2015 ESSS CONFERENCE & ANSYS USERS MEETING

Grand Mercure São Paulo Ibirapuera
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# Demage evaluation due to thickness loss in oil tank

Development of auxiliary methodology for maintenance planning procedure

Authors:

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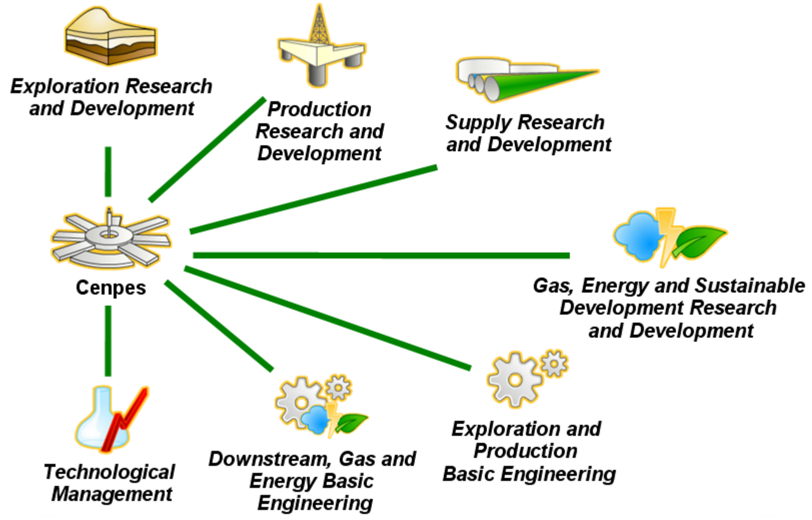
ANSYS CONVERGENCE 2015 REGIONAL CONFERENCES

# Company Overview

Petrobras and Transpetro have in operation a large amount of tanks installed at refineries and terminals, these equipments are subjected to operations of stored products that cause demages over time.

In this project, developed by Petrobras/CENPES and ESSS was studied the influence of material loss along the thickness at bottom oil tanks.



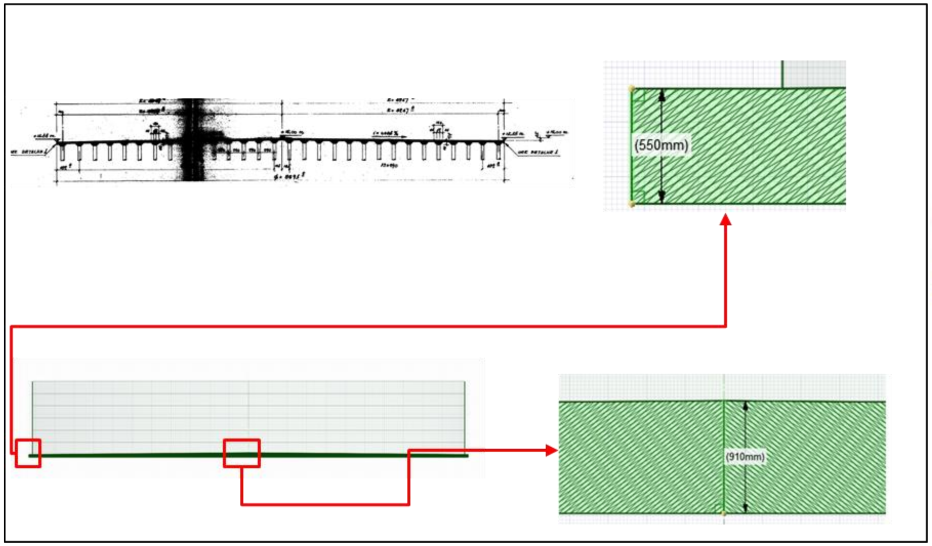
# Goals

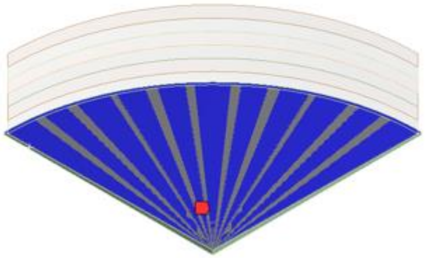
Recommendations as the API 650 [1] and N-270 [2] are used as guidelines for tanks design and exhibit constructive requests and operational limits for oil tanks subjected to various types of damage.

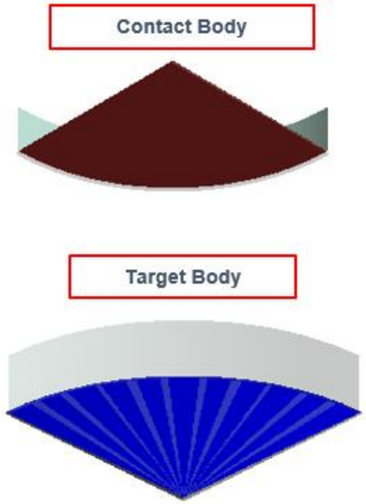
The numerical study aims to evaluate the structural integrity by stresses criterion as presented at API653 for evaluating the integrity of tanks with thickness loss at bottom.

# Methodology

The interaction between the tank bottom and the slab was implemented numerically using a non-linear contact, allowing sliding and separation between the components (tank and slab).

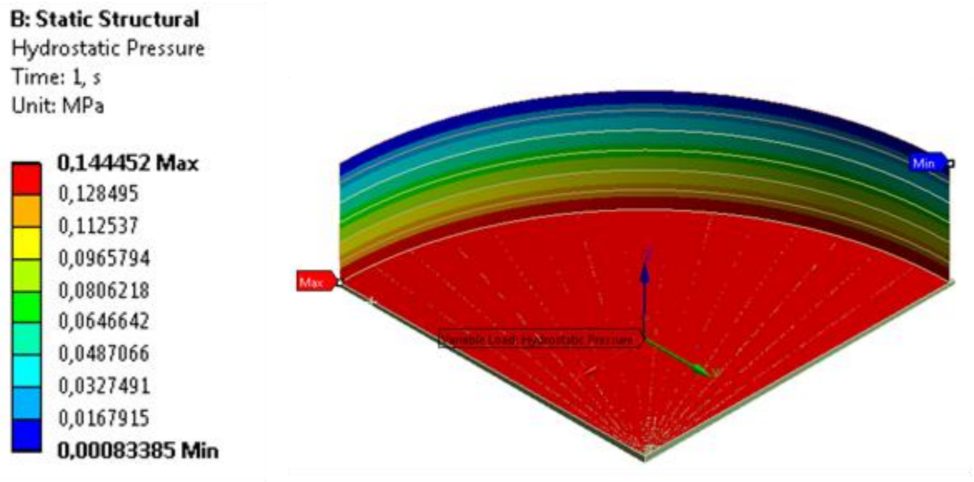




# Methodology

The study includes the loading on the tank corresponding to its maximum storage load by means of a hydrostatic effort and the floating roof weight.




For the floating roof representation was adopted the hypothesis that the roof inertial load is replaced by a equivalent hydrostatic pressure, in other words, a liquid column corresponding to the roof weight about 500 tons is determined.

# Methodology

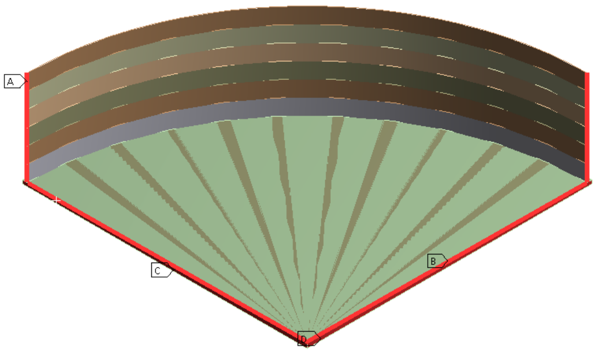
In the project were developed models for analyzing damaged and undamaged tank bottoms, using different methodologies for each type of evaluation:

- Evaluation of undamaged bottom -> ¼ symmetric model

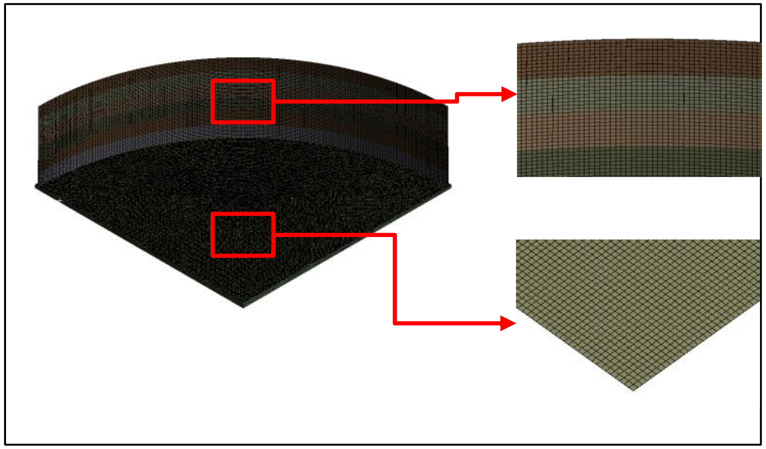
- Evaluation of damaged bottom -> symmetric model, 2 degree sector

# Methodology

- Undamaged bottom analysis



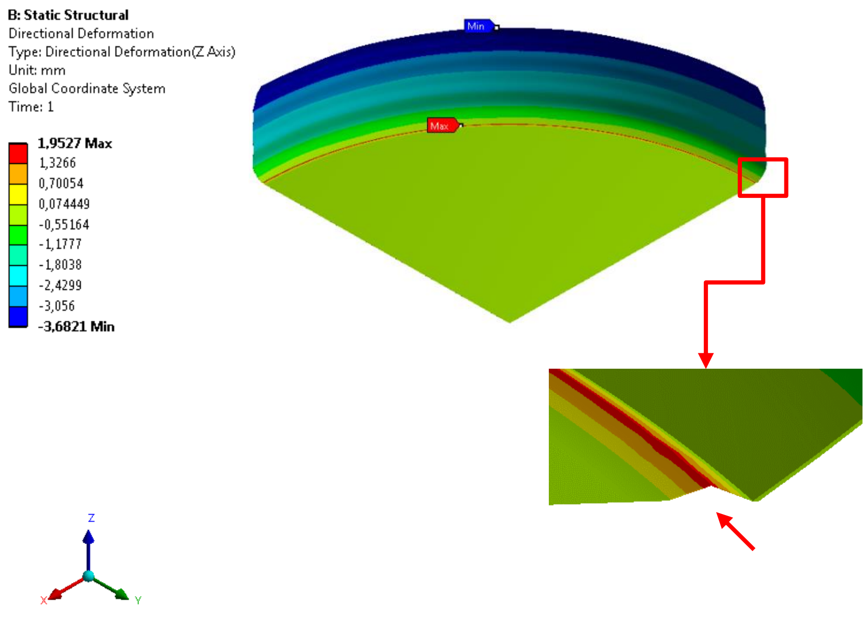

Symmetry developed for global analysis

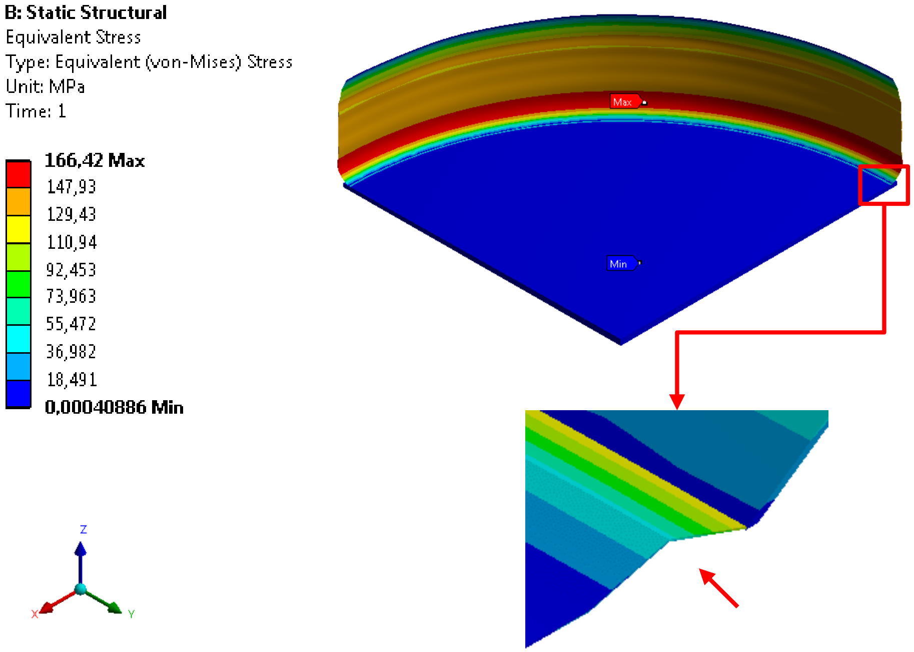


Finite element mesh developed for global analysis

# Results

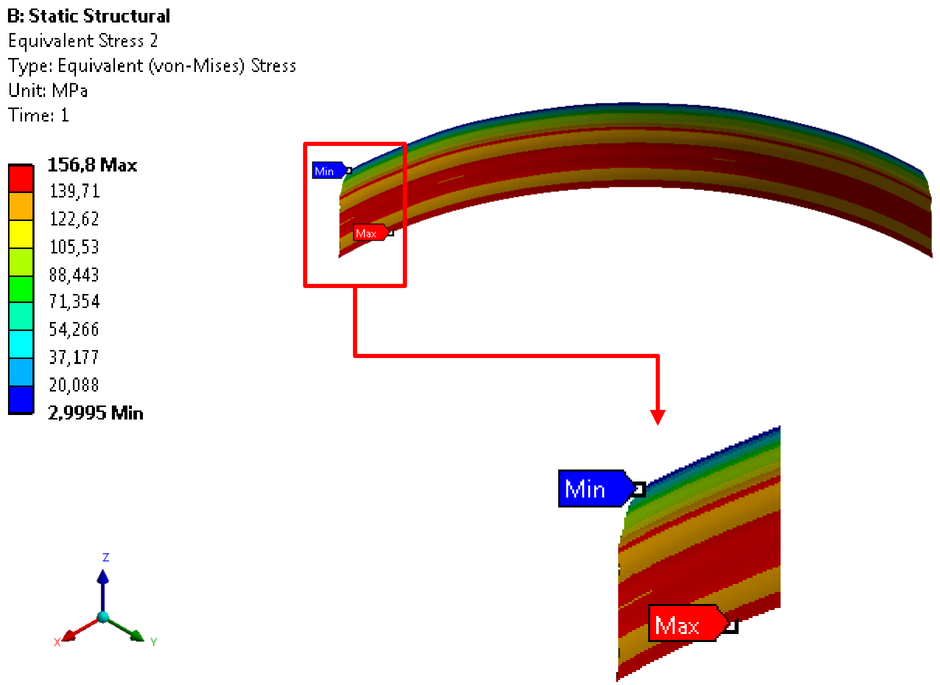
- Undamaged bottom analysis

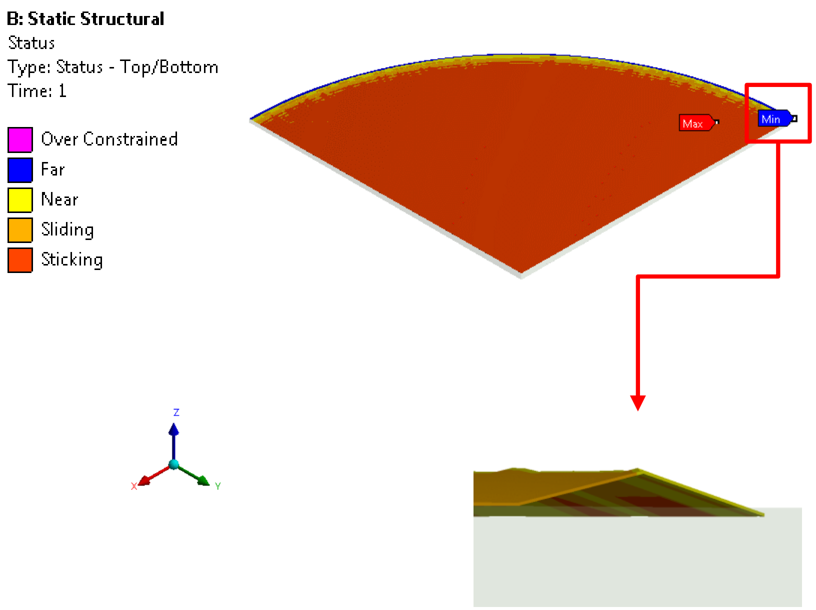


# Results

- Undamaged bottom analysis

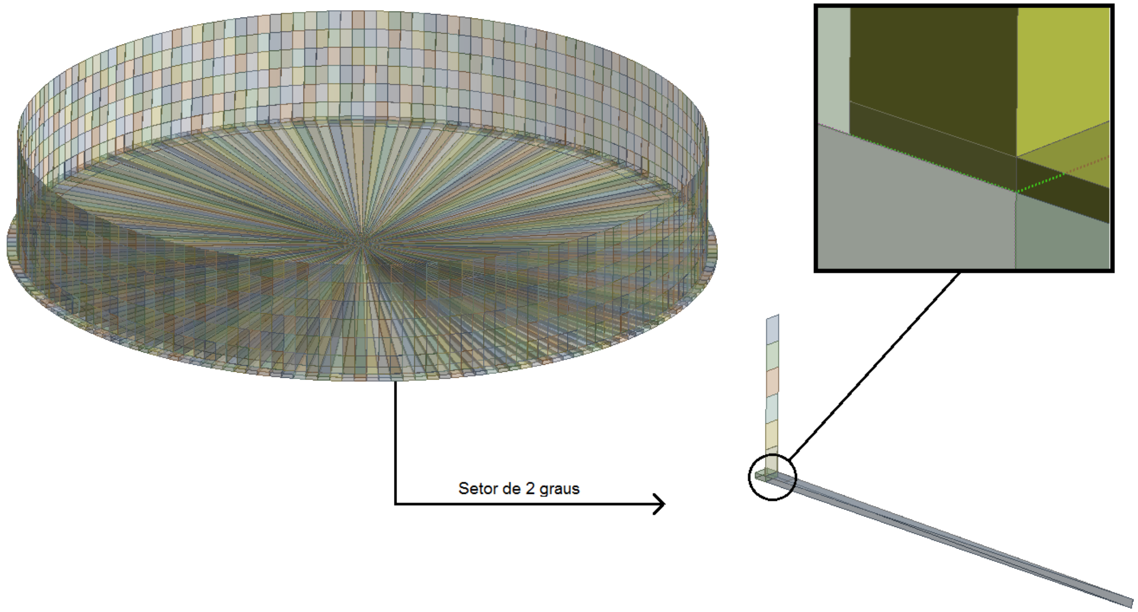


# Methodology

- Damaged bottom analysis

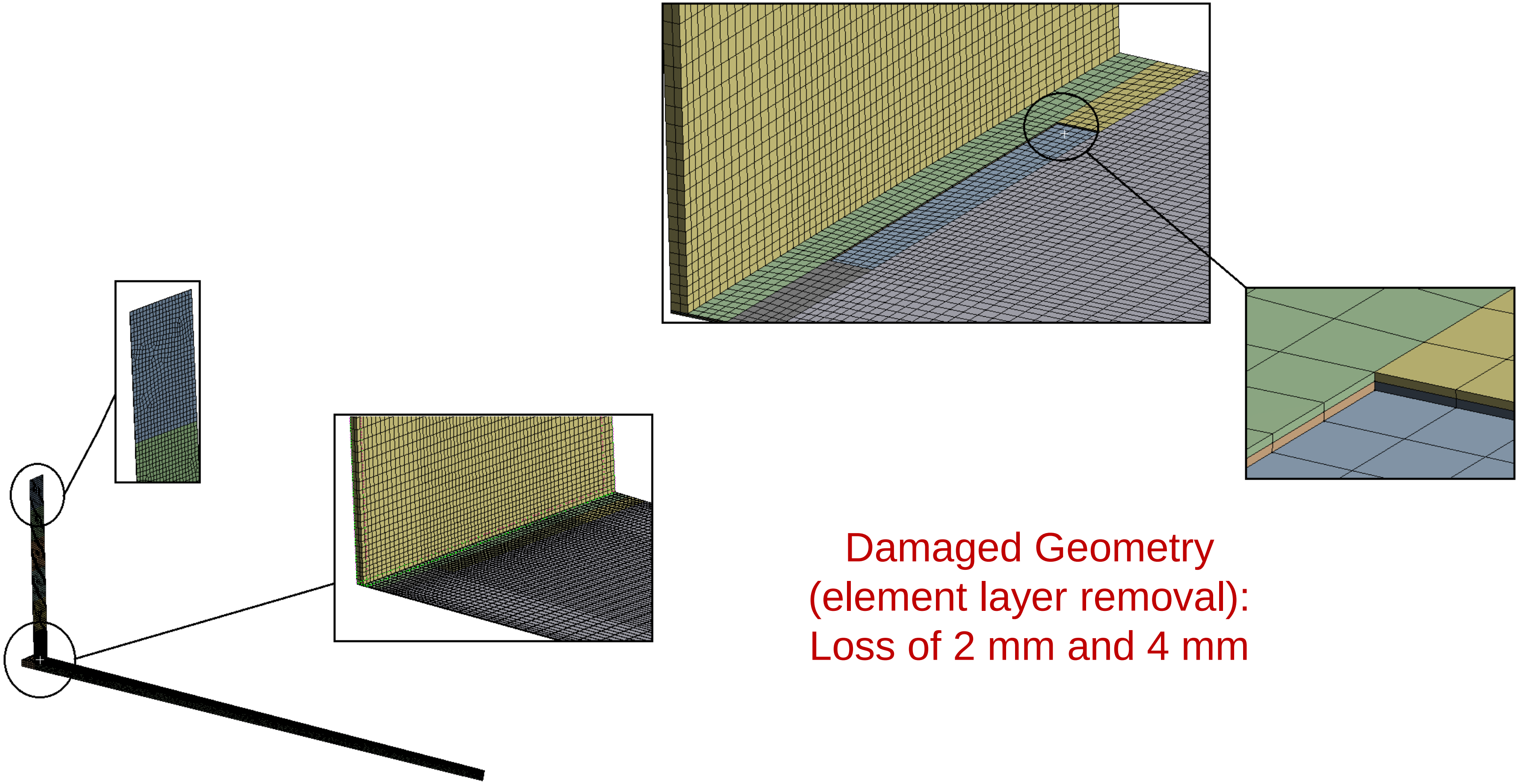
Model developed with 2 degree sector, a hybrid modeling of shell and solid elements was adopted.




Solid geometry Detail in the highlighted area (side interaction with bottom).

# Methodology

- Damaged bottom analysis - Damage evaluation model out of the annular region

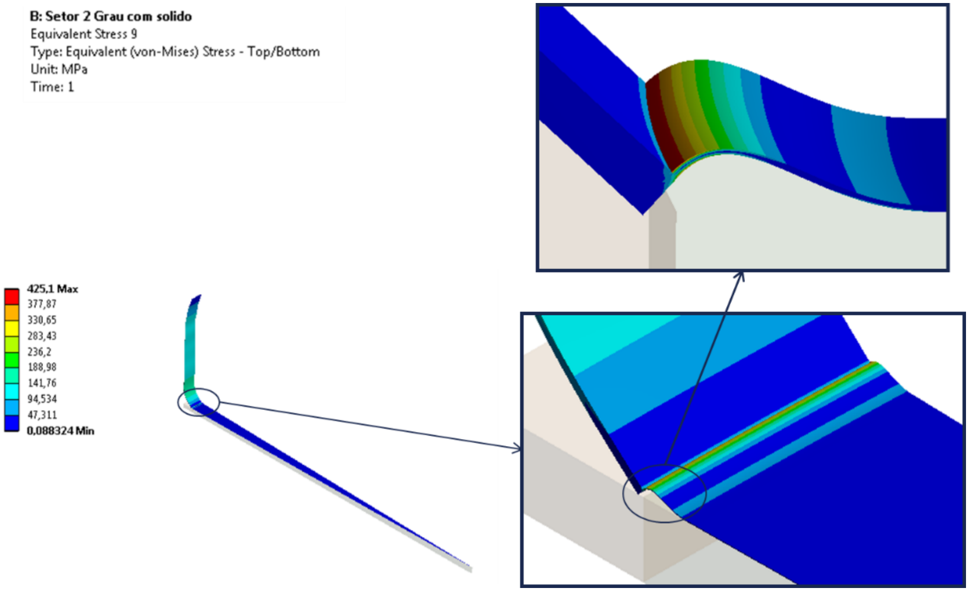


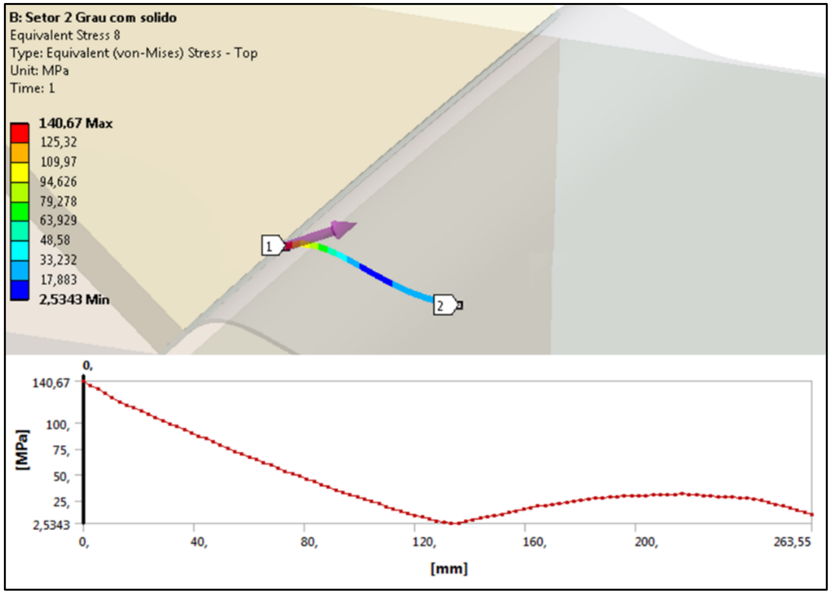
Damaged Geometry
(element layer removal):
Loss of 2 mm and 4 mm

# Results

- Damaged bottom analysis - Damage evaluation model out of the annular region

A undamaged model with 2 degree sector was developpted and simulated for evaluation



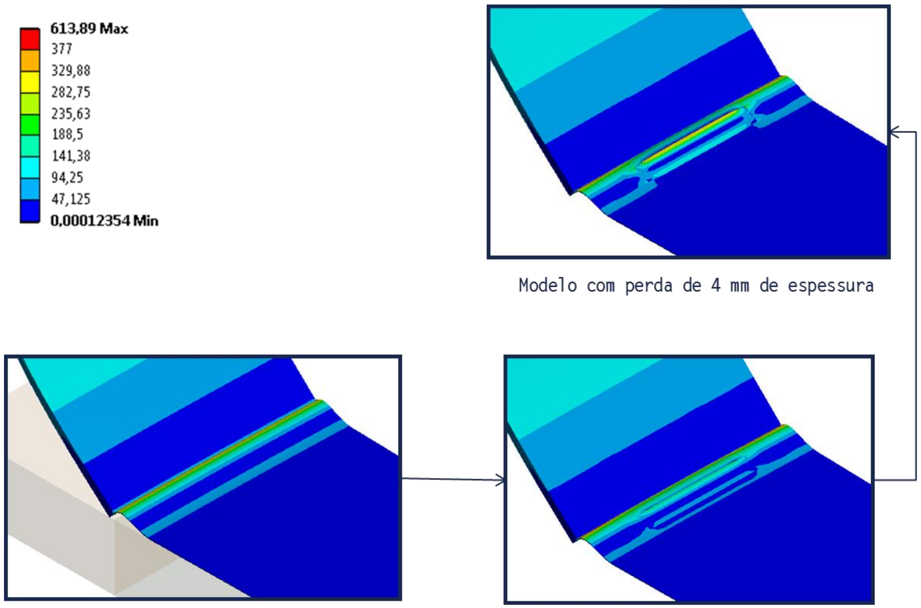



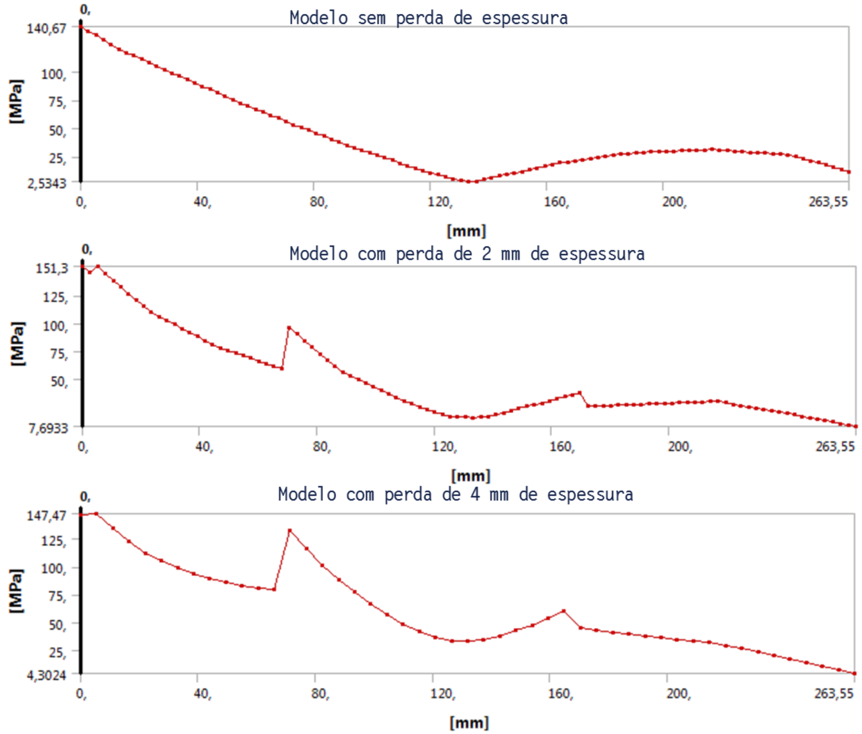
# Results



- Damaged bottom analysis - Damage evaluation model out of the annular region

## Damaged models results

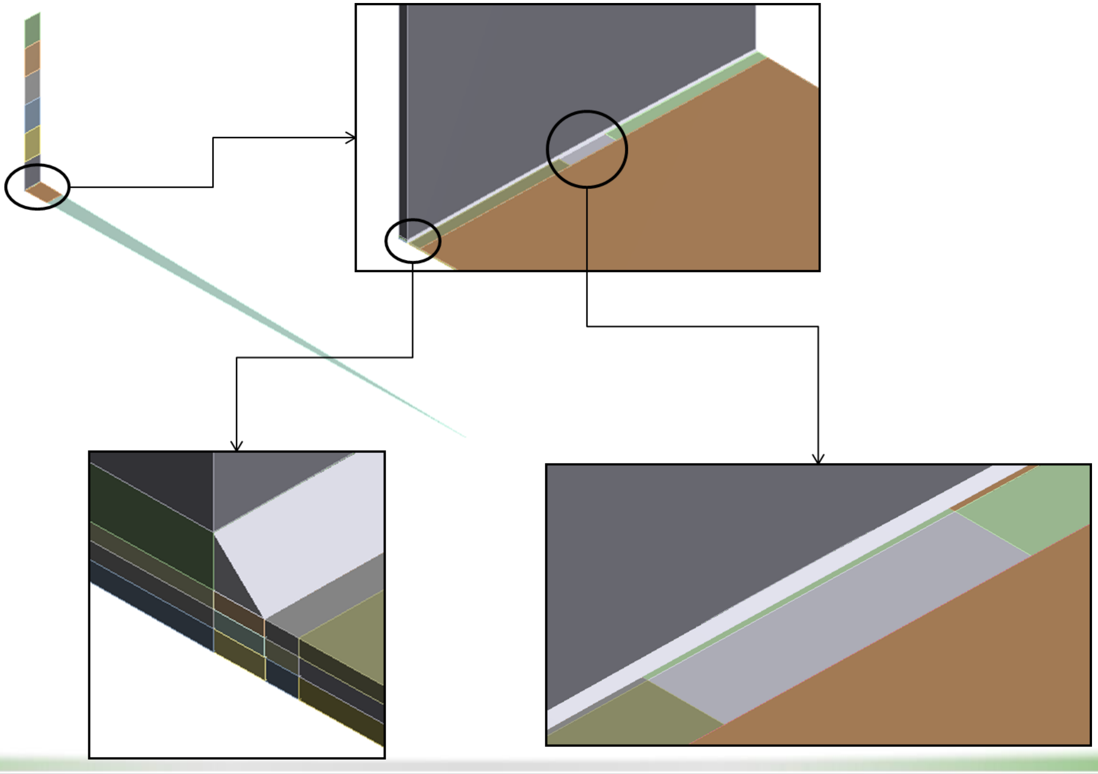


# Methodology

- Damaged bottom analysis - Damage evaluation model at annular region

Study developed to evaluate the stresses at annular region of 3 inches in length from the inner side



# Methodology

**Damaged bottom analysis - Damage evaluation model at annular region**

The analysis of this region is a great challenge for the numerical evaluation since it is a influence zone of a geometric discontinuity, creating the need for high numerical refinement and observance with regard to stress criteria presented in ASME VIII Division 2

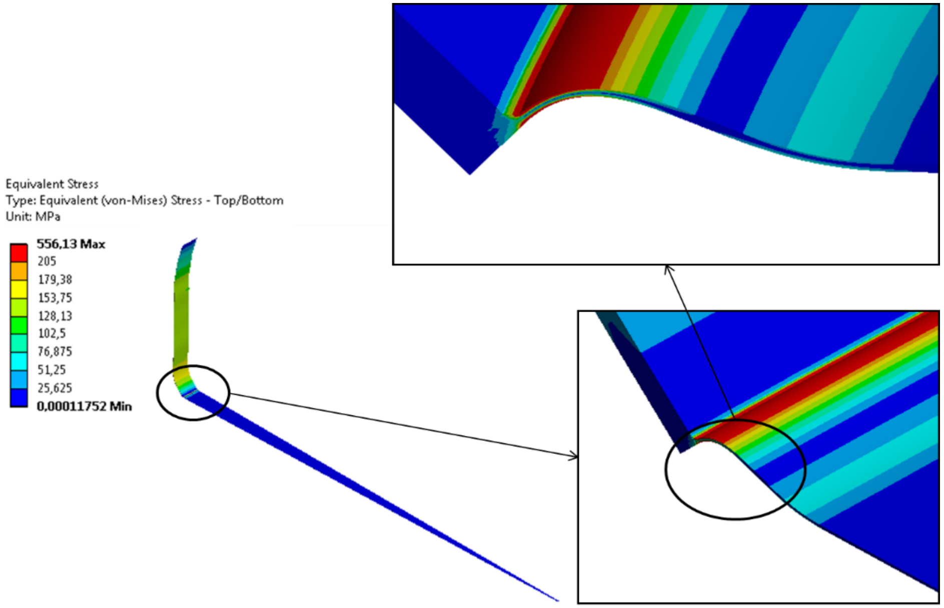
The secondary nature of the stresses in the annular region is associated with geometric discontinuity between the tank bottom and the tank side (sharp edge and variation and wide variation in stiffness / plate thickness) and they are self-limiting by deformation

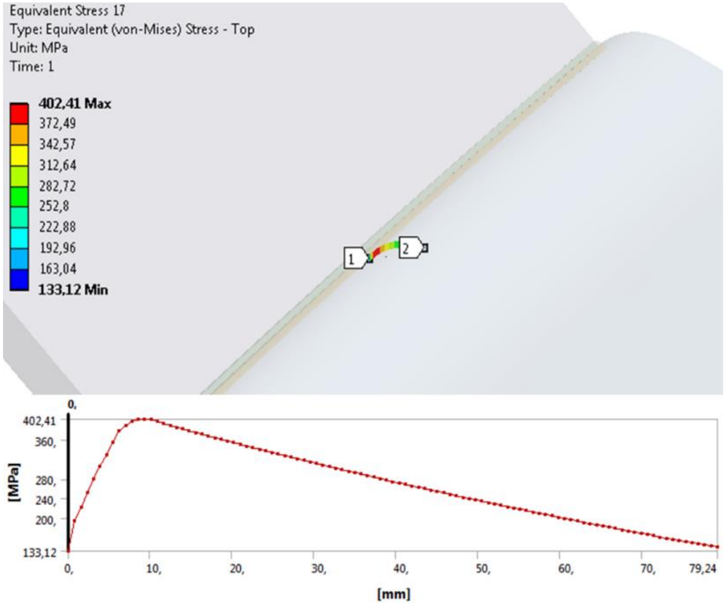
This feature justifies a different evaluation for this area, considering for it the stress linearization (Linearization occurs in the central region where the thickness loss will happen)

# Results

- Damaged bottom analysis - Damage evaluation model at annular region

A undamaged model with 2 degree sector was developted and simulated for evaluation

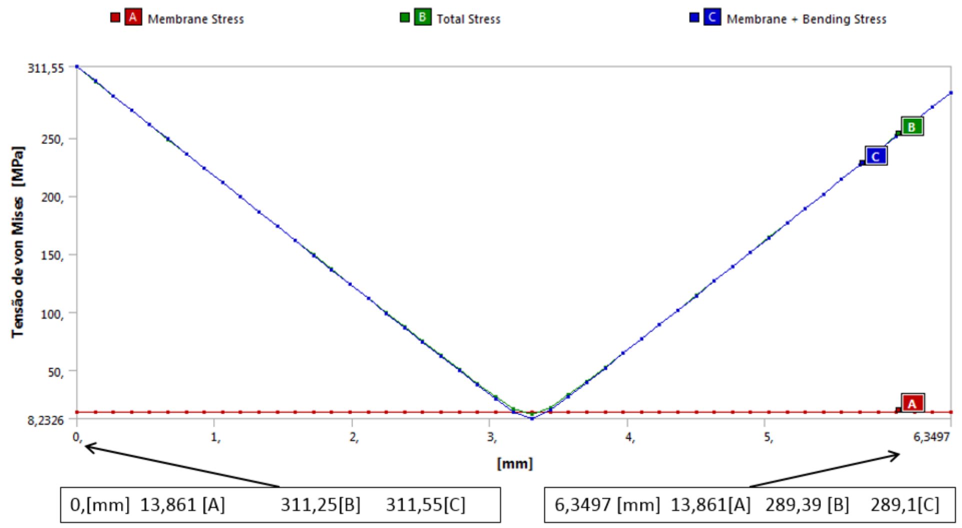


# Results

- Damaged bottom analysis - Damage evaluation model at annular region

A undamaged model with 2 degree sector was developted and simulated for evaluation

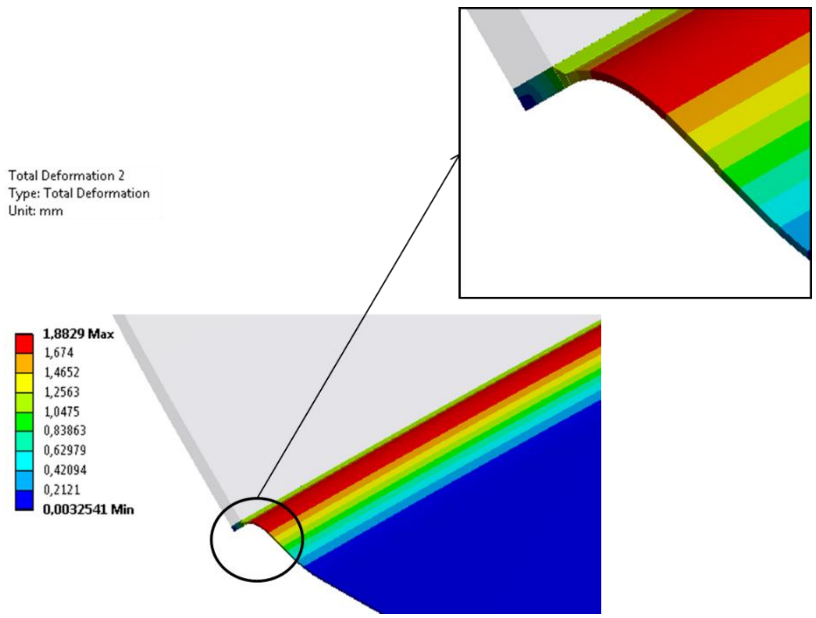


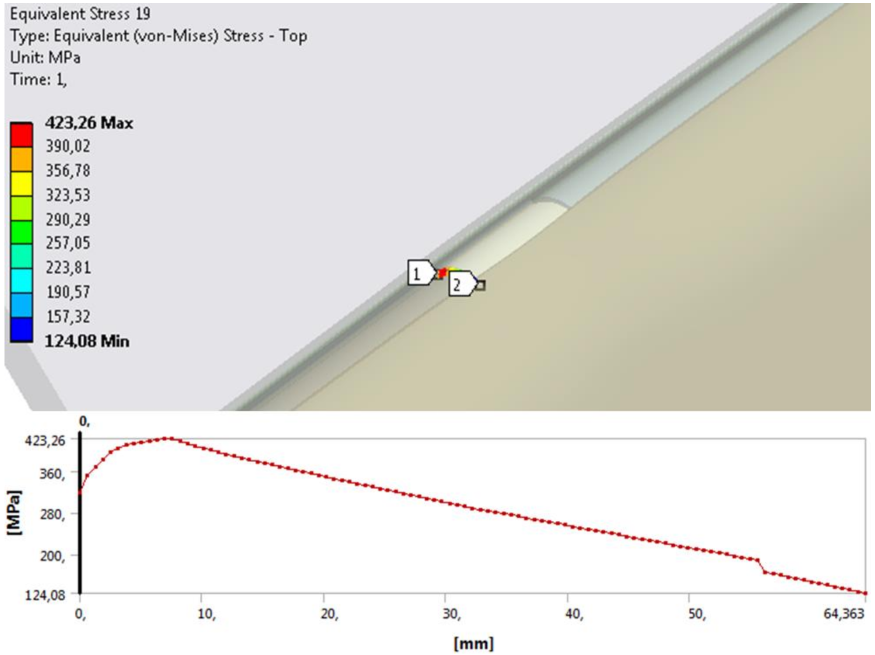

Linearização de tensão para o modelo sem perda de espessura

# Results

- Damaged bottom analysis - Damage evaluation model at annular region

Model with thickness loss of 2 mm

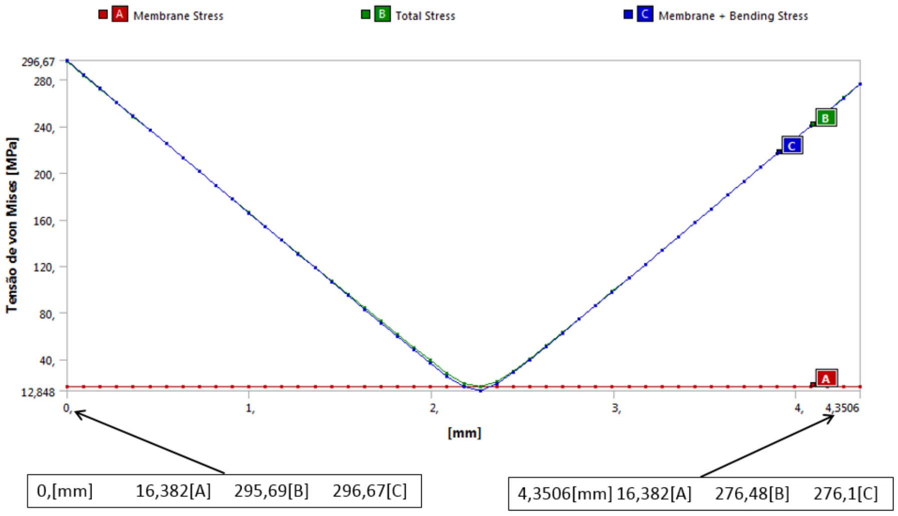


# Results

- Damaged bottom analysis - Damage evaluation model at annular region

Model with thickness loss of 2 mm




Linearization of stress for the model with thickness loss of 4 mm

# Results

- Damaged bottom analysis - Damage evaluation model at annular region

Model with thickness loss of 4 mm

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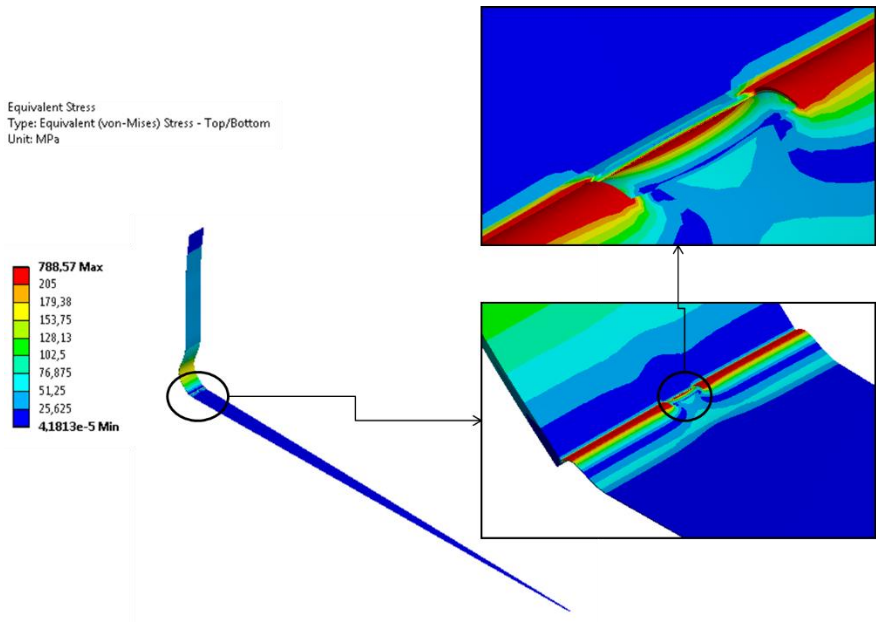
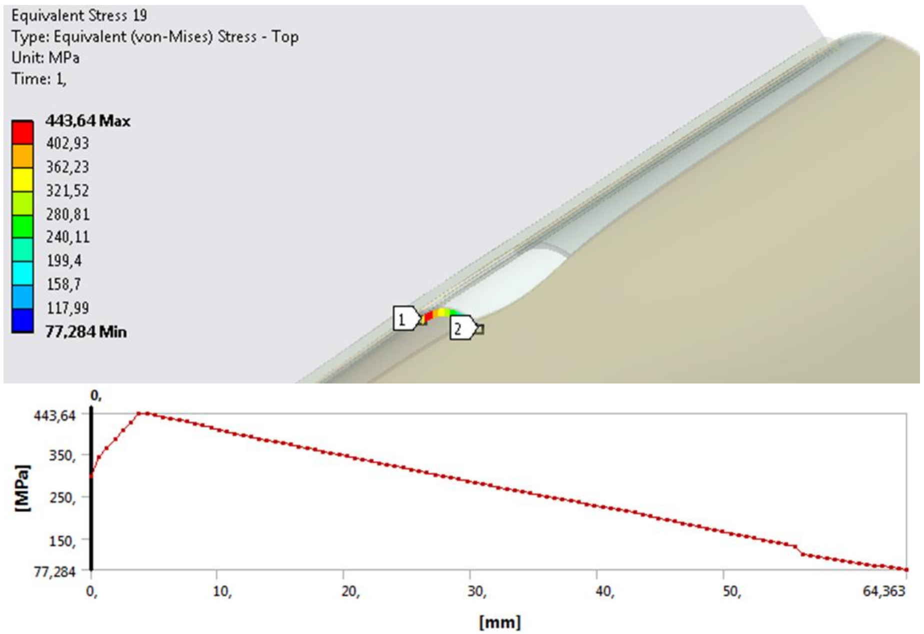
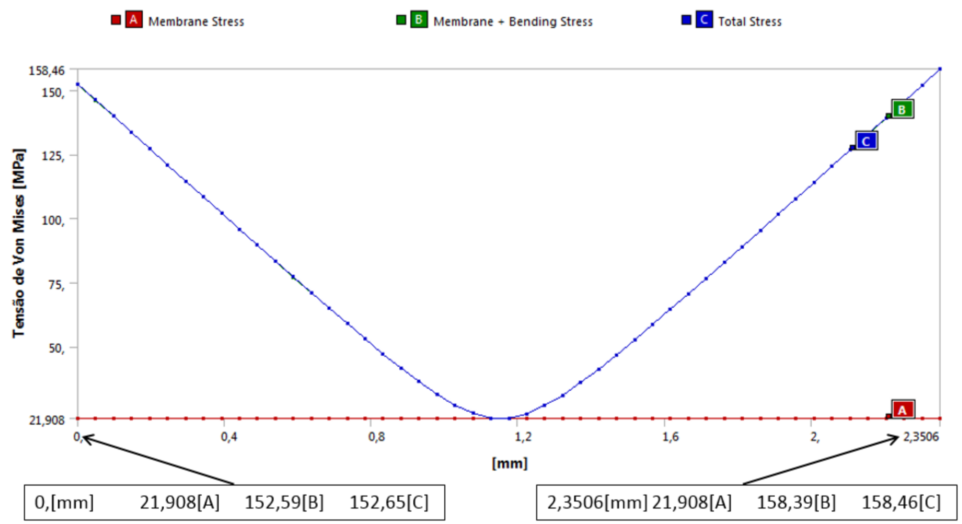


# Results

- Damaged bottom analysis - Damage evaluation model at annular region

Model with thickness loss of 4 mm




Linearization of stress for the model without thickness loss

# Results

## Considering the stresses categorization

| | | | |
|---|---|---|---|
| Membrane stress limit [MPa] | (P) | P = S* | 160 |
| Membrane stress limit + Bending [MPa] | (P +B) | P+B=1,5S* | 240 |
| Total stress limit [MPa] | (P+B+Q) | P+B+Q=3S* | 480 |
| P= Membrane stress, B = Bending Stress, Q= Secondary stresses | | | |
| *S*= allowable stress= 160 MPa - Adopted in accordance with API650 criterion* | | | |

## Damaged bottom analysis - Damage evaluation model at annular region

| Cases evaluated / Stress categorization | P (MPa) | P+B (MPa) | TOTAL (MPa) |
|---|---|---|---|
| Case I – Without thickness loss | 13,861 | 311,25 | 311,55 |
| Case II - with thickness loss of 2 mm | 16,382 | 295,69 | 296,67 |
| Case III - with thickness loss of 4 mm | 21,908 | 152,59 | 152,65 |

# Conclusion

The study results indicate a critical trend according as greater thickness loss in the tank bottom are simulated.

The annular region evaluation maintained the stress intensification tendency due to thickness loss. In this region is found a value of 443 MPa for maximum damage scenario and 402 MPa for undamaged scenario therefore the difference between these two cases is 40 MPa.

Whereas these stresses are discontinuous, there is no indication that the stress variation of 40 MPa mentioned above generates a inadequate condition of bottom since the nominal stress of bottom is 20 MPa order.

**This result allows the tank operation even at thickness loss conditions indicated in standard size criterion, thereby the maintenance cost of the equipment is minimized with greater safety evaluation**