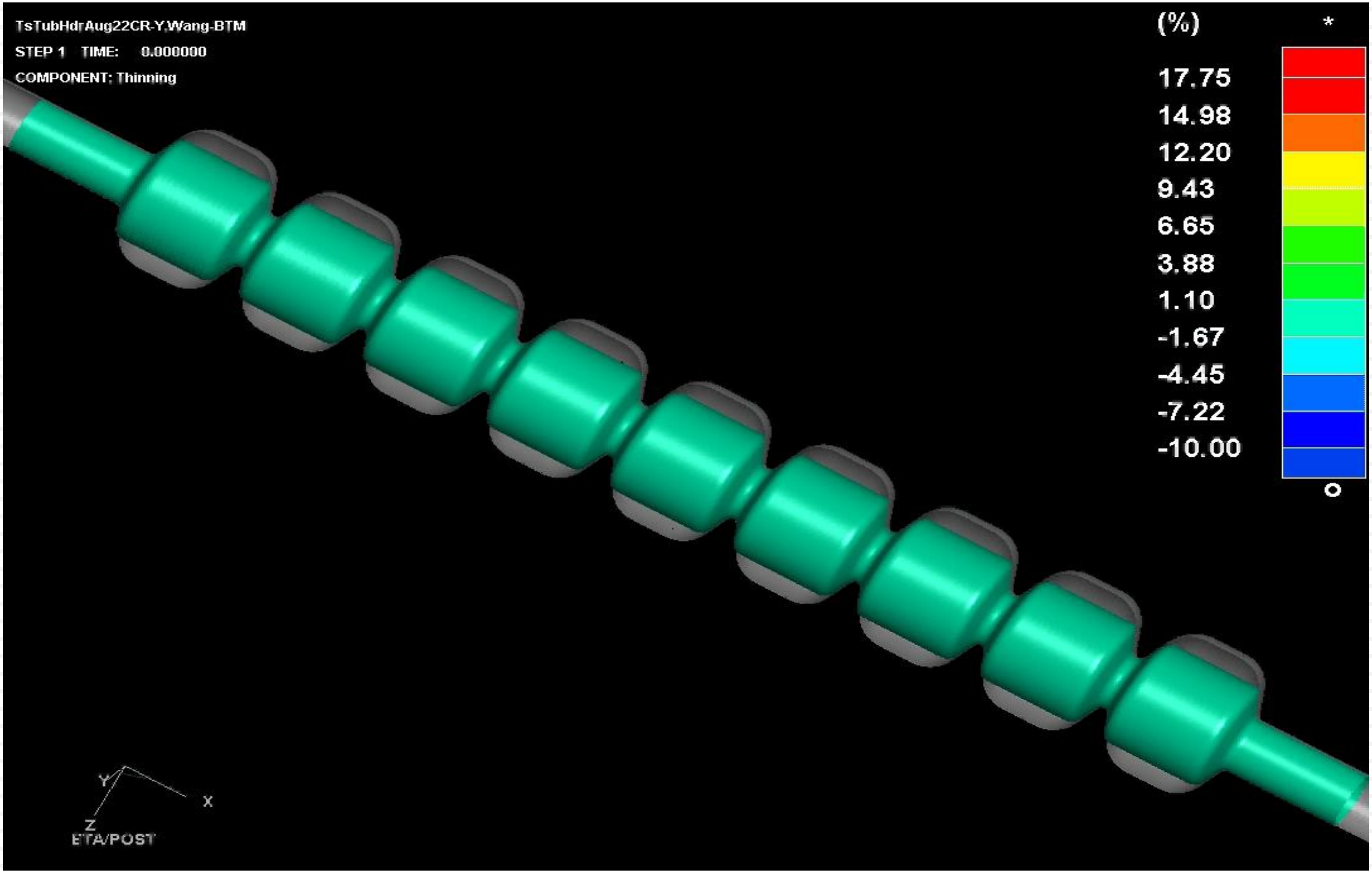




Thinning (thickness reduction) in hydroforming

6.4 FEA Results: Hydroforming Avi.

t0 = 3.0mm, Zero Stress-strain in Blank



7. Conclusions & Work in Progress

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BTM conducted FEA modeling of spin-necking in excess of 4,000 hrs CPU time; solved complex modeling problems and achieved goals of balanced forming with reduced process thinning.

1. **Spin-necking + hydroform (2 ops) is viable production method at BTM.**
2. **BTM spin-necking offers novel tooling innovation.**
3. **BTM can offer this process to HEP industry.**

Work in progress:

1. **2011 DOE SBIR – "recommended for funding" – resubmitted in 2012.**
2. **Correlate FEA with physical spin-necking prototyping – in process.**
3. **Prototype 3-cell cavity for SRF application – in process now.**
4. **Identify customer on Niobium cell fabrication – coordinating this now.**
5. **Further advancement in optimizing material thinning – see slide attached.**

Thank you for your attention!

Questions please….

We are available during this conference to discuss applications regarding this process.