Cracks evaluation of coke drums

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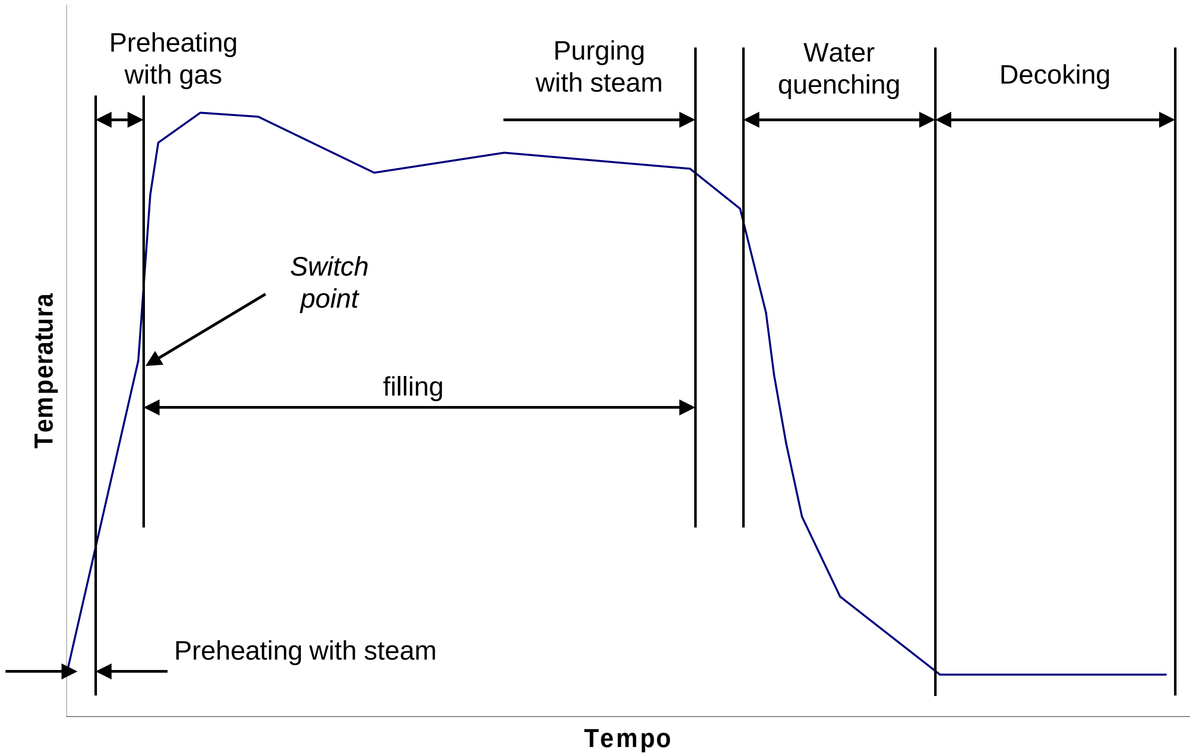
Objectives:

- Failure Risk Evaluation due to thermal fatigue at the skirt to head juncture of a coke drum.
- When will a crack initiated by fatigue become a critical or through-wall crack?

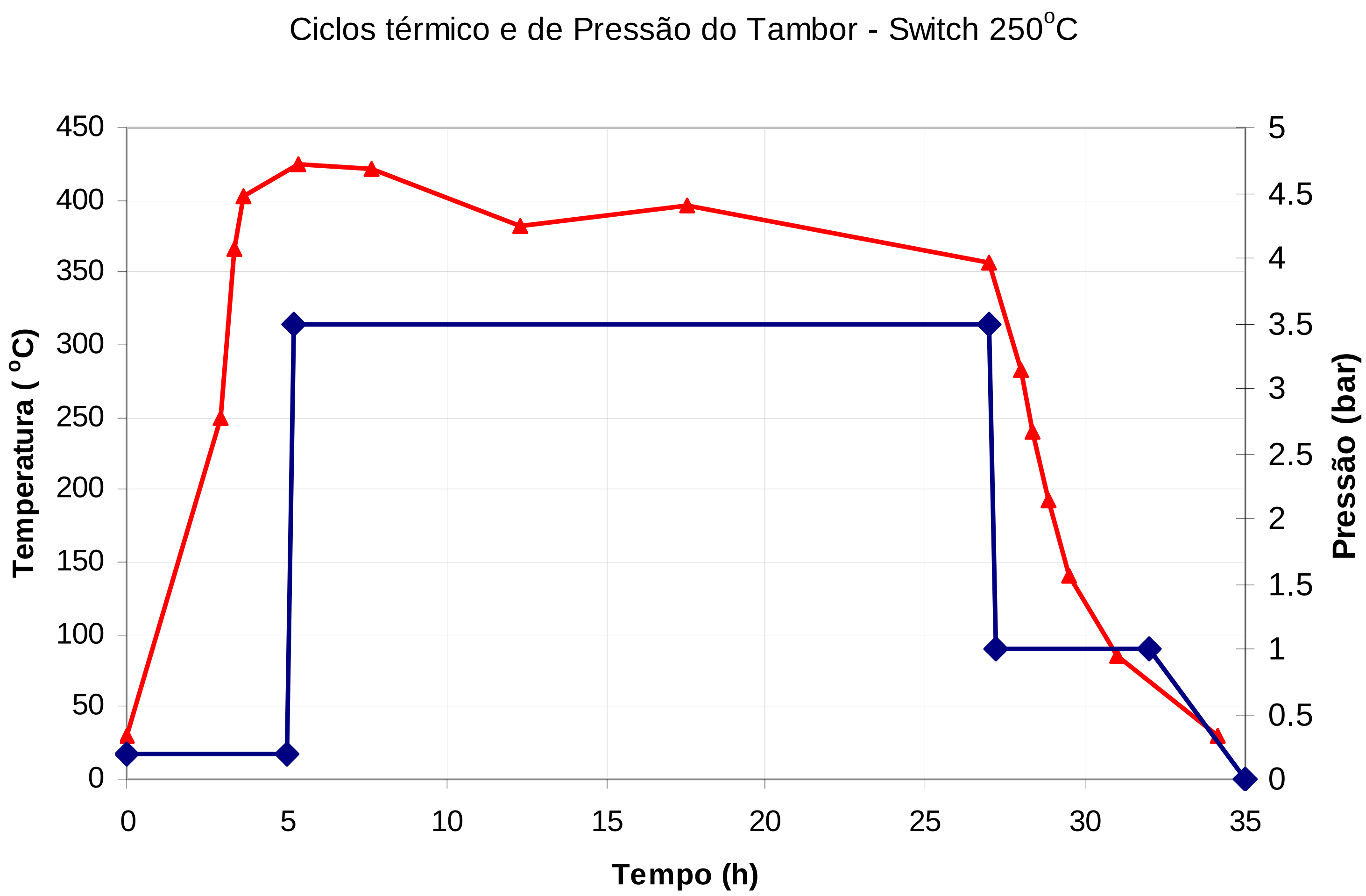
INTRODUCTION:

This paper presents the design concerns to obtain a well-designed welding which connects the skirt support to the coke drum wall.
It is also shown that is very important to consider the transient temperature along that welding which happens during the water quenching step.

Typical operating temperature cycle of a coke drum

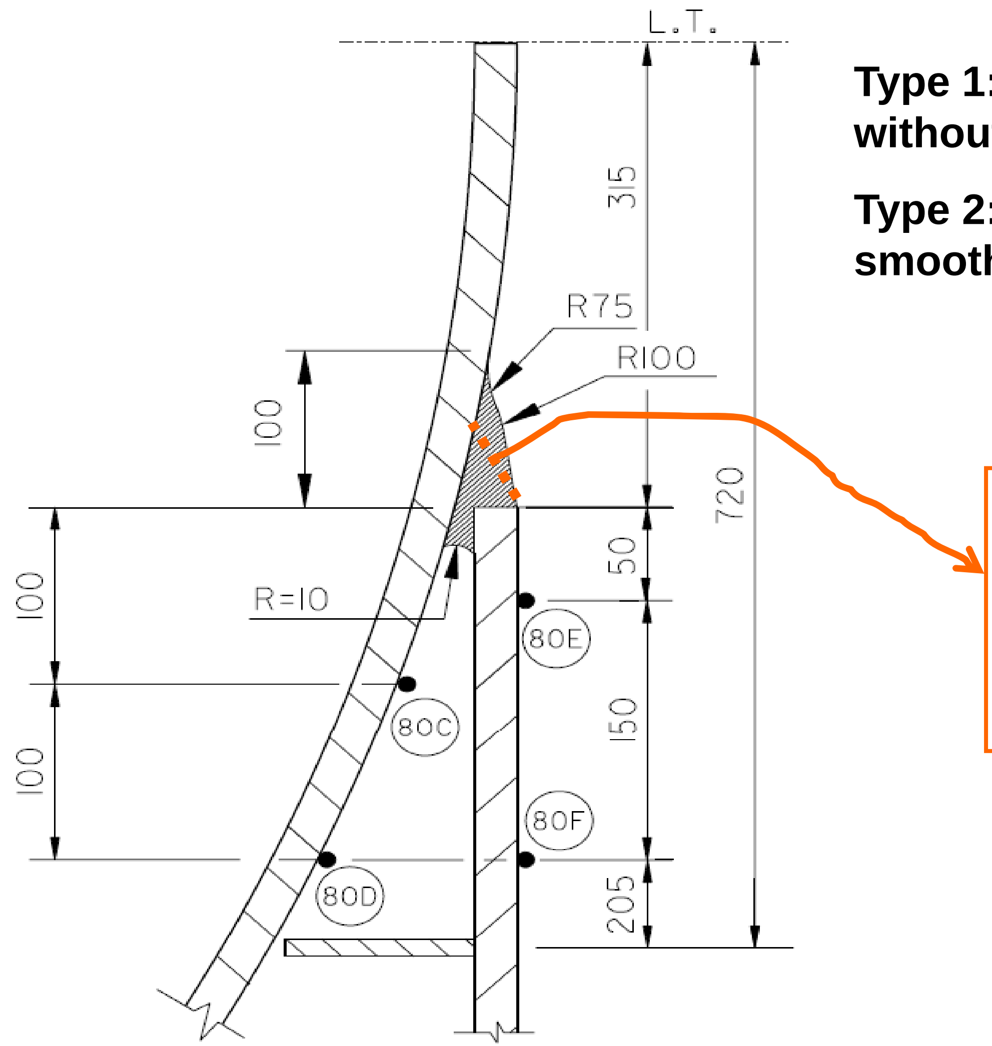


Typical cycles of operating temperature and pressure of a coke drum



Fatigue evaluation of skirt to head weld

- Comparation between two types of build-up welding



Type 1: Short Weld Build-up (slope = 1:2.5), without smooth grind radius;

Type 2: Long Weld Build-up (slope = 1:5), with smooth grind radius;

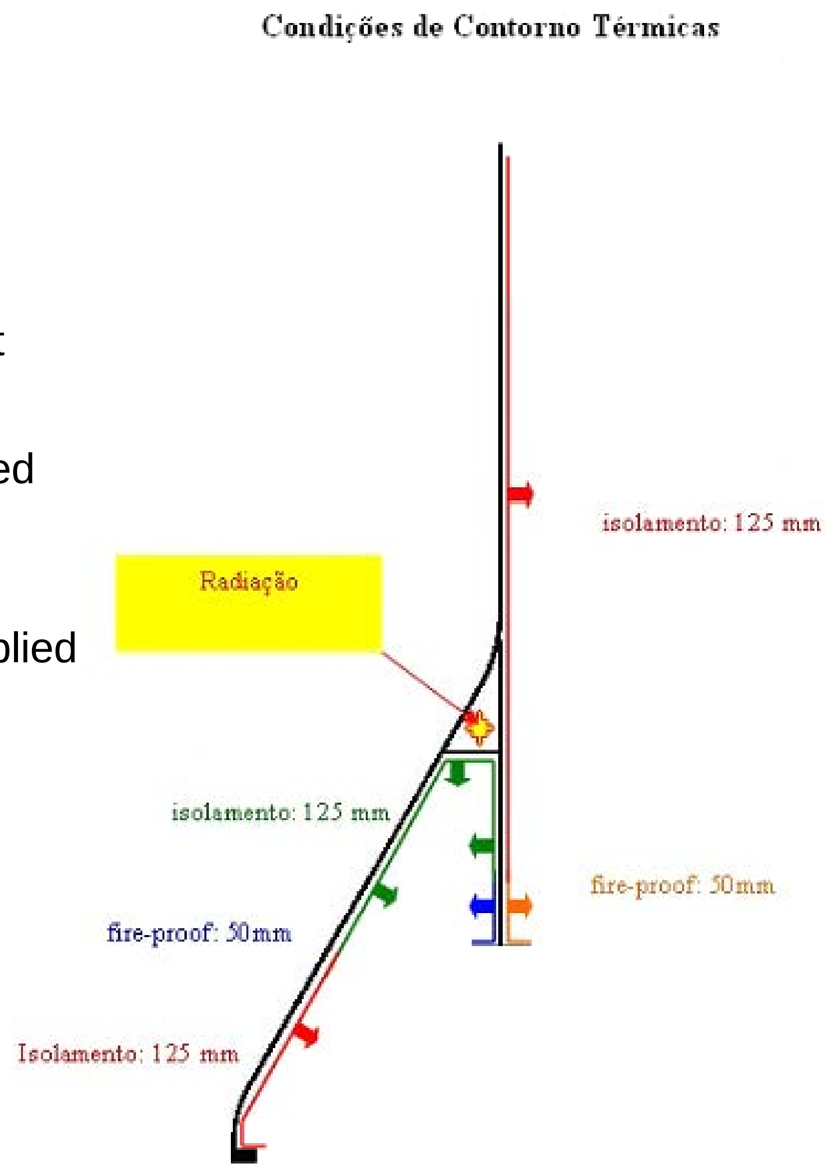
Type 1: the welding length is much shorten then Type 2.

Type 1: It is not foreseen to make any smooth profile

Thermal Evaluation –

Thermal Boundary conditions

- Hot box*:* heat transfer by radiation
- Concrete deck: to provide the heat flux from the skirt support to the concrete structure.
- Temperature loading varying along the time: is applied as a forced temperature on the internal surface of the head and shell.
- Each proper equivalent heat transfer coeff. (h_{eq}): applied on surface of the model
- External heat transfer coeff. (he) = 3,0 BTU/hr.in^{2}F
- The thermal conductivity of these materials was considered on the average temperature of 300 °C



Thermal analysis - Model

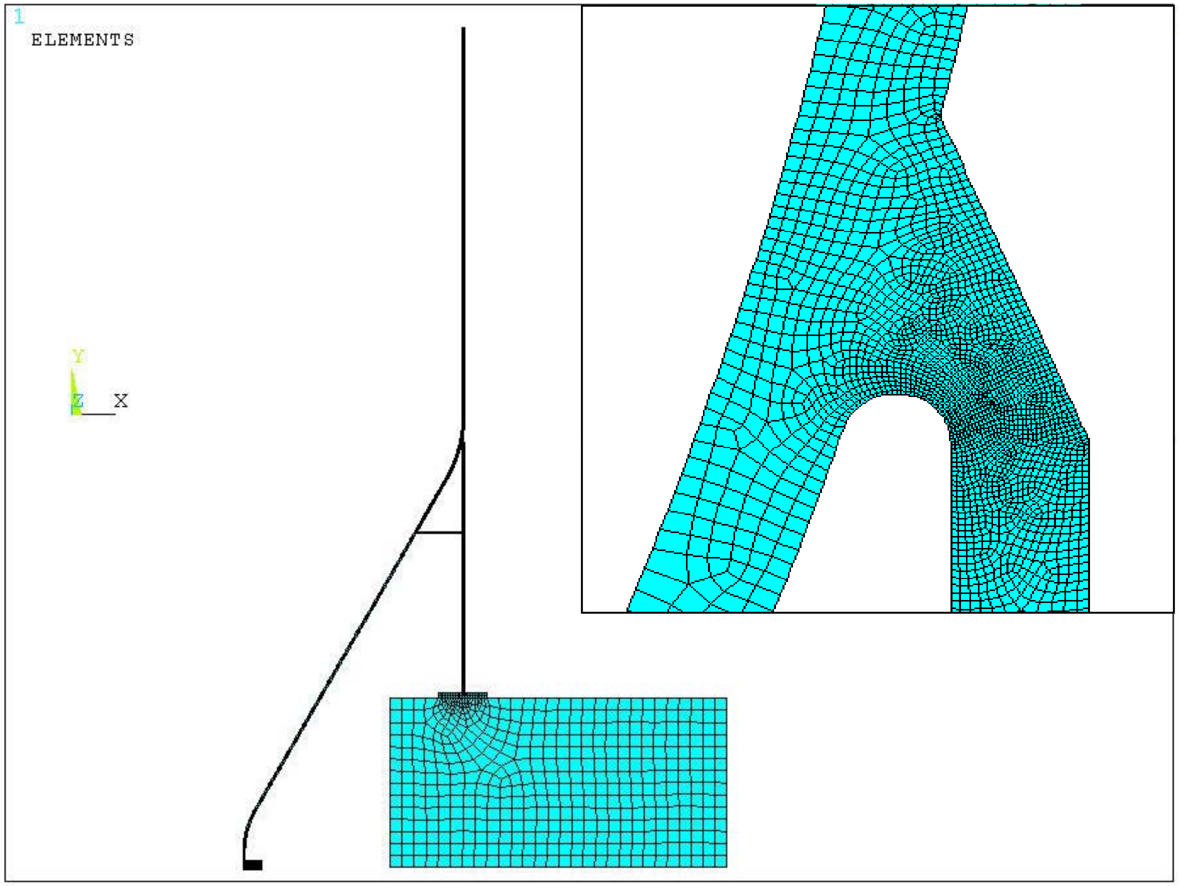
Axisimetric Model (element: 8 nodes - PLANE77)

t_{sh}=25,4mm

t_{cone}=25,4mm

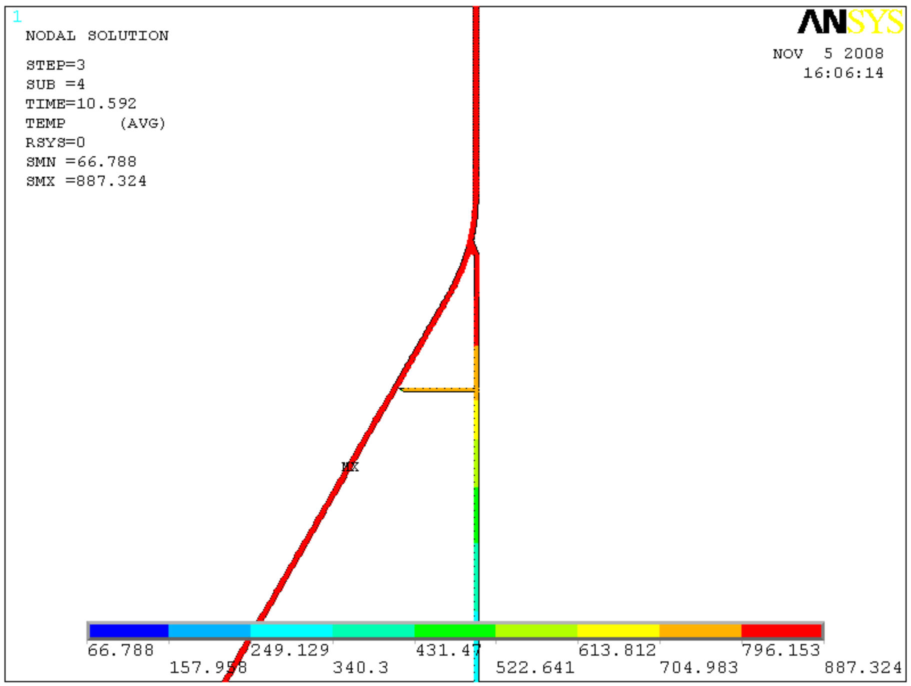
t_{saia}=25,4mm

D_{int}=6400 mm

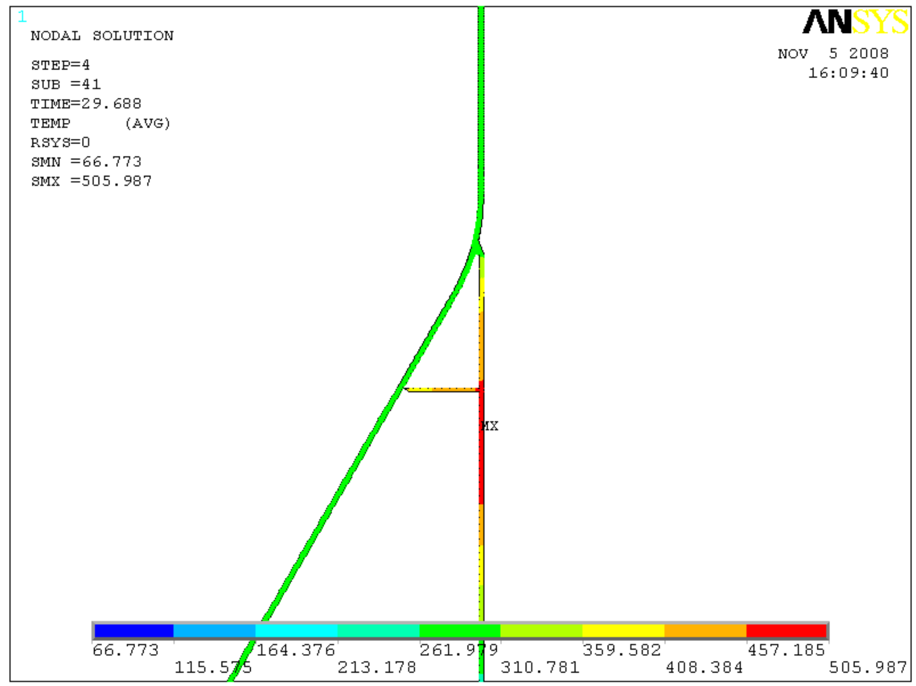


Thermal analysis – Results

Filling step



Quenching step (*)

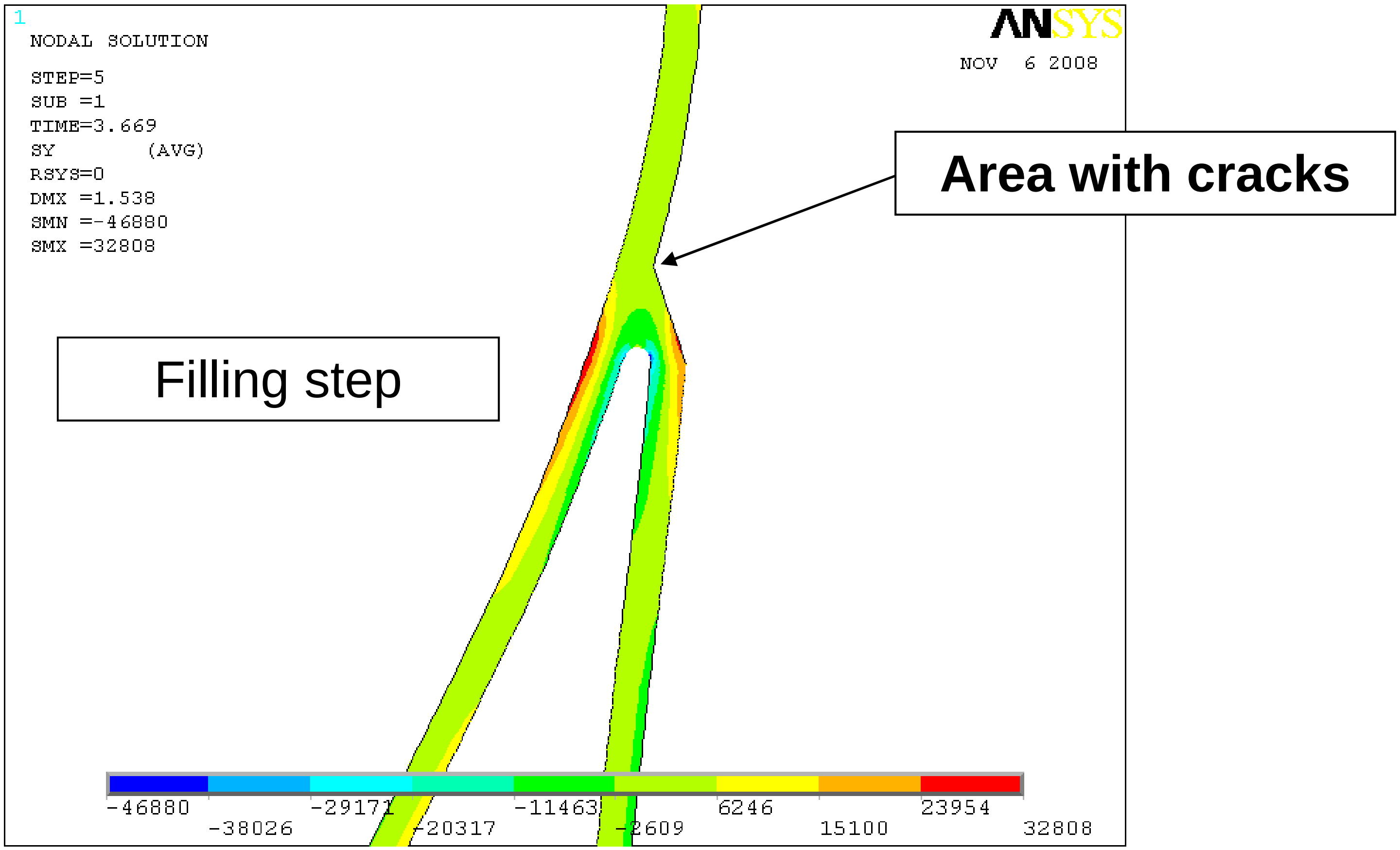


(*) It was not considered the specific effect of the increasing of the level of water along the time during the quenching step, which is supposed to influence the gradient of temperature in the vicinity of the weld and consequently the stress field.

Fatigue evaluation of welding "Type 1"

Stresses (psi) due to the thermal transient

(It was not considered the water cooling transient effect along the model)(*)



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Fatigue evaluation of welding "Type 1"

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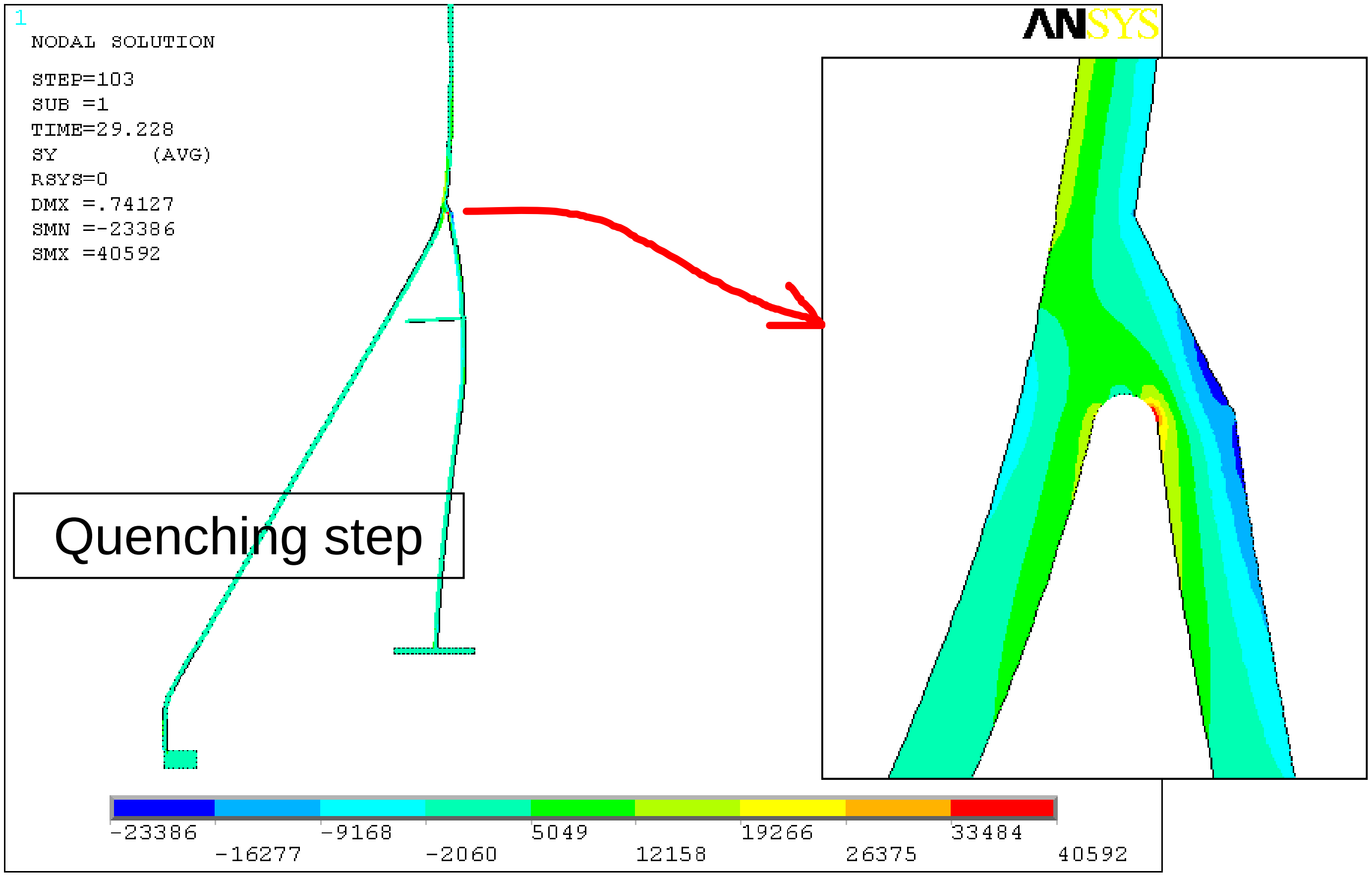


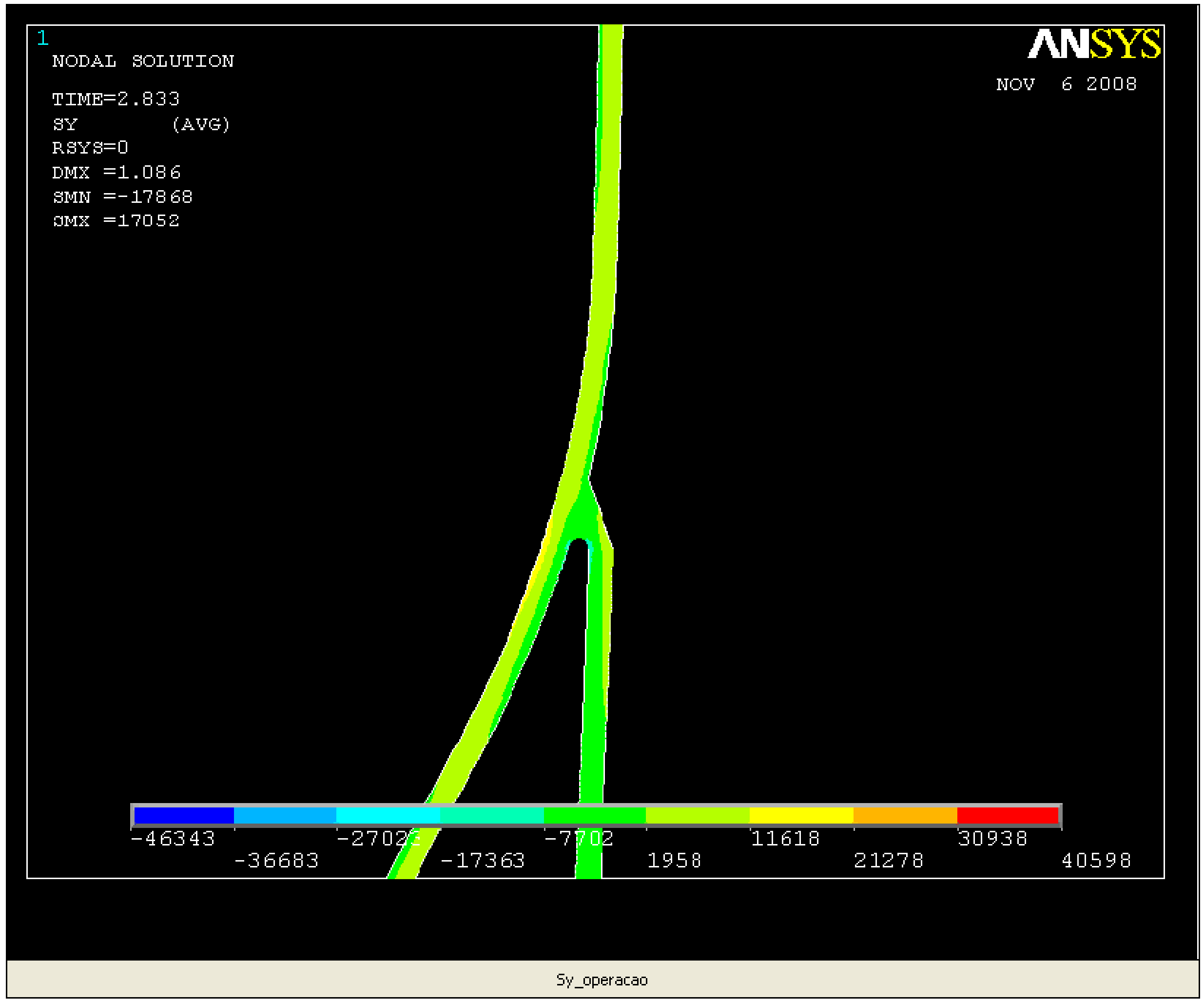
(*) It was not considered the specific effect of the increasing of the level of water along the time during the quenching step, which is supposed to influence the gradient of temperature in the vicinity of the weld and consequently the stress field.

Fatigue evaluation of welding "Type 1"

Stresses (psi) due to the thermal transient

(It was not considered the water cooling transient effect along the model) (*) (Moving of the cyclic operation)

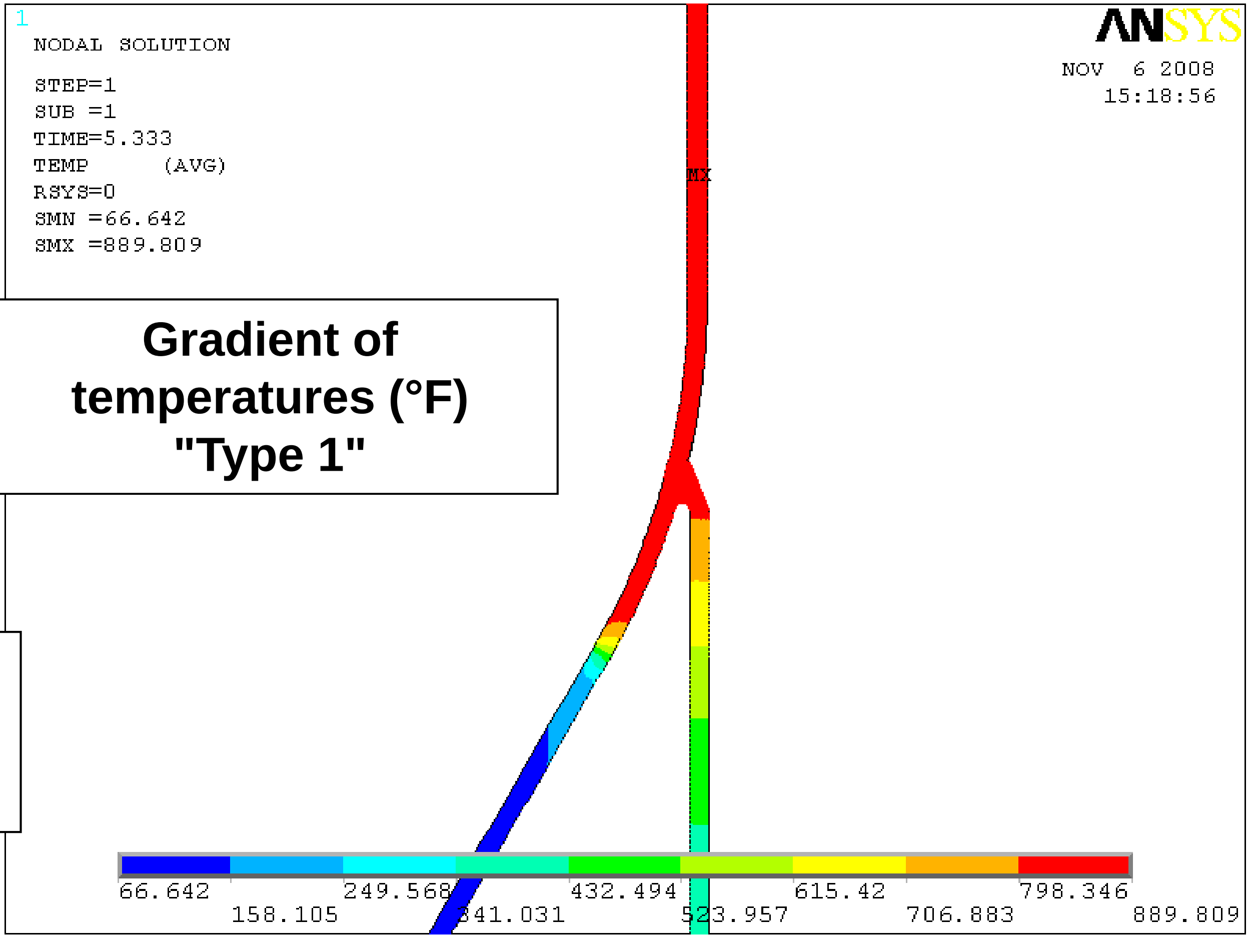
(*) It was not considered the specific effect of the increasing of the level of water along the time during the quenching step, which is supposed to influence the gradient of temperature in the vicinity of the weld and consequently the stress field.



Fatigue evaluation of welding "Type 1"

Gradient of temperature which causes the maximum stress at the weld

(It was considered the water cooling transient effect along the model) (*)



Gradient of temperatures (°F) "Type 1"

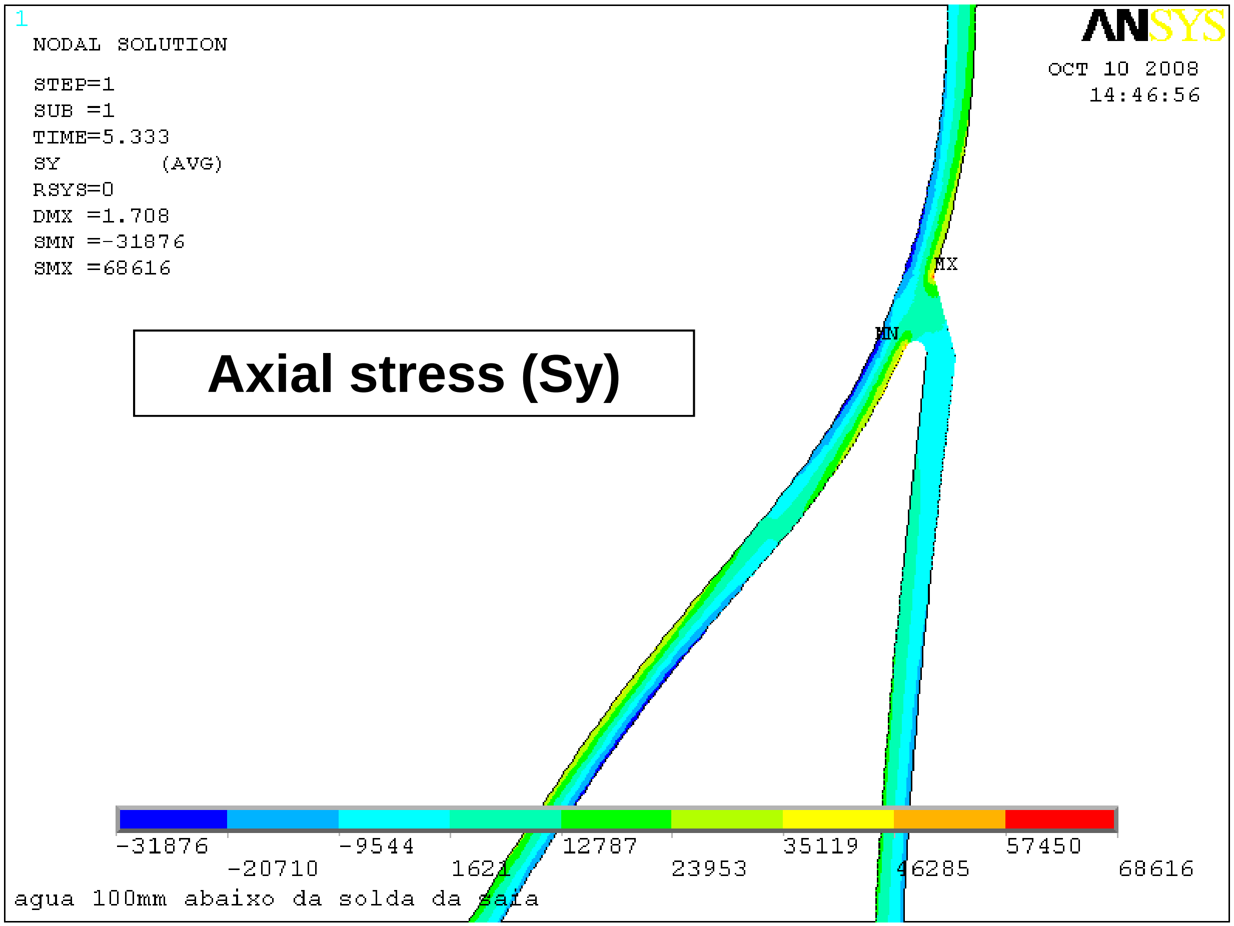
(*) It was considered the specific effect of the water level rising along the time during the quenching step.

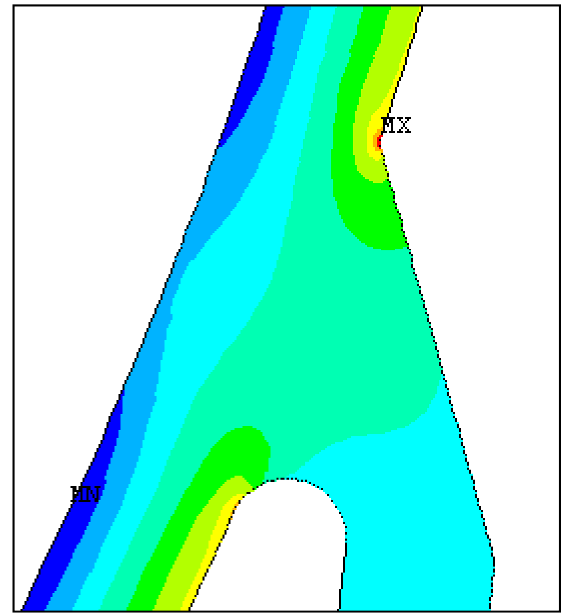
Plotting at the time which the water level was 100mm below the welding

Fatigue evaluation of welding "Type 1"

Maximum stresses (psi) due to the worse gradient of temperature

(It was considered the water cooling transient effect along the model) (*)





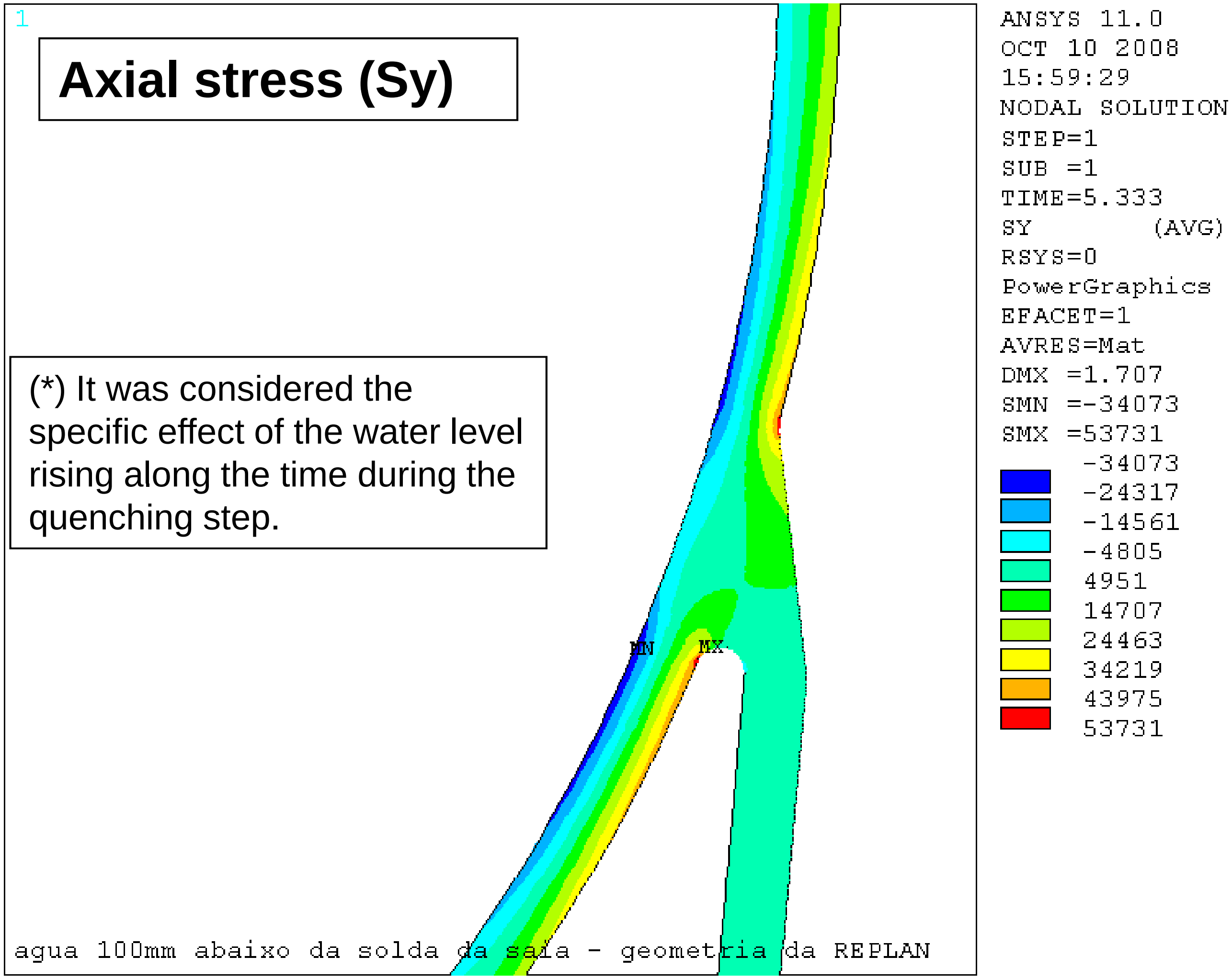
(*) It was considered the specific effect of the water level rising along the time during the quenching step.

Plotting at the time which the water level was 100mm below the welding

Fatigue evaluation of welding "Type 2"

Maximum stresses (psi) due to the gradient of temperature

(It was considered the water cooling transient effect along the model) (*)



Plotting at the time which the water level was 100mm below the welding

Fatigue evaluation of the 2 types of weldings

Time to initiate a crack according to ASME VIII-2

Location – External surface of the welding (Real case of study).

Type 1:

Radial stress range Sy: 68616 – (-9168) = 77784 psi

The radial stress range is low ➔ The equivalent stress range (TRESCA) is 77784Psi

The stress range above needs to be corrected using the modulus the elasticity ratio to take in consideration the average temperature of 315°C.

Then, acc. to ASME VIII-2:

$$Salt = K_f * K_e * 77784 * (E_{amb}/E_{315})/2 = 42962 * K_f * K_e \text{ [Psi]}$$

Since $(P_L+Pb+Q) > S_{PS}$, then, $Ke = 1.7$

So, *Salt* increases to $\cong$73 Ksi.

Resulting in an estimated lifetime for “Type 1” weld build up ➔ 1600 cycles

Fatigue evaluation of the 2 types of weldings

Time to initiate a crack according to ASME VIII-2

Location – External surface of the welding (Real case of study).

Type 2:

Longitudinal stress range Sy: 53731 – (-3472) = 57203 psi

The radial stress range is low ➔ The equivalent stress range (TRESCA) is 57203Psi

The stress range above needs to be corrected using the modulus the elasticity ratio to take in consideration the average temperature of 315°C.

Then, acc. to ASME VIII-2:

$$Salt = K_f*K_e*57203*(E_{amb}/E_{315})/2 = 31596*K_f*K_e \text{ [Psi]}$$

In this case, (PL+Pb+Q) < S_{PS}, then, *Ke* = 1.0.

So, *Salt* is 32 Ksi.

Resulting in an estimated lifetime for “Type 2” weld build up ➔ 10500 cycles

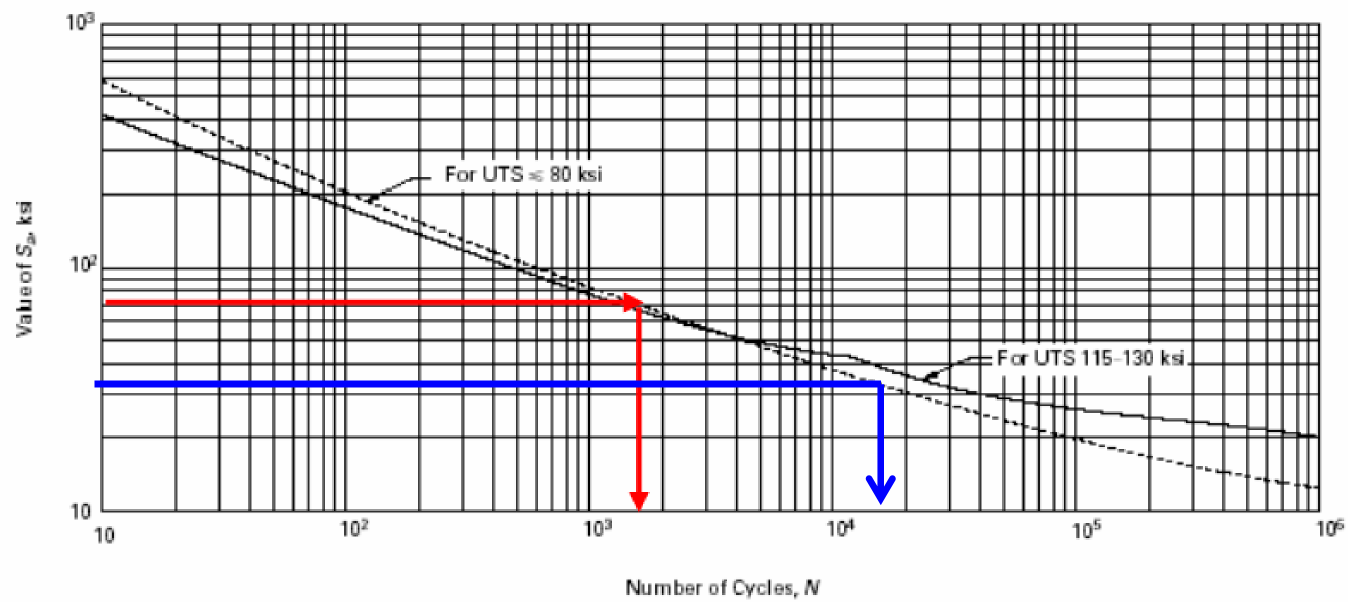
Fatigue evaluation of the 2 types of weldings

Time to initiate a crack according to ASME VIII-2

Location – External surface of the welding (Real case of study).

Type 1:

Type 2:



GENERAL NOTES:
(a) $E = 30 \times 10^6$ psi.
(b) Interpolate for UTS 80.0-115.0 ksi.
(c) Table 5-110.1 contains tabulated values and a formula for an accurate interpolation of these curves.

FIG. 5-110.1 DESIGN FATIGUE CURVES FOR CARBON, LOW ALLOY, SERIES 4XX, HIGH ALLOY STEELS AND HIGH TENSILE STEELS FOR TEMPERATURES NOT EXCEEDING 700°F AND $N \leq 10^6$ (USE FIG. 5-110.1.1 FOR $N \geq 10^6$)

Fatigue Crack Propagation from a initial crack at the top of skirt to shell weld via CrackWise program

Project Information

Current input file	C:\Program Files (x86)\TWI Software\Crackwise 4.1\crackwise.cwt
Project title	Análise trinca na solda da saia tambor REGAP
Date	7/11/2008
Calculation type	Fracture and Fatigue
Assessment level	Level 2

Comments

O range de tensão usado considera o efeito combinado térmico + pressão.

Efeito térmico: deltaPm = 152 MPa e deltaPb = 378 MPa

Efeito de pressão: deltaPm = 12 MPa e deltaPb = 72 MPa

Flaw Dimensions

Flaw height, a	2	mm
Flaw length, 2c	1000	mm
Parametric angle	Max	

Fatigue Crack Propagation from a initial crack at the top of skirt to shell weld via CrackWise program

Toughness (K)

Toughness	110	MPa √ m

Fatigue Crack Growth Constants

Data source	BS 7910 recommended
Stress ratio	Weld
Environment	Air
Material type	Steel induding austenitic

Delta K	m	A
63	5,1	2,1E-17
144	2,88	1,29E-12

Fatigue Stress Spectrum

SCFm	1	**SCFb**	1
Blocks	20	**Increment**	1000

Cycles	Delta Pm MPa	Delta Pb MPa
200	152	378

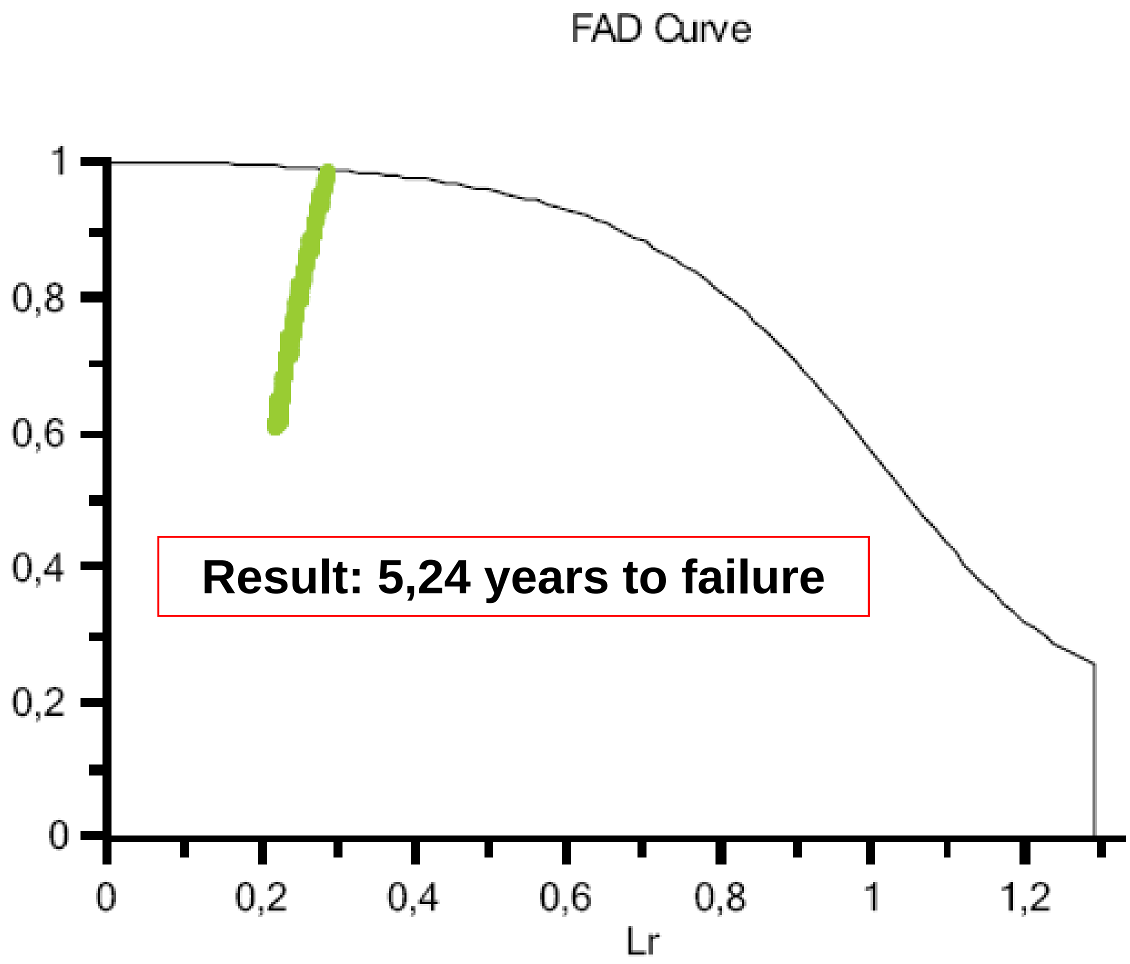
Fatigue Crack Propagation from a initial crack at the top of skirt to shell weld via CrackWise program

Fracture Results

Assessment results	Kr	Lr	Qm		Qb		Errors
Acceptable	0,9856	0,2891	210	MPa	333	MPa	

Fatigue Results

Blocks of spectrum used	5,24	
Final Flaw height (a)	5,5311	mm
Final Flaw length (2c)	1000	mm



Conclusion:

A initial crack of 2mm x 1000mm (height x length) at the top of skirt to shell weld (external surface) would last 5 years to become critical. Then all cracks were removed by mean of grinding and repaired using INCONEL A.

This work showed the hole of a well-done design of the weld build-up, including its geometry, so as to reduce the local stress concentration and the risk of thermal fatigue.

The simulation of the quenching step, considering the water level rising along the cycle, is extremely important to preview and avoid the fatigue problem reported in this paper.

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