HSNA104 – Detensioning of heterogeneous joints welded by friction

Summary:

This CAS-test corresponds to part of the study described in the note [bib1]. It constitutes a validation of the thermomechanical models of behavior taking account of the metallurgical transformations with cooling in steels. It is the simulation of the phase of cooling of the detensioning of bimetallic joints Steel 16MND5 – Stainless steel 304L welded beforehand by friction, in order to determine the residual stresses generated at the end of this cooling. The linear calculation of thermics of the homogeneous phase of cooling is first of all carried out, then the metallurgical evolution in the 16MND5 is calculated (transformation of the ferritic type). After which the simulation of the mechanical problem taking account of the metallurgical transformations of phases is carried out by applying at the beginning of the phase of cooling a state of stresses no one (released perfectly) in the structure.

Mechanical modeling is carried out by taking account of decarburization with interface 16MND5-304L and the plasticity of transformation. The behavior is elastoplastic with linear isotropic work hardening for the 16MND5 (all phases), and elastoplastic with nonlinear isotropic work hardening for steel 304L.

The results in residual stresses obtained in external skin are compared with results of measurement carried out by diffraction of X-ray [bib1].

1 Problem of reference

1.1 Geometry

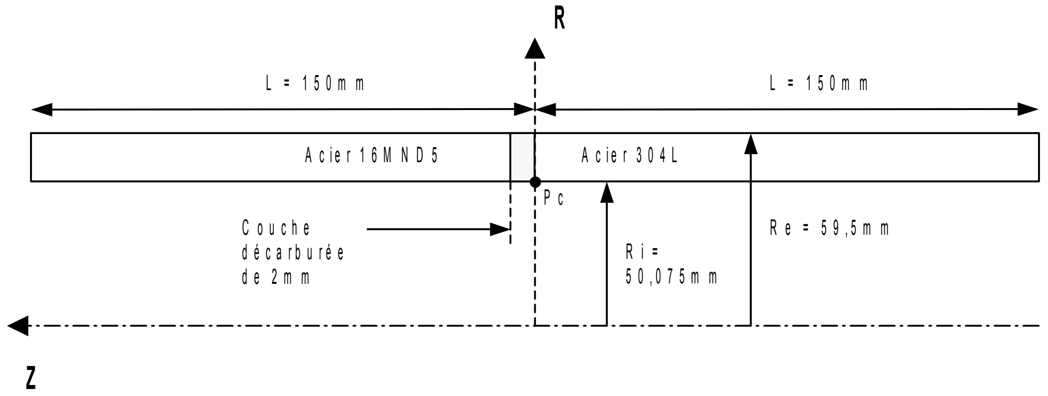

Figure 1. : Geometry of the tubes

Dimension of the tubes:

- Interior ray: $50{,}075\,mm$
- External ray: $59{,}5\,mm$
- Thickness: $9{,}425\,mm$
- Overall length 2L: $300\,mm$

1.2 Properties of materials

The welded tubes are out of steel 16MND5 of dimensioned and steel 304L of the other. The mechanical properties vary with the temperature for these two materials. They are given, as well as the metallurgical properties for the 16MND5 in the reference [bib1].

A decarburization is observed with interface 16MND5-304L, which results in experiments in a fall of Vickers pyramid hardness of $250\,HV$ with 2mm interface, until $130\,HV$ on the interface.

1.3 Boundary conditions and loadings

Thermal calculation : Continuous homogeneous cooling of $875°C$ with $20°C$

Metallurgical calculation :
Transformation of austenite into ferrite in the 16MND5 enters $758{,}5°C$ and $650{,}5°C$
Pas de transformation in stainless.

Mechanical calculation :
1) Not PC blocked in the direction Z
2) Loading in temperature

1.4 Initial conditions

$$T(r,z)=875°C.$$

Steel 16MND5 is entirely austenitic in an initial state is: $Zf=0$, $Zp=0$, $Zb=0$ and $Zm=0$.

2 Reference solution

There does not exist analytical solution. However experimental results are available (residual stress measurements in external skin by diffraction of X-rays [bib1]).

2.1 Bibliographical references

[1] With. BEBEY-FOURCOT, F. WAECKEL, Note EDF DER HI-74/97/028/0. Digital simulation of heterogeneous joints welded by friction (January 19th, 1998).

3 Modeling A

3.1 Characteristics of modeling

Axisymmetric modeling

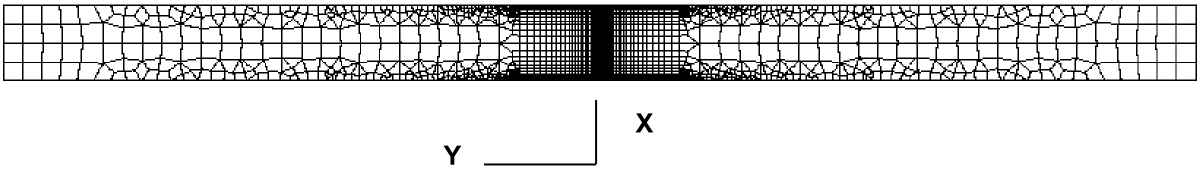

Figure 4.1-a: Total grid of the tube

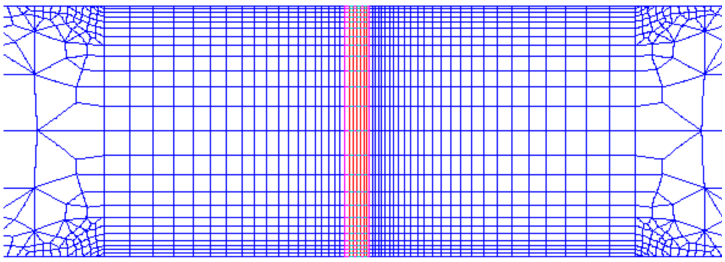

Figure 4.1-b: Enlarged grid of junction 16MND5-304L and detail of the interface and the decarbonized zone

The elementary density of nodes near the interface is of $0{,}2\,mm$ to allow a good representation of the peaks of constraints expected this place.

3.2 Characteristics of the grid

Many nodes: 6513
Many meshs and types: 2616 including 1908 `QUAD8`, 204 `TRIA6`, 504 `SEG3`

3.3 Remarks

- Linear isotropic work hardening for steel 16MND5 (any confused phase): the elastic limit defined according to the temperature is the elastic limit with 0% of plastic deformation. The linear slope of work hardening (according to the temperature) is the slope with $0{,}5\%$ of plastic deformation.
- Nonlinear isotropic work hardening for steel 304L
- The fall of hardness in the decarbonized zone is taken into account in modeling by a reduction in the elastic limit of steel in this zone. To evaluate the reduction in the elastic limit according to measurements of hardness, one applies that for the same metallurgical structure, the Rm/SY report remains constant, and that the value of Rm is worth one the third of measured hardness [bib1].

- 26 pas de calculation of 0 with $154000\ s$ (1 pas de $9000\ s$; 4 pas de $36000\ s$; 10 pas de $54000\ s$; 7 pas de $118000\ s$; 4 of 154000s).

3.4 Sizes tested and results

Node	Localization	Type of value	Aster	Measurement	Variation (%)
N674	External skin (X = 59,5mm) Y = + 44.515 mm	SIYY	64.245	60.23	6.7
N882	External skin (X = 59,5mm) Y = + 30.493 mm	SIYY	113.819	99.58	14.3
N1316	External skin (X = 59,5mm) Y = + 20 mm	SIYY	141.806	119.07	19.1
N1834	External skin (X = 59,5mm) Y = + 9.657 mm	SIYY	169.971	109.07	55.8
N2278	External skin (X = 59,5mm) Y = + 4.739 mm	SIYY	213.459	153.34	39.2
N2719	External skin (X = 59,5mm) Y = + 1.872 mm	SIYY	258.022	188.54	13.6
N3755	External skin (X = 59,5mm) There = - 1.872 mm	SIYY	-230.442	-181.92	26.7
N4199	External skin (X = 59,5mm) There = - 4.739 mm	SIYY	-209.876	-220.18	-4.7
N4525	External skin (X = 59,5mm) There = - 9.657 mm	SIYY	-180.092	-174.06	3.5
N4742	External skin (X = 59,5mm) There = - 20 mm	SIYY	-166.688	-190.52	-12.5
N5458	External skin (X = 59,5mm) There = - 30.493 mm	SIYY	-140.201	-145.52	-3.7
N5759	External skin (X = 59,5mm) There = - 44.515 mm	SIYY	-81.641	-87.00	-6.2

Node	Localization	Type of value	Aster	Measurement	Variation (%)
N674	External skin (X = 59,5mm) Y = + 44.515 mm	SIZZ	30.937	40.35	-23.3
N882	External skin (X = 59,5mm) Y = + 30.493 mm	SIZZ	23.686	61.39	-61.4
N1316	External skin (X = 59,5mm) Y = + 20 mm	SIZZ	-9.541	48.03	-119.8
N1834	External skin (X = 59,5mm) Y = + 9.657 mm	SIZZ	-70.264	7.78	-1003
N2278	External skin (X = 59,5mm) Y = + 4.739 mm	SIZZ	-104.430	-64.98	60.71
N2719	External skin (X = 59,5mm) Y = + 1.872 mm	SIZZ	-75.962	-98.83	-23.1
N3755	External skin (X = 59,5mm) There = - 1.872 mm	SIZZ	15.857	29.26	-45.8
N4199	External skin (X = 59,5mm) There = - 4.739 mm	SIZZ	26.372	-26.56	-199.3
N4525	External skin (X = 59,5mm) There = - 9.657 mm	SIZZ	40.284	53.15	-24.2
N4742	External skin (X = 59,5mm) There = - 20 mm	SIZZ	9.290	39.47	-76.5
N5458	External skin (X = 59,5mm) There = - 30.493 mm	SIZZ	-23.355	-16.58	40.9
N5759	External skin (X = 59,5mm) There = - 44.515 mm	SIZZ	-34.912	-40.32	-13.4

4 Summary of the results

The values of calculated constraints are in concord with the measured profiles of constraints, which comprise them even a rather high uncertainty (cf curves below).

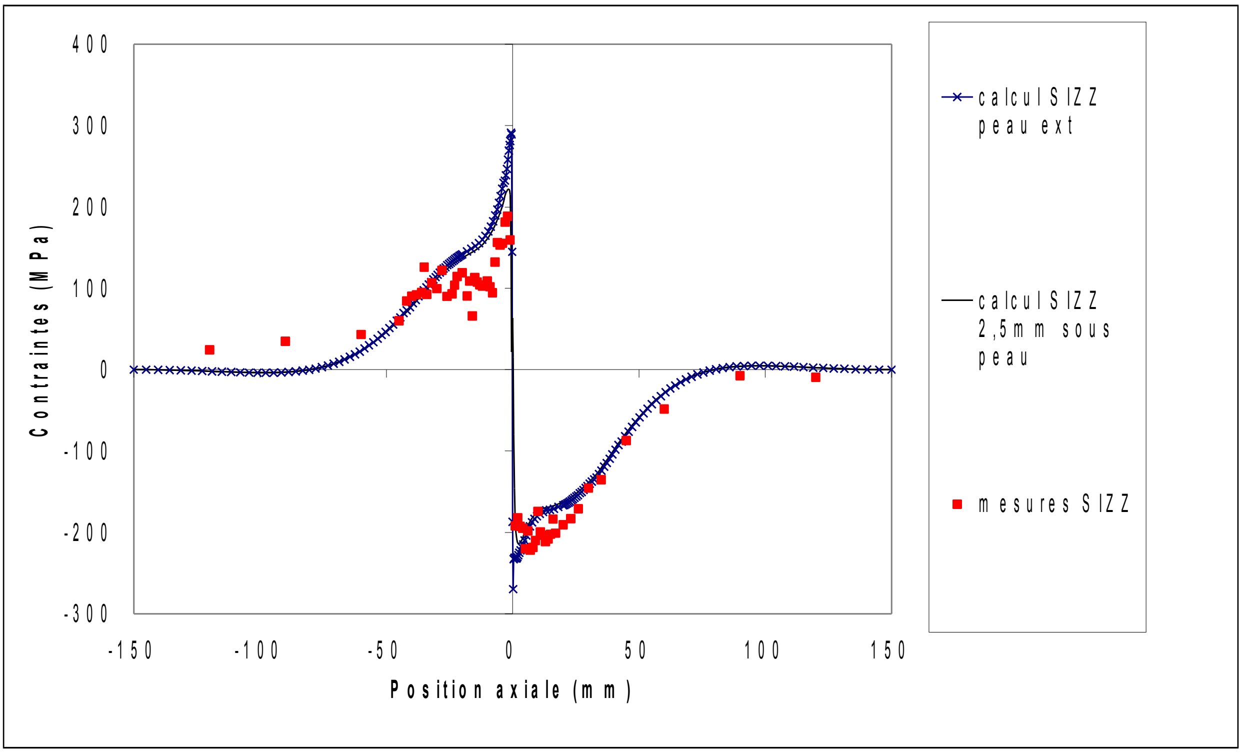

Figure 4.1: Profile of the longitudinal stresses calculated and measured in external skin

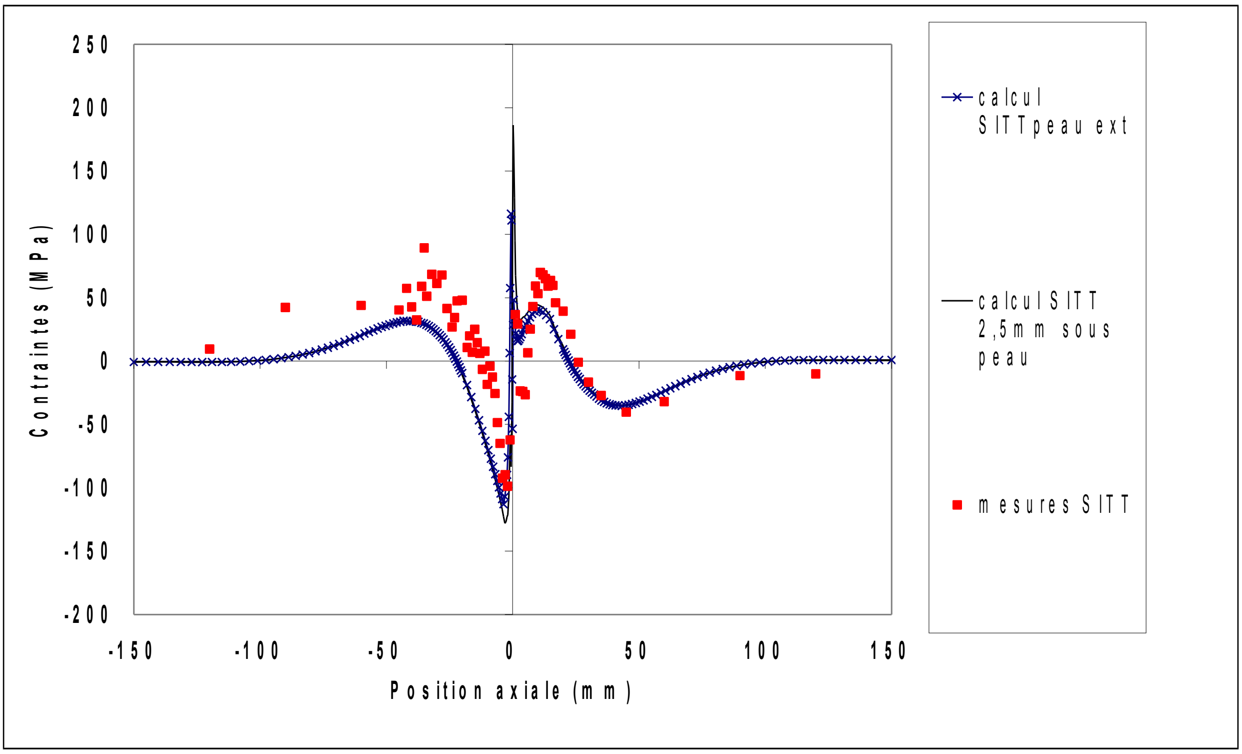

Figure 4.2: Profile of the circumferential stresses calculated and measured in external skin