Review of Cavity *Load Cases* and relevant analysis

L. Dassa and C. Zanoni feat. N. Kuder

08/02/2016

ENGINEERING
DEPARTMENT

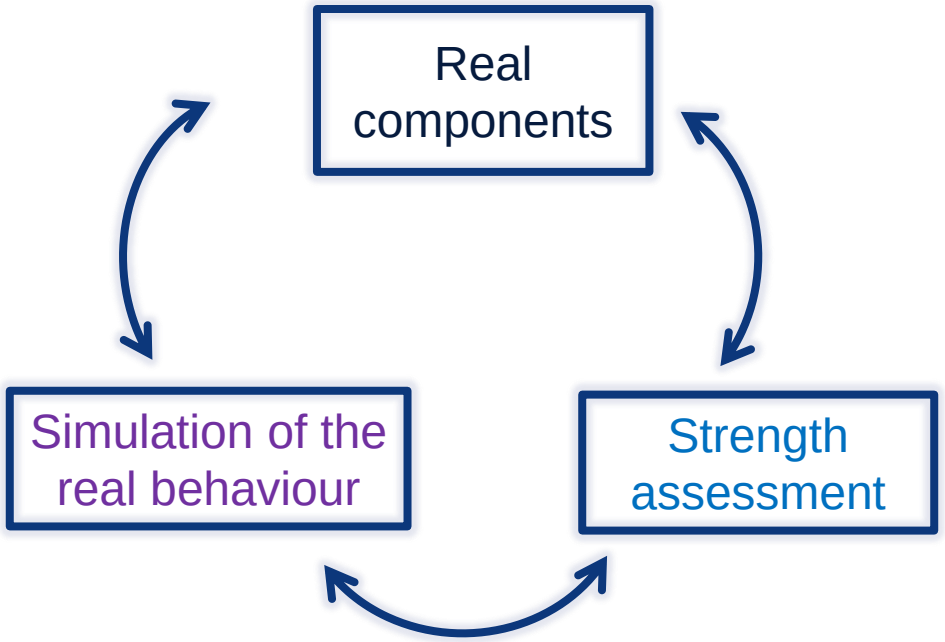
Lifecycle

Cavity production
- forming process
- plastic tuning (not confirmed)

Cavity assembly with He tank
- welding process

Cavity operation

Loads:
- Pressure
- Weight
- ΔT during cool-down
- T ≠ 300 K → differential contraction
- Coarse tuning displacement
- Fine tuning displacement



Cavity production

- forming process

FEM

- FEA on forming → explicit analysis → evaluate shape after forming, spring-back, residual ductility, plastic strain
- FEA → non linear, implicit or explicit → evaluate shape after tuning, plastic strain

- plastic tuning (TBC)

Cavity assembly with He tank

- welding process with He tank

FEM

- FEA → plastic model → evaluate the behaviour of the cavity, plasticized areas, stress distribution, simulation of the entire cycle?

Cavity operation

FEM

- Guidelines can be extracted from standards
- Linear or non-linear model are acceptable
- Validate the design

Tuning

• Preliminary coarse plastic tuning (TBC)	• could be considered as the last step of the forming process
• Coarse elastic tuning	• Applied with all the other operational loads → guidelines from standard are acceptable
• Coarse additional plastic tuning	• Applied with all the other operational loads → guidelines from standard are acceptable
• Fine tuning	• Applied with all the other operational loads → guidelines from standard are acceptable

Dressed cavity strength assessment according to EN 13445 (stress categories)

Which loads?
Which geometry?
Which material properties?
History of material processing during forming and assembling?

Remember that it is not possible to simulate everything!!!

We need some assumptions.

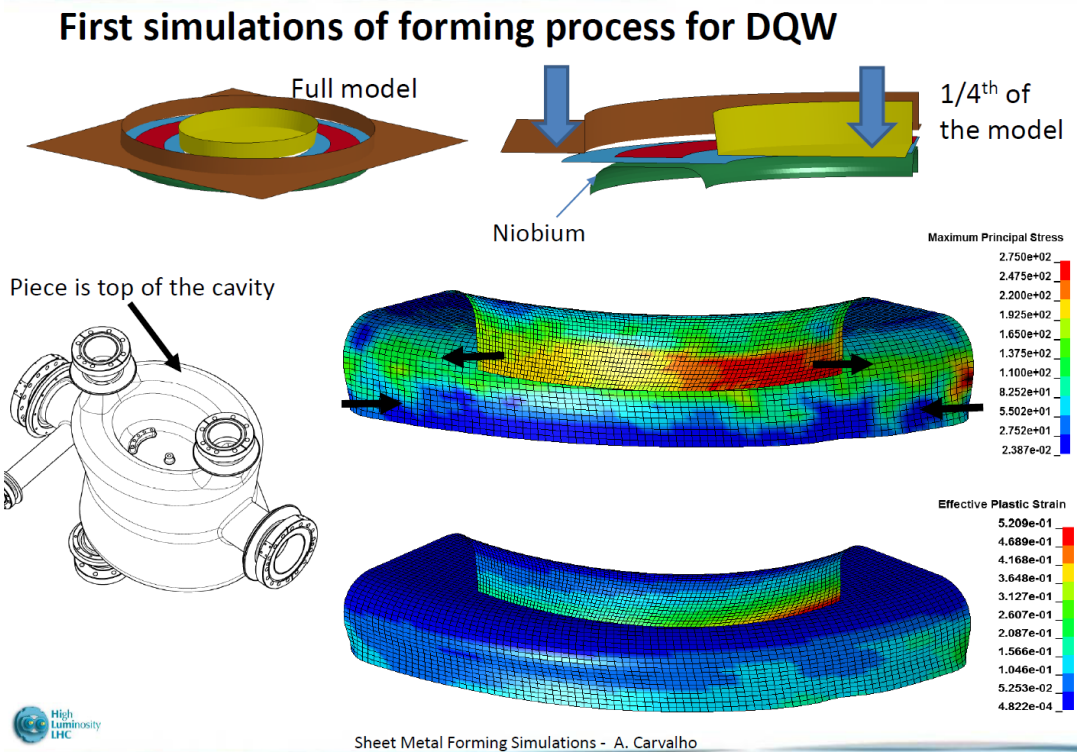
	Welding	Cool Down [300 K]	Cool Down [300 K → 2 K]	Operations [2 K]
Weld deformation	X			
Pressure [1.8 bara]		X	X	
Pre-tuning (elastic)		X	X	X
Weight		X	X	X
Fine tuning				X
ΔT		X ?	X	
$\Delta\alpha_T$			X	X
EP = elastoplastic *EL = elastic*	○ EP ○ Cavity	○ EL + bolts + friction ○ Cavity + Tuner + Tank ○ EP submodel of tuner interface		○ EL ○ Cavity + Tuner + Tank

	Welding	Cool Down [300 K]	Cool Down [300 K → 2 K]	Operations [2 K]
Weld deformation	X			
Pressure [1.8 bara]		X	X	
Pre-tuning (elastic)		X	X	X
Weight		X	X	X
Fine tuning				X
ΔT		X ?	X	
$\Delta\alpha_T$			X	X
EP = elastoplastic *EL = elastic*	○ EP ○ Cavity	○ EL + bolts + friction ○ Cavity + Tuner + Tank ○ EP submodel of tuner interface		○ EL ○ Cavity + Tuner + Tank

uncoupled

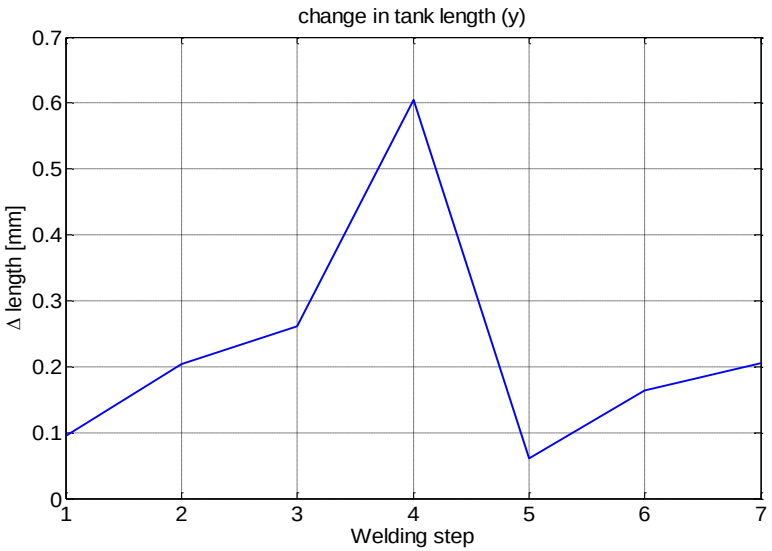
Cavity forming

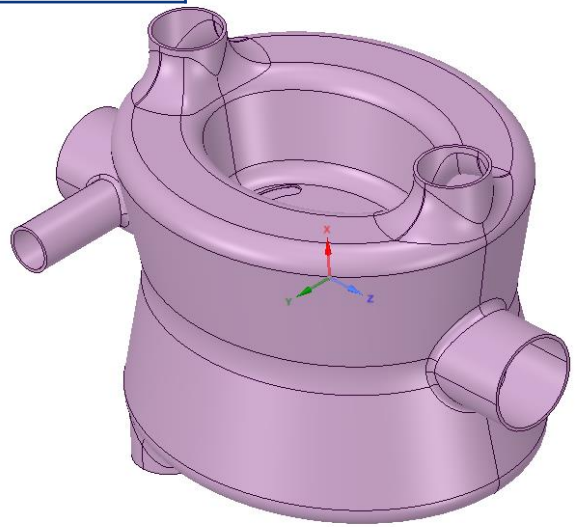
Material	Elasto-plastic analysis
Model	Only cavity / part of cavity
Scope of the analysis	Simulation: forming process study and parameters, spring-back effect, plastic strain…
Assumptions	Ref. Marco and Alexander



Welding to the tank

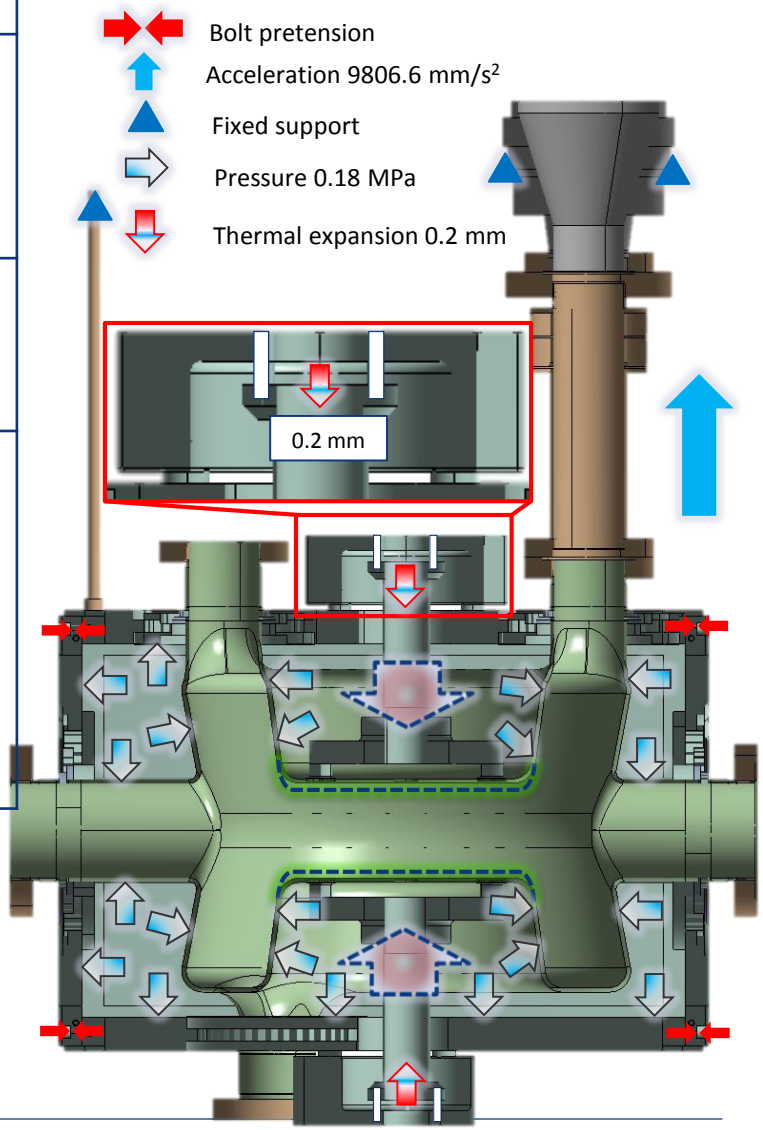
Material	Elasto-plastic analysis
Model	Only cavity
Scope of the analysis	Strength assessment / simulation?
Assumptions	Non linear material model, but not strain hardened (conservative) OPTION 1: after welding tank deformation returns to 0 → no impact on the following steps OPTION 2: residual tank deformation → residual load acting on cavity/tank → stress → linear analysis with stress categories → linear superposition??





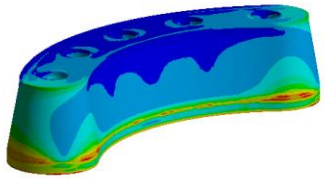
Cool Down [300 K]

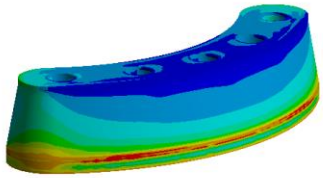
Material	Elastic analysis
Model	Cavity + Tuner + Tank + bolts model + friction
Scope of the analysis	Strength assessment: linear elastic
Assumptions	Material not strain hardened, at room T → conservative assumption deformation and stress levels are not real



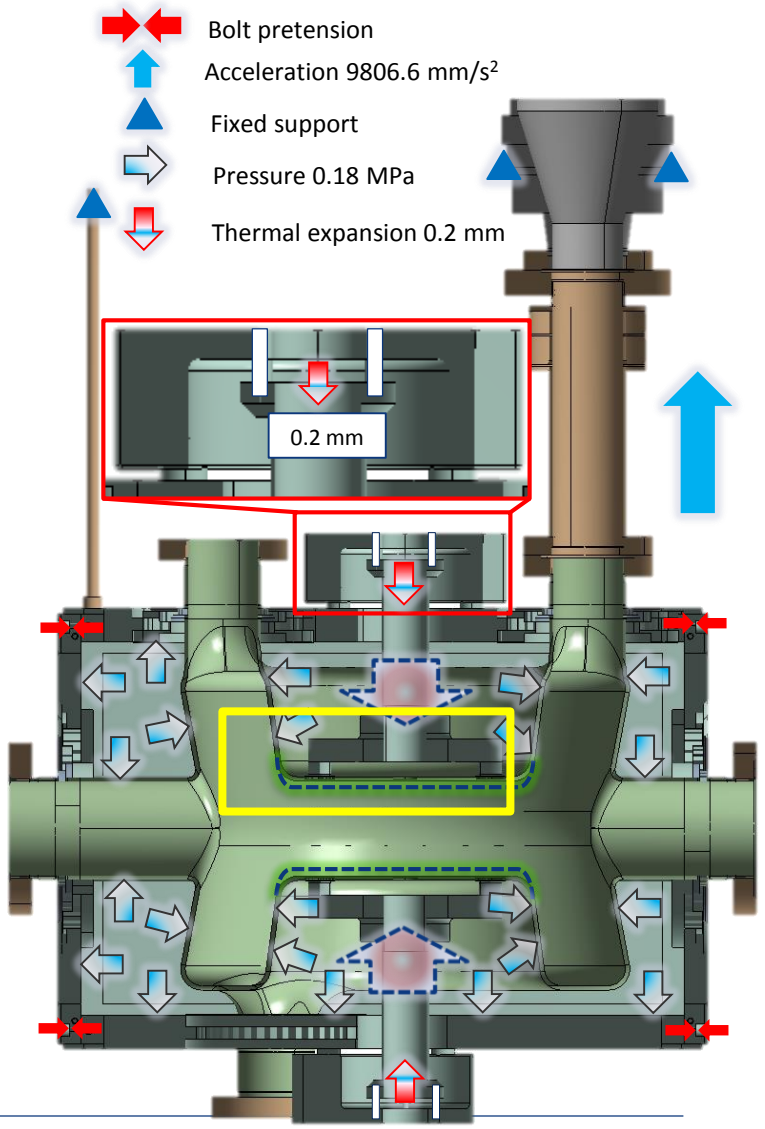
Cool Down [300 K], submodel

Material	Elasto-plastic analysis of peak areas
Model	(submodelling)
Scope of the analysis	Local strength assessment **(waiver to the general approach)**
Assumptions	Material not strain hardened, at room T → conservative assumption deformation and stress levels are not real



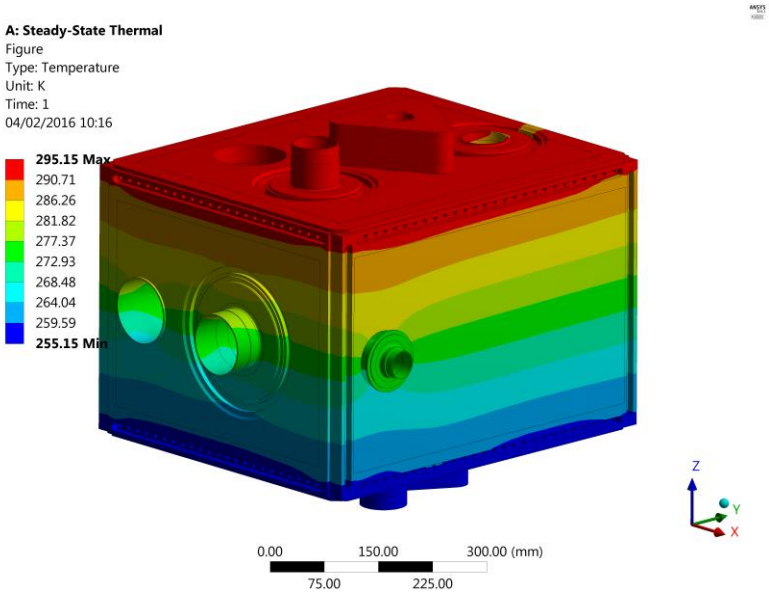


Work in progress…



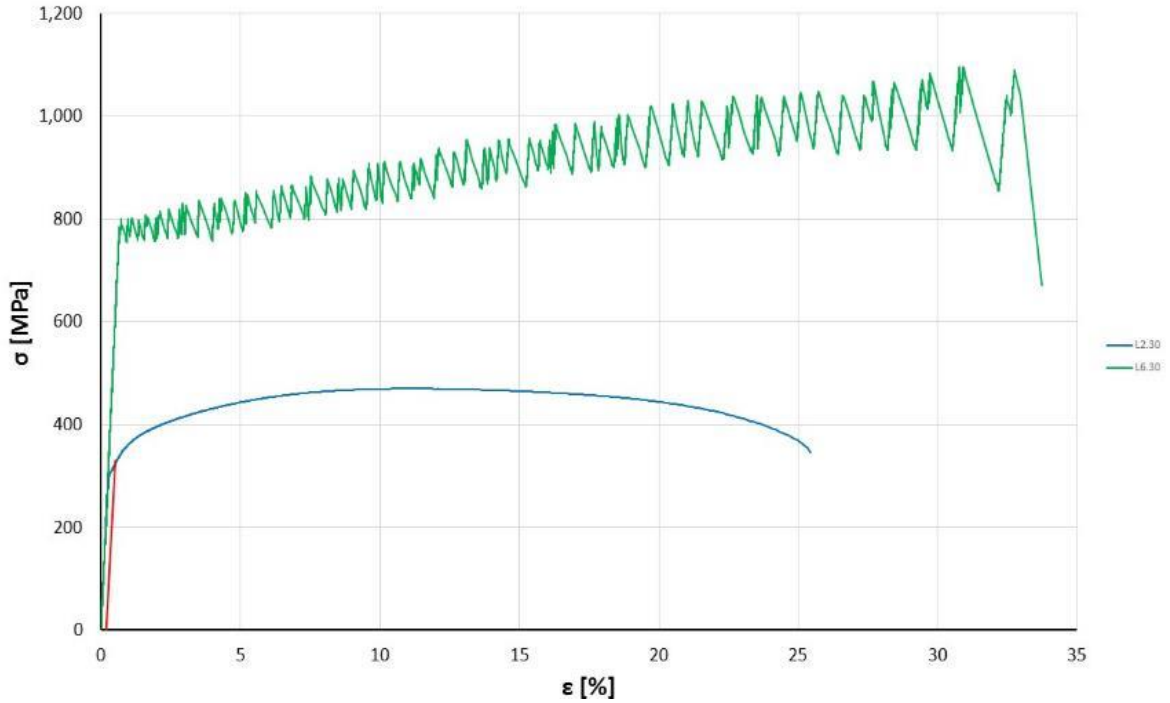
LC 3: Cool Down [300 K → 2 K]

Material	Elastic analysis
Model	Cavity + Tuner + Tank
Scope of the analysis	Simulation Rough calculation in order to get the order of magnitude, which is expected to be *small* with respect to pressure
Assumptions	no bolts (bonded) Worst-case: ΔT = 40 K (applied between bottom and top plate of the tank) - Hard to estimate deformation and stress levels are not real



Operations [2 K]

Material	NA
Model	NA
Scope of the analysis	Strength assessment
Assumptions	less critical because material properties at cold are improved a lot



Strength assessment

- Clarify tuning loads
- effects on the cavity due to the welding process? to be considered or not in the strength assessment?
- In principle… as done up to know it is acceptable, with some minor correction (fine tuning,…)

FEA analysis

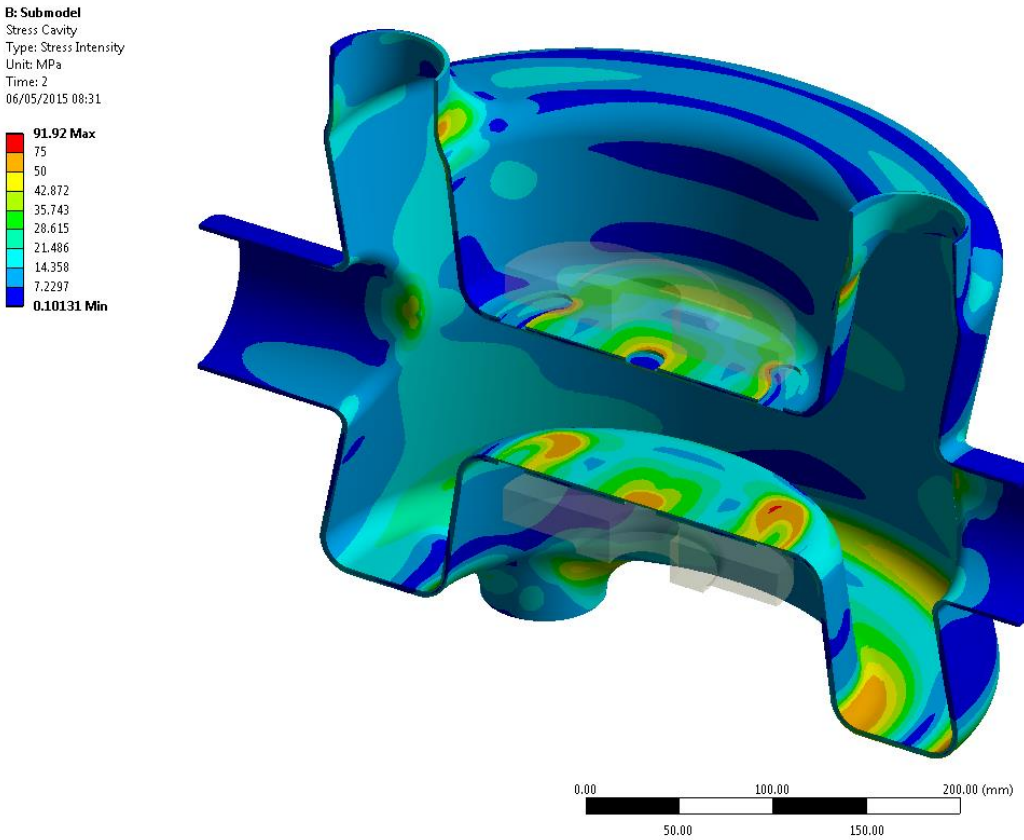
- EP analysis of cavity + tuner + tank, with bolts and friction is NOT feasible (possible solution: no friction and no bolts)
- The real behaviour of the cavity (plasticization and similar) can be studied but it is not related with the strength assessment.

Material properties

- Comparison should be done between material before forming and after forming


CERN
EN
ENGINEERING
DEPARTMENT

Just a reminder



Pressure ONLY
Stress due to pre-tuning (secondary stress) not present
ONLY primary stress

Cavity production

- *forming process*
- *plastic tuning (not confirmed)*

Evaluated separately with FEM explicit (?) on bare cavity model.
Non linear material model (as close as possible to the real one!) -> end of the process: cavity with no external loads, material with sufficient ductility (at least 30% TO BE CONFIRMED)

Cavity assembly with He tank

- *welding process with He tank -> partially elastic, partially plastic*

Non linear material model (not strain hardened -> conservative assumption) -> elastic perfectly plastic ->

OPTION 1 -> after welding tank deformation returns to 0 -> cycle on the cavity materials -> we assume that some additional plasticization occurs but no impact on the following steps

OPTION 2 -> residual tank deformation -> residual load acting on cavity/tank -> stress -> linear analysis with stress categories -> linear superposition??

end of the process: material with sufficient ~~ductility (at least 30% TO BE CONFIRMED)~~

Cavity operation

- *Cavity*
- *Vessel*
- *Bolts*
- *Welded joints*
- *Bellows*

Loads

- *Pressure*
- *Weight*
- *Thermal gradient during cool-down*
- *Cold temperature -> differential contraction*
- *Additional coarse tuning applied displacement*
- *Fine tuning applied displacement*

Material not strain hardened, at room T -> conservative assumption

Linear elastic model for material (non linearity in contacts) is used -> deformation and stress levels are not real

Some plasticization are can be identified, but the values are not relevant. The stress assessment is based on “semi-empirical” approach

Dressed cavity tuning performances

• *Preliminary coarse plastic tuning*	Considered in the forming process, not included in the strength assessment
• *Coarse elastic tuning*	included in the strength assessment
• *Coarse additional plastic tuning*	included in the strength assessment The result of the “stress categories” approach gives an idea but not real behaviour If real behaviour is needed -> plastic analysis with real (???) material properties can be performed but IT IS NOT a strength assessment
• *Fine tuning*	Today not included in the strength assessment It shall be included in the strength assessment

Conclusions

Strength assessment

- As done up to know is acceptable with some minor correction (fine tuning,…)

FEA analysis

- The real behaviour of the cavity (plasticization and similar) can be studied but it is not related (in principle) with the strength assessment, if assumptions in this document are accepted.

Material properties:

- Comparison should be done between material before forming and after forming