MTLP103 - Soak of a cylindrical Summarized steel 16MND5 bar

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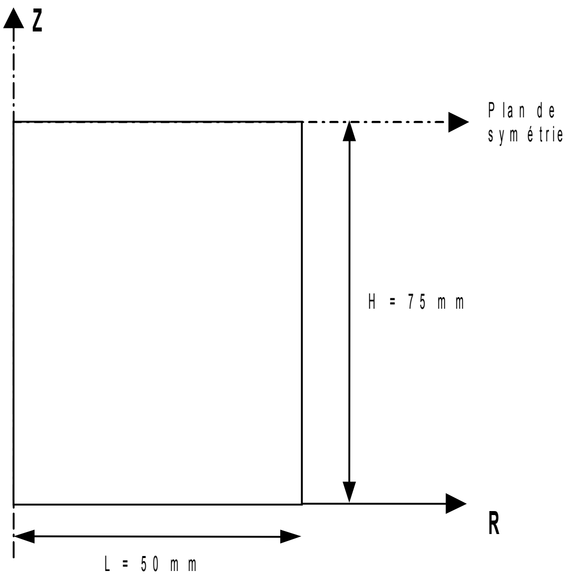
This benchmark constitutes a validation of the models of transformations metallurgical to cooling in steels. It is the hardening of a cylindrical steel 16MND5 bar, for which experimental data of measurements of final hardnesses are available. The computation of nonlinear thermal of the phase of cooling is first of all carried out from the identification of a thermal coefficient of heat exchange (when the bar is in the air), then of one density flux surface function of time on the external border (during hardening). These boundary conditions were identified thanks to temperature measurements by thermocouples taken during the test. The computation of the metallurgical evolution is then carried out in postprocessing of thermal computation. The values of calculated final hardnesses (dependant on the proportions of formed phases) are compared with the mesures taken in various points of the section of the bar.

1 Problem of reference

1.1 cylindrical



Geometry Bar:

Total height: $2H=150\,mm$
Diameter: $2L=100mm$

1.2 Properties of the material

the bar is out of steel 16MND5. The thermal properties (conductivity and enthalpy of the material) vary with the temperature and are given in [bib1].

Coefficients for the metallurgy:

“ Standard” TRC

$AR3=830°C$ $alpha=-0.0249$
$MS0=415°C$ $AC1=724°C$ $AC3=846°C$
$\tau_1=0.034$, $\tau_3=0.034$

Microhardness of the various metallurgical phases:

for ferrite $d=184.\,HV$
for the pearlite $d=184.\,HV$
for bainite $d=309.\,HV$
for martensite $d=450.\,HV$
for austenite $d=100.\,HV$

1.3 Boundary conditions and loadings

thermal Coefficient of heat exchange with outside during 14 dryness. (before hardening) fixed on the temperature measurements by thermocouples:

Time (s)	$H(W.m^{-2}.°C^{-1})$
0.	100.
13.100	.
14.	10000.

$T_{\infty}=25°C$

Surface density of heat flux function of the températuresur T borders (during hardening) fixed on the temperature measurements:

$T(°C)$	25.	50.	100.	150.	200.	250.300	.
Flux $(W.m-2)$	0. E+06	-0.03 E+06	-0.08 E+06	-0.16 E+06	-0.71 E+06	-1.51 E+06	-1.99 E+06

$T(°C)$	350.	400.	450.	500.	550.	600.
Flux $(W.m-2)$	-2.53 E+06	-3.34 E+06	-3.78 E+06	-6. E+06	-7. E+06	-7.9 E+06

1.4 Initial conditions

$T(r,z)=906°C.$

Bar entirely austenitized in an initial state is $Zf(r,z)=0.$ $Zp(r,z)=0.$, $Zb(r,z)=0.$ and $Zm(r,z)=0.$

2 Reference solution

It does not exist of analytical solutions. However experimental results are available (measurements of hardness).

2.1 Results of reference

Thermal computation: Temperature at the points T0, T9, T10 at metallurgical $t=13s, 20s, 30s,$

time Computation: Profiles of hardness to $t=240s$ for the segments H5, H10, H15, H25, H35, H38, H45, H55, H65, and H75.

2.2 Bibliographical references

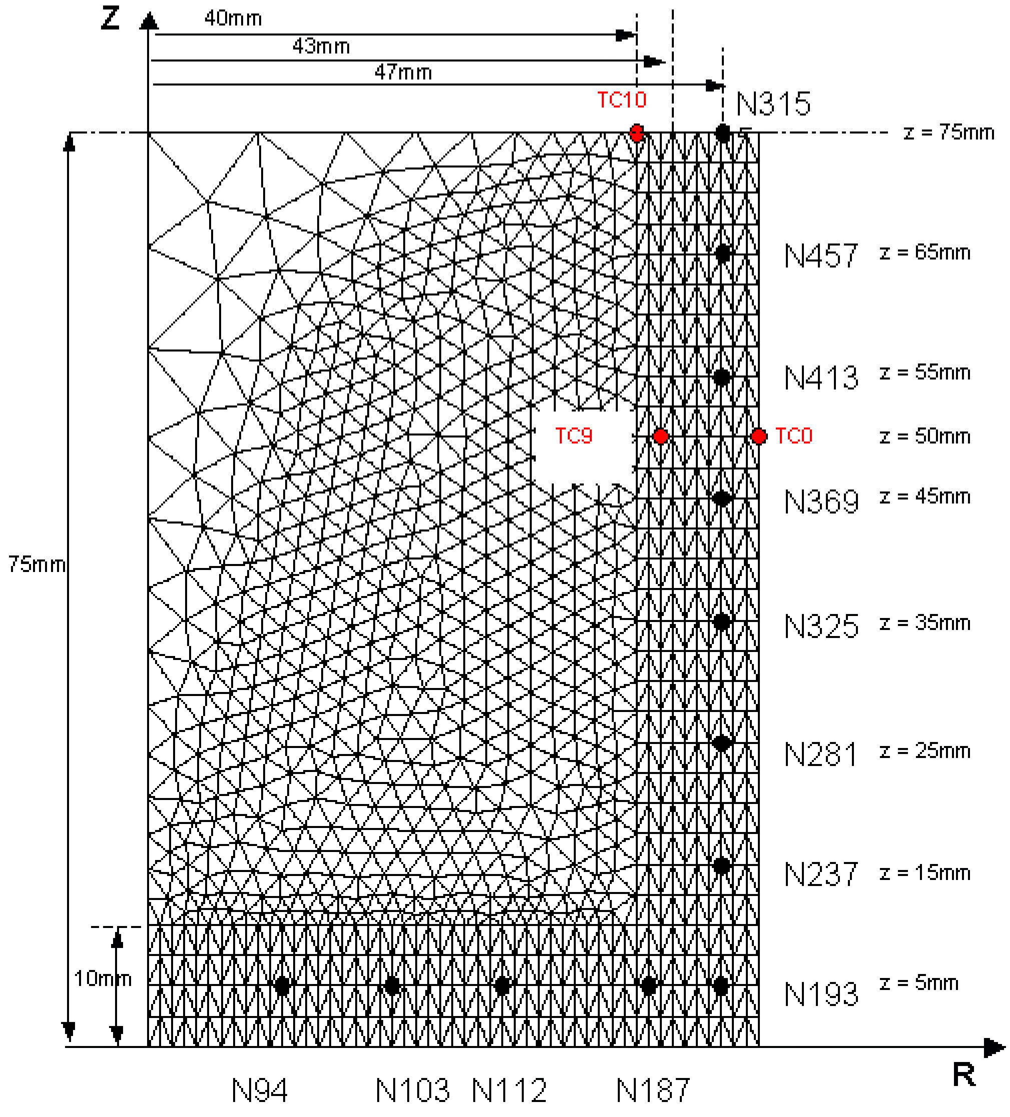
[1] A. BEBEY-FOURCOT, F. WAECKEL, Note EDF DER HI-74/98/003/0. Validation of the metallurgical models of the Code_Aster via the simulation of two hardenings (July 10th, 1998).

3 Modelization A

3.1 Characteristic of the axisymmetric

modelization Modelization

By reason of symmetry, one nets only one half-section.



Boundary conditions:	On Z = 75 mm	Adiabatic (symmetry: null flux) $\phi=0$
	on X = 50mm and Z = 0mm	Of 0 with 14s: $-\lambda\cdot\partial T/\partial n=h(T(r,z,t)-T_{\infty})$ of 14s with 240s: $-\lambda\cdot\partial T/\partial n=F(T(r,z,t))$

3.2 Characteristics of the mesh

Many nodes: 4316
Number of meshes and types: QUAD8, SEG3

3.3 Remarks

105 computation steps from 0 to 240 S (60 steps of 1 S, then 45 steps of 4 S).

3.4 Quantities tested and results

Fields `TEMP` and `DURT_ELNO` :

TPN: Temperature with node
HV: hardness of Vickers

Identification	Quantity	*Aster*
T = 13s, Node TC0	TPN	871,348
T = 20s, Node TC0	TPN	291,800
T = 30s, Node TC0	TPN	226,905
T = 13s, Node TC9	TPN	890,128
T = 20s, Node TC9	TPN	608,298
T = 30s, Node TC9	TPN	432,164
T = 13s, Node TC10	TPN	895,338
T = 20s, Node TC10	TPN	717,098
T = 30s, Node TC10	TPN	520,166

Position	Node	nets	Quantities	*Aster*	measurements	Variation (%)
Z (mm) = 5						
R (mm) = 11	N94	M101	HV	361,145	398	-9,3 (relative)
R (mm) = 20	N103	M120	HV	365,324	404	-9,6 (relative)
R (mm) = 29	N112	M137	HV	371,928	408	-8,8 (relative)
R (mm) = 41	N187	M341	HV	408,118	413	-1,2 (relative)
R (mm) = 47	N193	M353	HV	432,139	427.1,2	(relative)

Position	Node	nets	Quantities	*Aster*	measures	Variation (%)
H =15; R=41	N231	M421	HV	374,327	381	-1,8
H =15; R=47	N237	M433	HV	400,68	401	-0,1
H=25; R=41	N275	M501	HV	359,687	355.1,3	
H=25; R=47	N281	M513	HV	392,703	396	-0,8
H=35; R=41	N319	M581	HV	346,007	345.0,3	
H=35; R=47	N325	M593	HV	391,844	425	-7,8
H=45; R=41	N363	M661	HV	344,908	335.3,0	
H=45; R=47	N369	M673	HV	391,77	425	-7,8
H=55; R=41	N407	M741	HV	345,728	370	-6,6
H=55; R=47	N413	M753	HV	391,836	430	-8,9
H=65; R=41	N451	M821	HV	346,752	350	-0,9
H=65; R=47	N457	M833	HV	391,863	410	-4,4
H=75; R=41	N3148	M901	HV	346,871	330.5,1	
H=75; R=47	N3154	M913	HV	391,842	425	-7,8

average (H=35; H=75)	Quantities	aster	measures	Variation (%)
R=41	HV	346,0532	346.0,0	
R=47	HV	391,831	423.7,4	

4 Summary of the results

the comparison CALCUL-measurements in terms of hardness is satisfactory (less than 10% of relative variation). This benchmark thus makes it possible the model to validate behavior with the cooling of steel.