QUARTERLY REPORT

Project WP#339: Structural Significance of Mechanical Damage

For Period Ending: November 30, 2008

Contract No: DTPH56-08-T-000011

Prepared For: United States Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Pipeline Safety

Prepared By: Aaron Dinovitzer
Principal Investigator
BMT Fleet Technology Limited
311 Legget Drive
Kanata, Ontario, Canada K2K 1Z8
613 - 592 - 2830 ext 203
adinovitzer@fleetech.com

Mures Zarea, Rémi Batisse
Principal Investigators
GDF SUEZ, R&I Department
361 Ave du President Wilson
B.P. 33, 93211 Saint-Denis, France
+3-366-413-5637
mures.zarea@gdfsuez.com
remi.batisse@gdfsuez.com

Mr. Ian Wood
Team Project Manager
Electricore, Inc.
27943 Smyth Drive, Suite 105
Valencia, CA 91355
ian@electricore.org

Mark Piazza
Team Technical Coordinator
Pipeline Research Council, International
1401 Wilson Blvd., Suite 1101
Arlington, VA 22209
mpiazza@prci.org

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ELECTRICORE

PRCI LEADING PIPELINE RESEARCH

Milestone and Deliverable Accomplishments this Reporting Period

Task No.	Task	Scheduled Completion Date	Completed Date	Milestone
1	Project Kick Off Meeting and Subcontracting	8/31/2008	8/31/2008	
2	Purchase & Characterize Pipe Material	11/30/2008	Ongoing	
3	Literature Review	11/30/2008	Ongoing	
4	Testing of Dents on Welds and Corrosion Features	11/30/2009	Ongoing	MS
5	Testing of Dents with Gouges	5/31/2010	Ongoing	MS
6	Demonstration of Mech. Damage Model Performance	5/31/2009	Not Yet Started	
7	Industry Workshop	5/31/2010	Not Yet Started	
8	Project Management and Reporting	5/31/2010	Ongoing	MS

Technical Status

Technical activities undertaken through the second quarter focused on the following tasks:

Task 2: Purchase & Characterize Pipe Material
Task 3: Literature Review
Task 4: Testing of Dents on Welds and Corrosion Features
Task 5: Testing of Dents with Gouges

A summary of the technical status and results or conclusions to date are presented below for each of these tasks.

The technical group for this program has maintained close communication to ensure program coordination. Issues of concern in the program have been forwarded to PRCI and DOT for their consideration.

Task 2: Purchase & Characterize Pipe Material

Technical Status

The entire program comprises 3 different pipe steels called:

- Pipe 1
- Pipe 2
- Pipe 3

GDF SUEZ has received three pipes of 11.8 meters length of Pipe 1 and two pipes of 11.8 meters length of Pipe 2. These pipe steels are current steels, one specified API X52 grade and the second API X70 grade. The diameter of all pipes is 24'' and the thicknesses are 7.9mm for the X52 grade (Pipe 1) and 9.0mm for the X70 grade (Pipe 2). The pipes are manufactured by IPSCO with ERW process.

In the first quarterly report, GDF SUEZ presented material characterization results for Pipe 1:

- Tensile properties;
- Charpy V impact values in different directions at room temperature;

- Toughness J Curve;
- Size of slip bands.

The study concerning the pre-strain effect on toughness is continuing and the following material characterizations have been launched:

- Tensile properties
- Charpy V impact values in different directions at room temperature;

The full report with all results is not yet available because the testing and characterization work are not yet completed. This information is expected to be included in the next quarterly report (3rd quarter).

Progress was made regarding the identification of pipe materials to represent older/vintage pipe for completing the testing program. A source has been identified for the manufacture of pipe with material properties replicating the observed lower toughness of 1950's or 1960' era linepipe, and cost/schedule data has been collected. The procurement schedule will meet the requirements of the project, as the materials manufactured would be available. However, the cost is substantially more than the funding allotted in the project budget for this task. One of the primary costs drivers is the need to purchase the entire heat of steel from the manufacturer. The additional steel would likely prove to be a substantial benefit to other research projects investigating various forms of degradation or damage to older pipeline steel.

The Project Technical Team has discussed the procurement of the vintage pipe with PHMSA. During the project kick-off meeting, PHMSA indicated a strong preference for the use of a manufactured pipe for the project testing rather than a vintage pipe removed from service (from a PRCI member company), as a manufactured pipe with vintage properties would not have been subjected to variations and unknown conditions during its operating history. The additional costs for the manufactured piping option have been raised with PHMSA, and the Project Technical Team is preparing a summary plan outlining the steel procurement justification and cost analysis.

Task 3: Literature Review

Technical Status

There is no substantive additional information pertaining to the literature review task to report. Any new information on pre-strain effect on toughness and on realistic defects from field feedback will be captured as it becomes available from other sources.

Task 4: Testing of Dents on Welds and Corrosion Features

Technical Status

The testing procedure, measurements and measurement systems/equipment, reporting and schedule details have been clarified and documented to allow testing to begin. The testing process will make use of a new higher capacity water pump purchased for this project and will increase the rate of testing in the program.

Results and Conclusions

Testing will commence in the next quarter with the first six test specimens being instrumented to capture the dent strain responses. An analysis of costs to more completely instrument the test specimens and add 100% radiographic inspection of welds is being prepared and will be forwarded to PRCI and DOT for consideration.

Task 5: Testing of Dents with Gouges

Technical Status

GDF SUEZ has in charge the creation, characterization, burst test and fatigue test of realistic combined defects "gouge in dent" following the program described in the next table:

PR 305, pipe 1 & pipe 2	MD 4-1					DOT BAA 07	
Pipe number	**Pipe 1** (current steel X52)			**Pipe 2** (current steel X70)		**Pipe 4** (older steel)	
Defect type agreed with Project team	Type 1	Type 2	Type 3	Type 1 or 2	Type 2 or 3	Type 1 or 2	Type 2 or 3
Defect 1: Detailed characterization	**Defect 1.1.1**	**Defect 1.2.1**	**Defect 1.3.1**	**Defect 2.1.1**	**Defect 2.2.1**	**Defect 4.1.1**	**Defect 4.2.1**
Defect 2: Burst test	**Defect 1.1.2**	**Defect 1.2.2**	**Defect 1.3.2**	**Defect 2.1.2**	**Defect 2.2.2**	**Defect 4.1.2**	**Defect 4.2.2**
Defect 3: Delayed failure	**Defect 1.1.3**	**Defect 1.2.3**	**Defect 1.3.3**	**Defect 2.1.3**	**Defect 2.2.3**	**Defect 4.1.3**	**Defect 4.2.3**

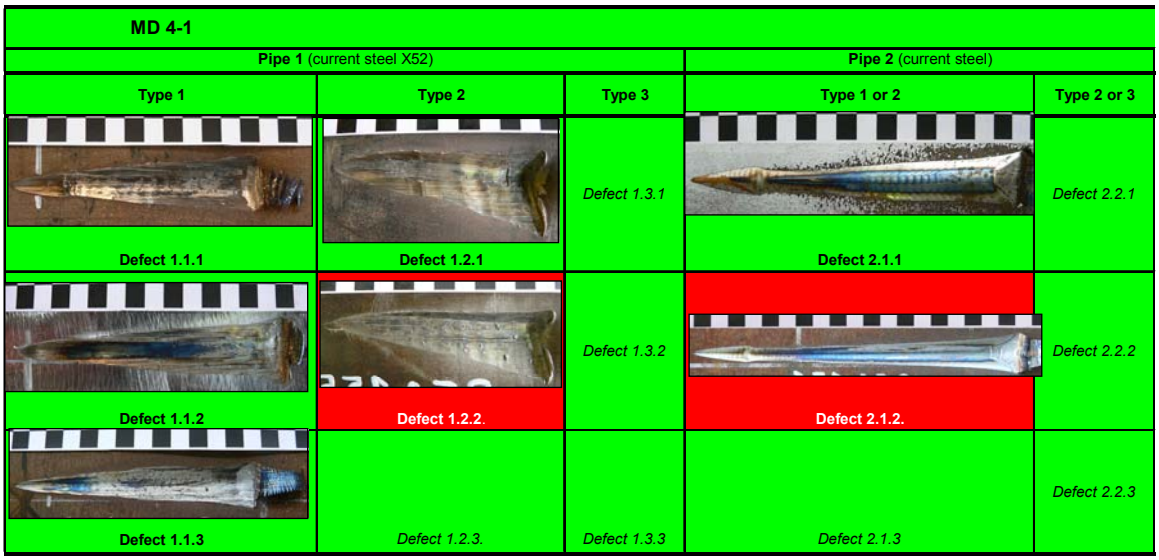
The defects are identified by three characters **x.y.z.** which are numbers:

- **x**.y.z. : **x** identifies the **Pipe x** material which can be in this program, 1, 2, or 3;
- x.**y**.z. : **y** defines the type of combined defect characterized by its geometry notably in terms of dent depth and length and gouge depth and length. In this program, the value of y can be in the range of 1 to 3, this program considering a maximum of three different kinds of defects per pipe material.
- x.y.**z.** : **z** is the number of defect in the defined type of defect. There are three similar defects per type of defect. The number 1 is for a detailed geometrical, mechanical and metallurgical in-depth defect characterization after its creation. Number 2 is a similar defect for the burst test to evaluate the defect behavior of under monotonic pressure load and number 3 is a similar defect for the fatigue test to evaluate the defect behavior under cyclic variation of the internal pressure.

In the First quarterly report, the following results were presented:

- Creation conditions and results of defects 1.1.1, 1.1.2 and 1.1.3.
- Burst test condition and results of defect 1.1.2, except strain rosettes interpretation in terms of principal strains and directions.
- Fatigue test condition and result of defect 1.1.3, except rosettes interpretation in terms of principal strains and directions.

New defects created during the second quarter are the defects 1.2.2, and 2.1.2 (red background in the following table), similar to defects 1.2.1. and 2.1.1 respectively.



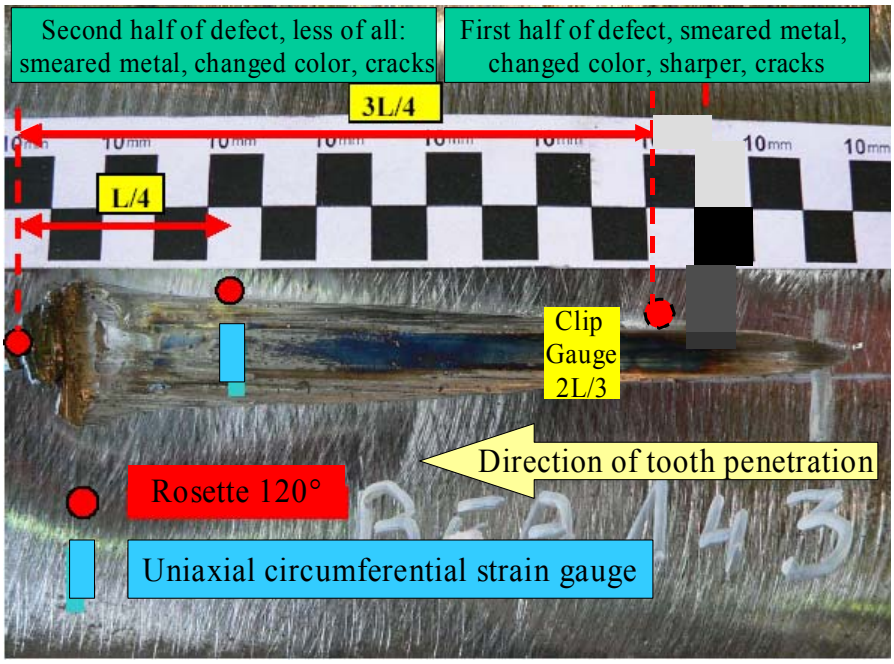
Creation data of these new defects were collected in terms of energy creation, sizing and surface micro-cracks examination. The defects were burst after instrumentation.

This report presents complementary interpretations of rosettes in terms of principal strains and directions for defects 1.1.2 (burst test) and 1.1.3 (fatigue test). Also included are conditions and results for the creation and burst tests for the new defects 1.2.1 and 2.1.1.

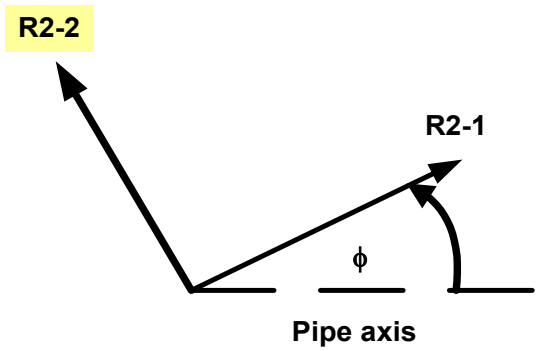
Results and Conclusions

Defect 1.1.2 – Burst test – principal strains and directions

The following picture details the defect instrumentation:

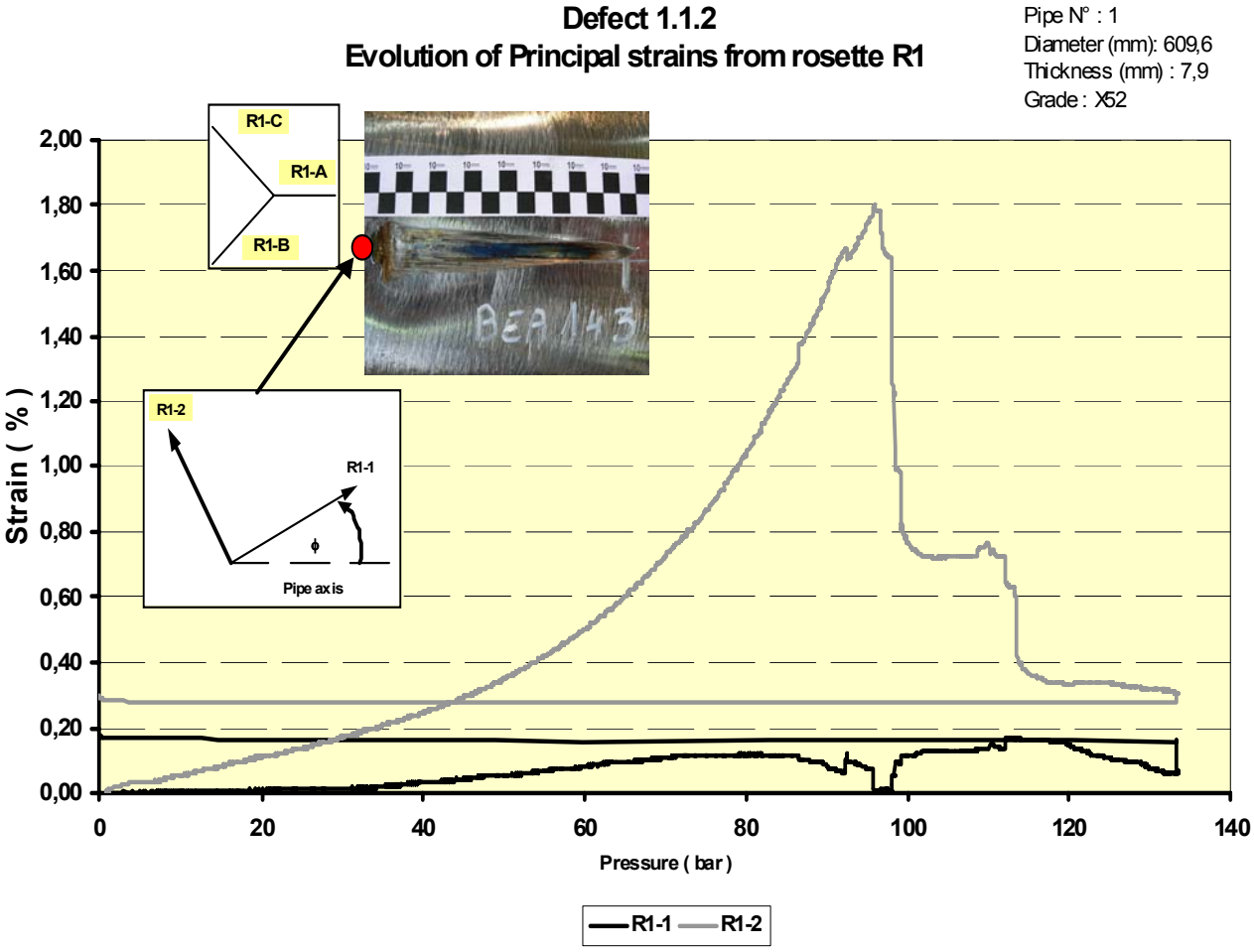


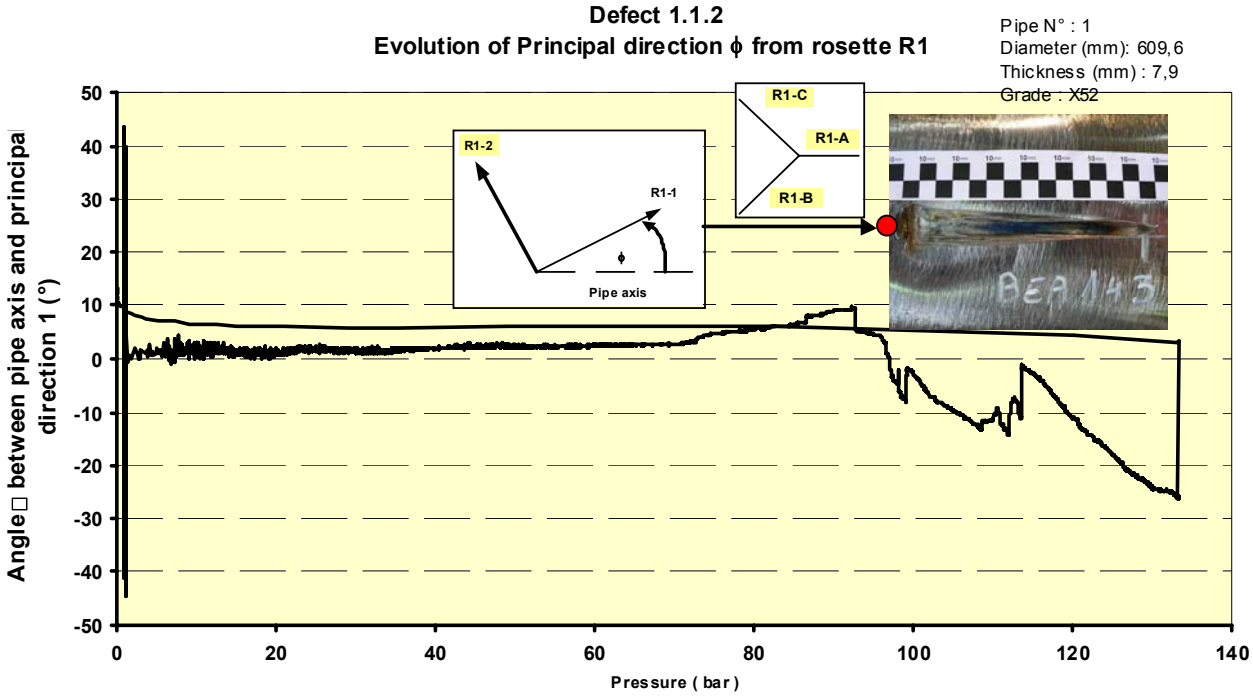
The principal direction closest to the pipe axis is given by the angle ϕ of this direction with the pipe axis, and the positive value is counter clockwise. The other principal direction is oriented at 90° counter-clock wise from the first.

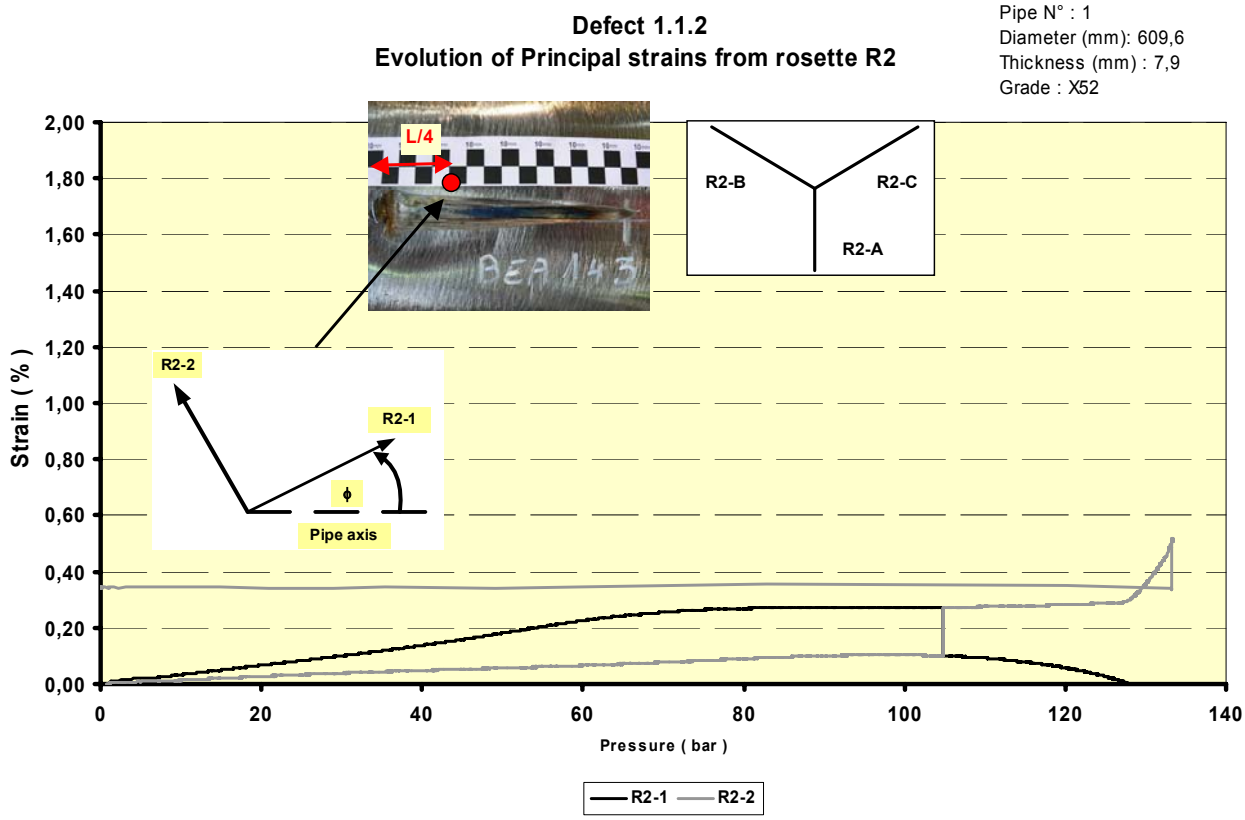


Principal strains and the ϕ angle definition.

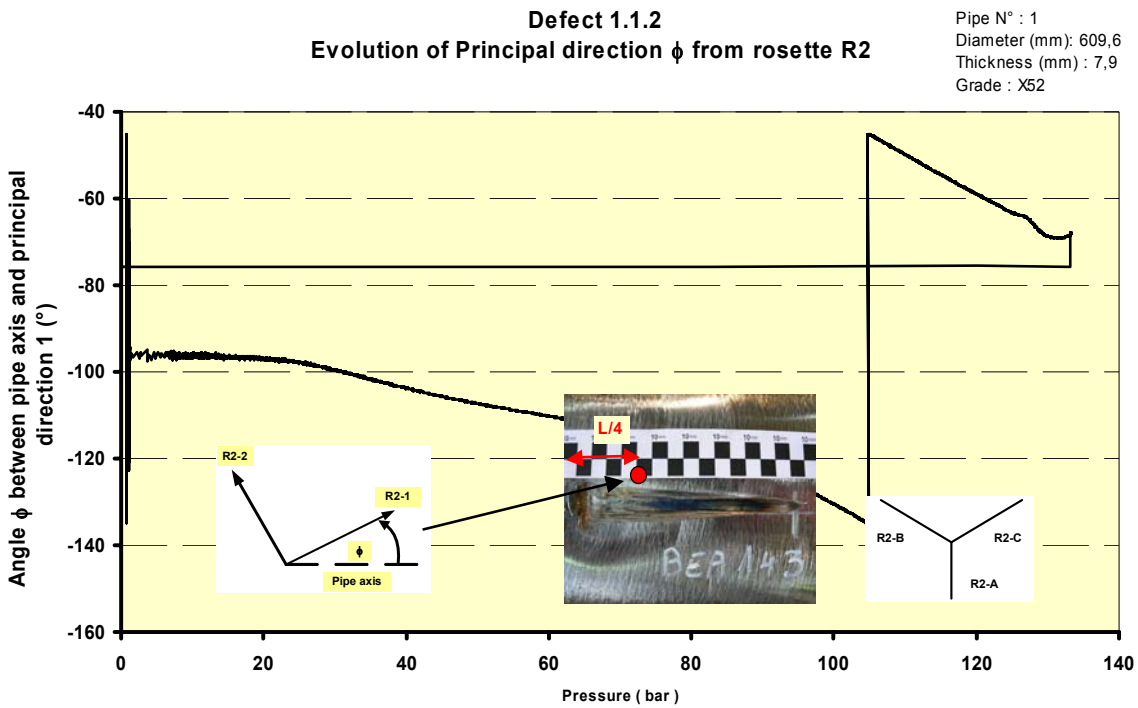
The graph below gives the principal strains and directions deduced from rosettes R1, R2 and R3 versus the pressure.



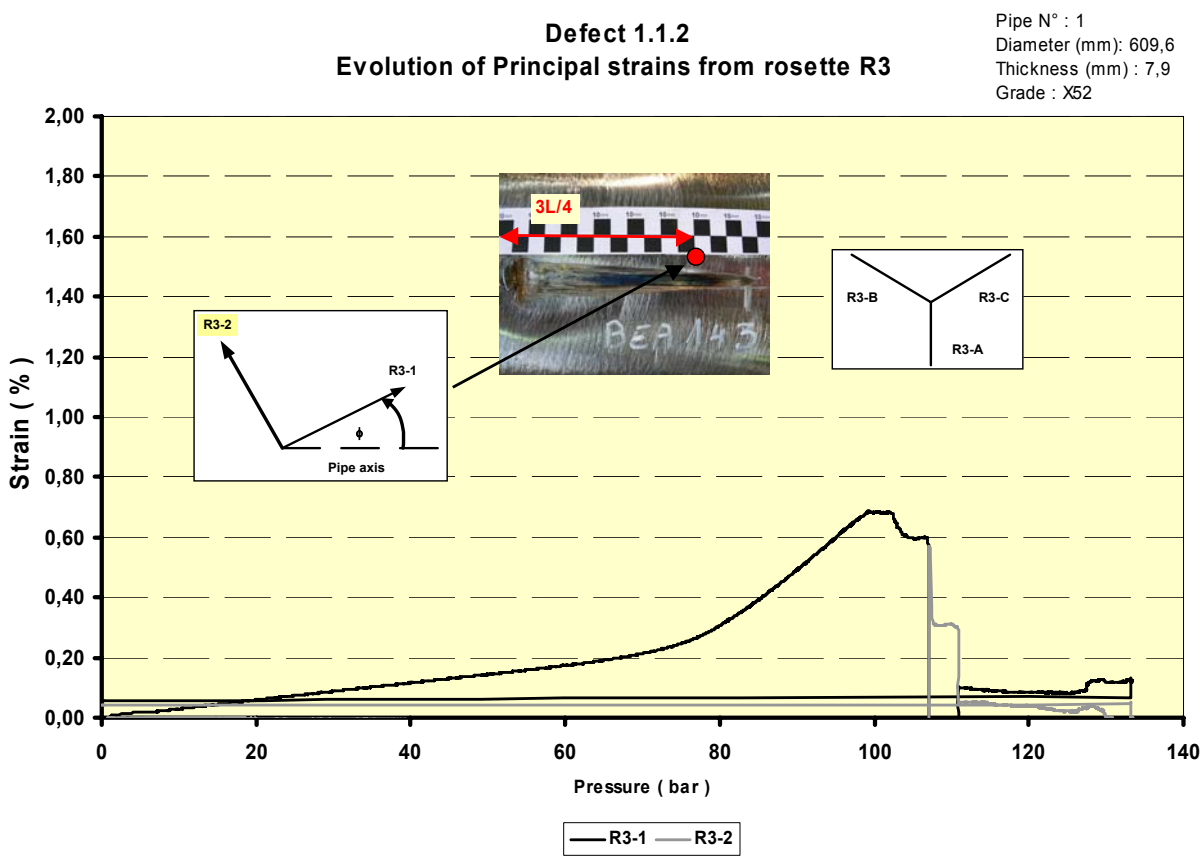


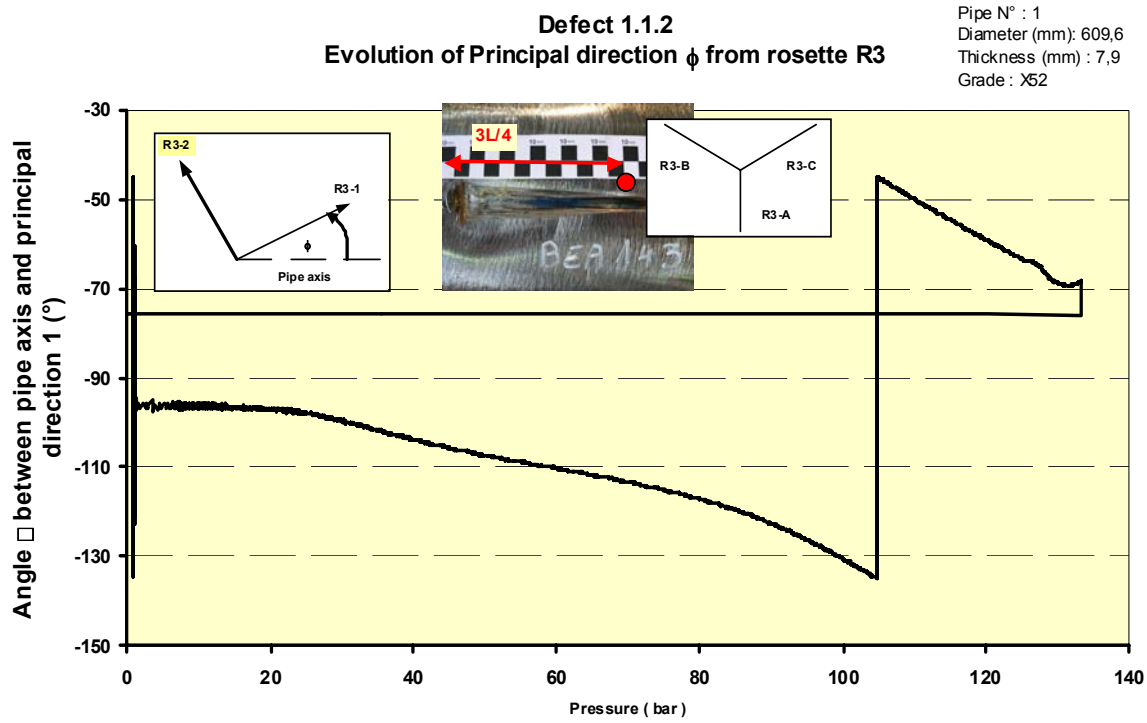


Note that the jump in angle is about 90°, which means that principal directions switch.



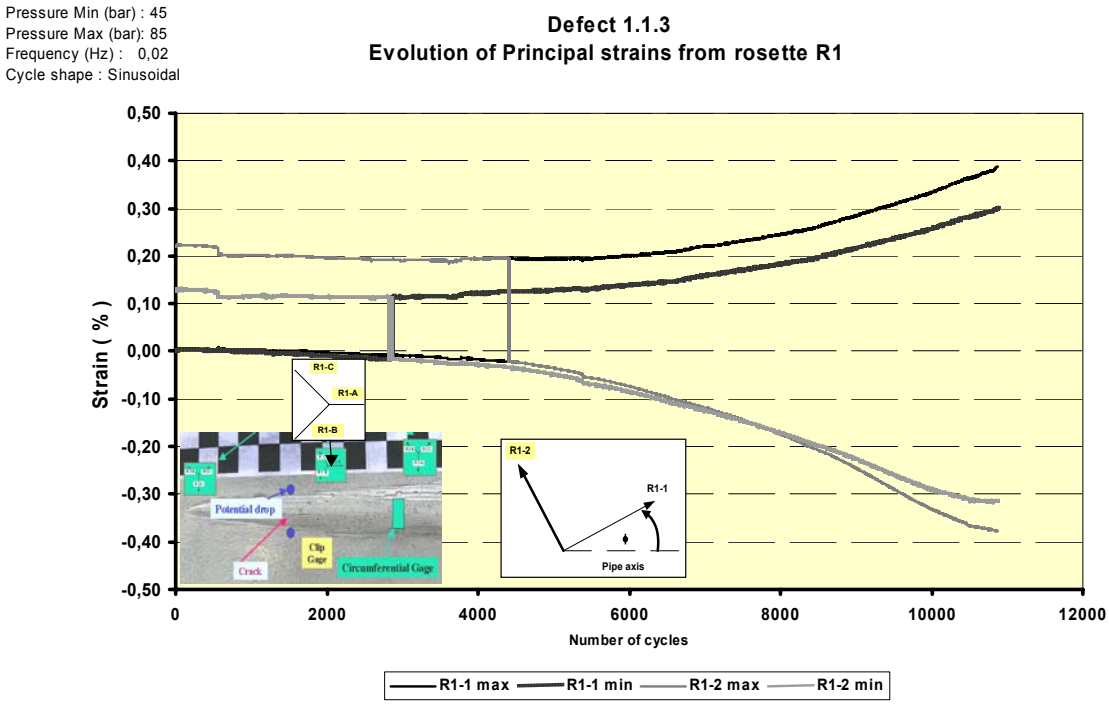
Note that the jump in angle is about 90°, which means that principal directions switch.

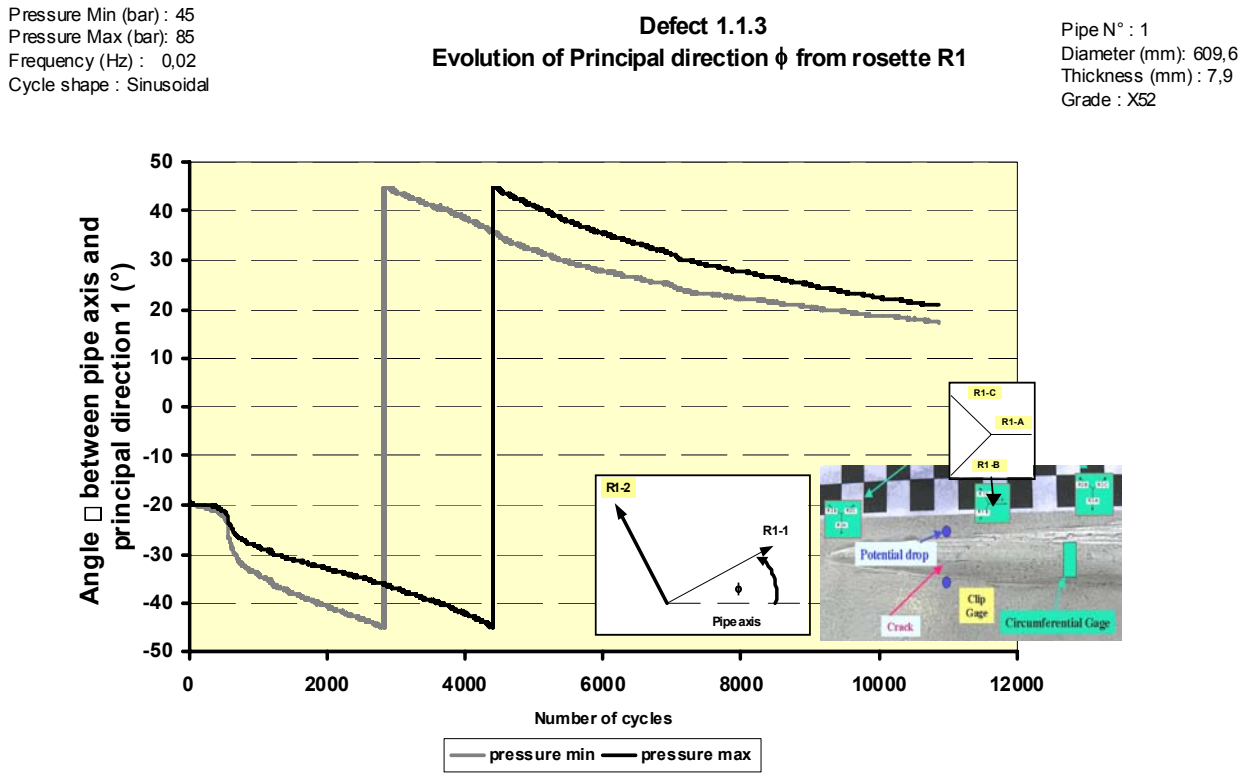


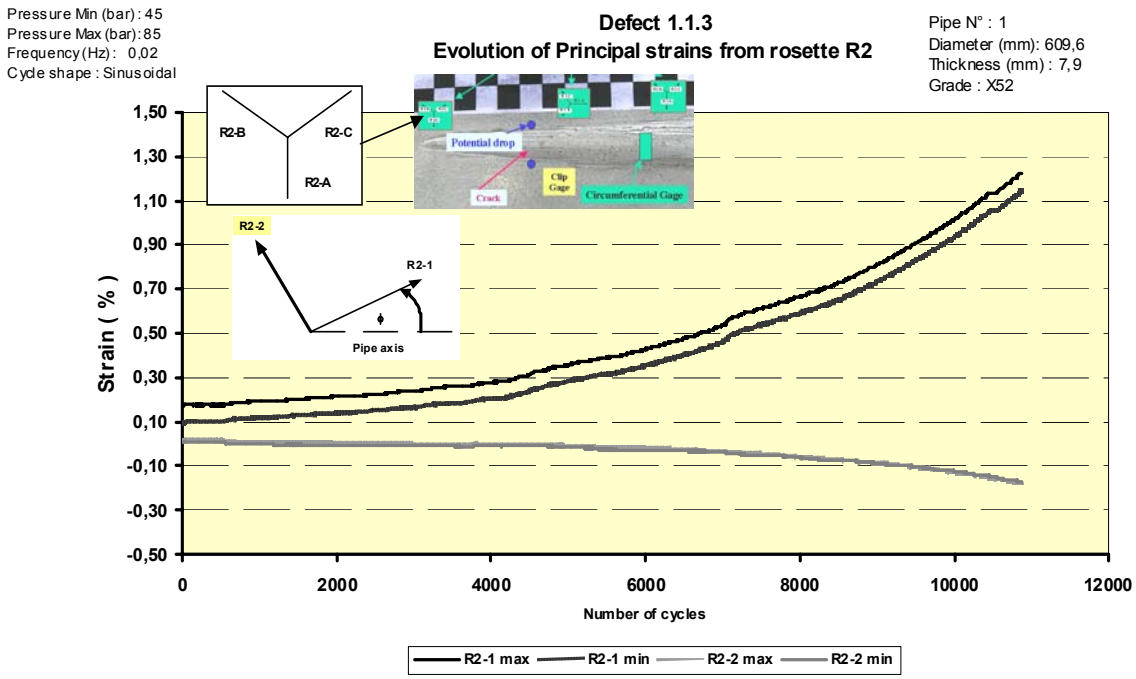


Defect 1.1.3 - Fatigue test – principal strains and directions

The principal strains and directions are plotted versus the number of cycles. The black lines are the principal strains or directions at the maximum pressure of 85 bar and the grey lines are the principal strains or directions at the minimum pressure of 45 bar. The exchange between strain values when a principal direction shifts by 90° can be noticed below.



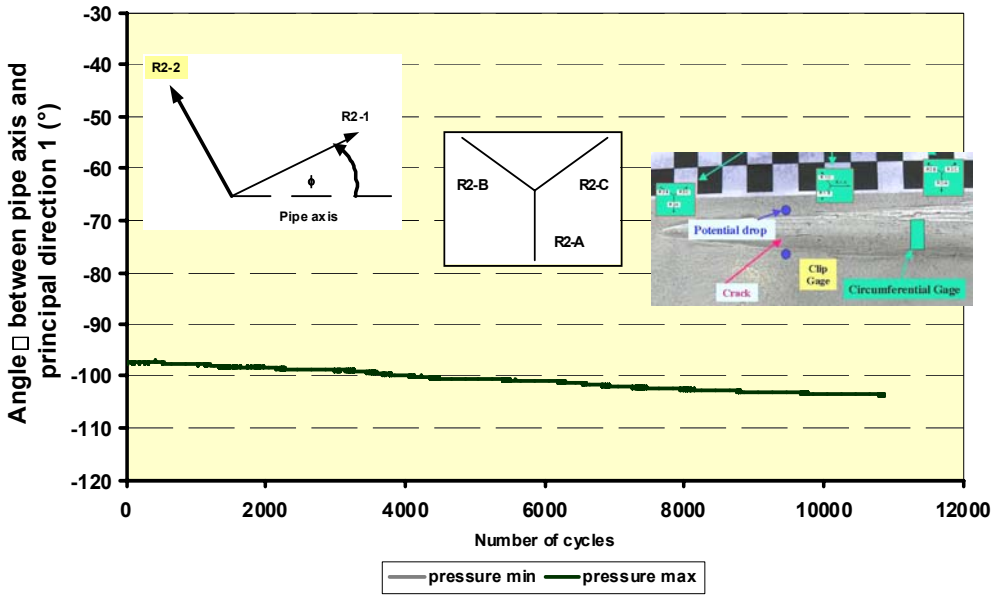

Pressure Min (bar) : 45
Pressure Max (bar): 85
Frequency (Hz) : 0,02
Cycle shape : Sinusoidal
Defect 1.1.3
Evolution of Principal direction ϕ from rosette R1
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Angle □ between pipe axis and principal direction 1 (°)
Number of cycles
R1-C
R1-A
R1-B
R1-2
R1-1
Pipe axis
Potential drop
Crack
Clip Gage
Circumferential Gage
pressure min
pressure max


Pressure Min (bar) : 45
Pressure Max (bar): 85
Frequency (Hz) : 0,02
Cycle shape : Sinusoidal
Defect 1.1.3
Evolution of Principal strains from rosette R2
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Strain (%)
Number of cycles
R2-B
R2-C
R2-A
R2-2
R2-1
Pipe axis
Potential drop
Crack
Clip Gage
Circumferential Gage
R2-1 max
R2-1 min
R2-2 max
R2-2 min

Pressure Min (bar) : 45
Pressure Max (bar): 85
Frequency (Hz) : 0,02
Cycle shape : Sinusoidal

Defect 1.1.3
Evolution of Principal direction ϕ from rosette R2

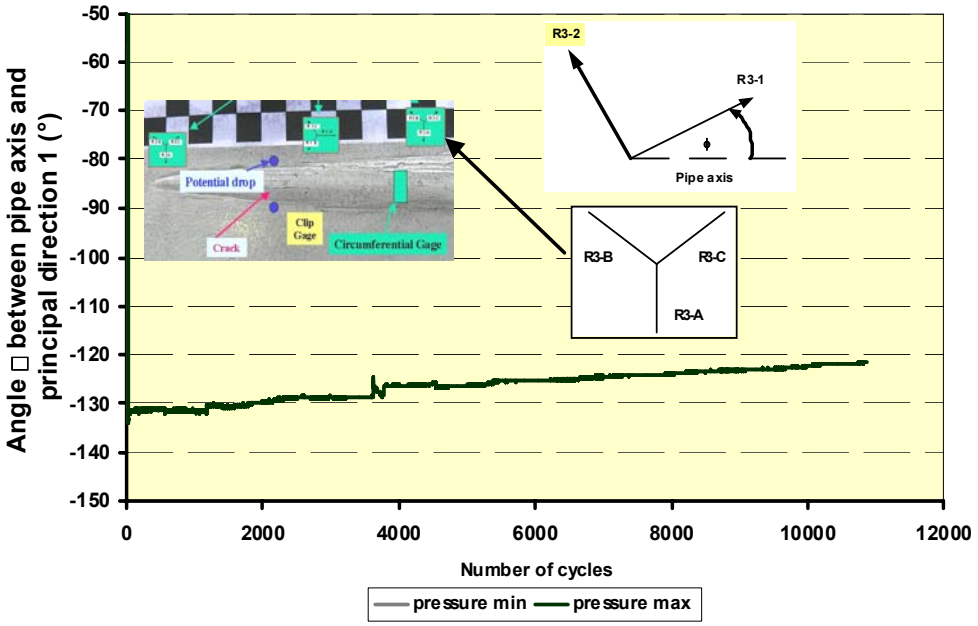
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52



Pressure Min (bar) : 45
Pressure Max (bar): 85
Frequency (Hz) : 0,02
Cycle shape : Sinusoidal

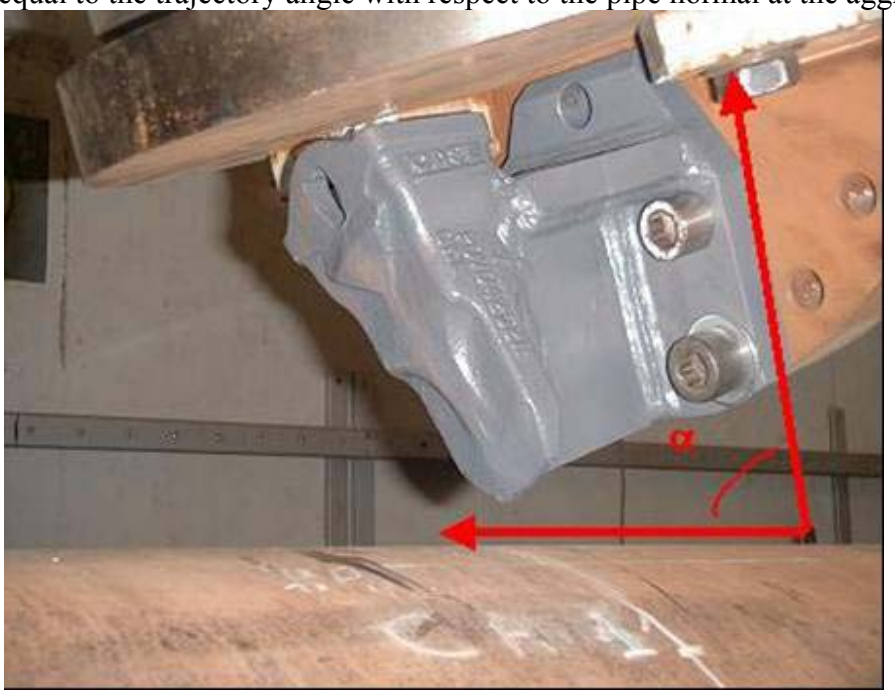
Defect 1.1.3
Evolution of Principal direction ϕ from rosette R3

Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52



Creation of defects 1.2.2 and 2.1.2

The parameters to create the defects are defined by the aggression tooth type and geometry, the height of the tooth before the fall, the additional mass and the impact angle α of the tooth with the pipe, also equal to the trajectory angle with respect to the pipe normal at the aggression point.



Impact angle α

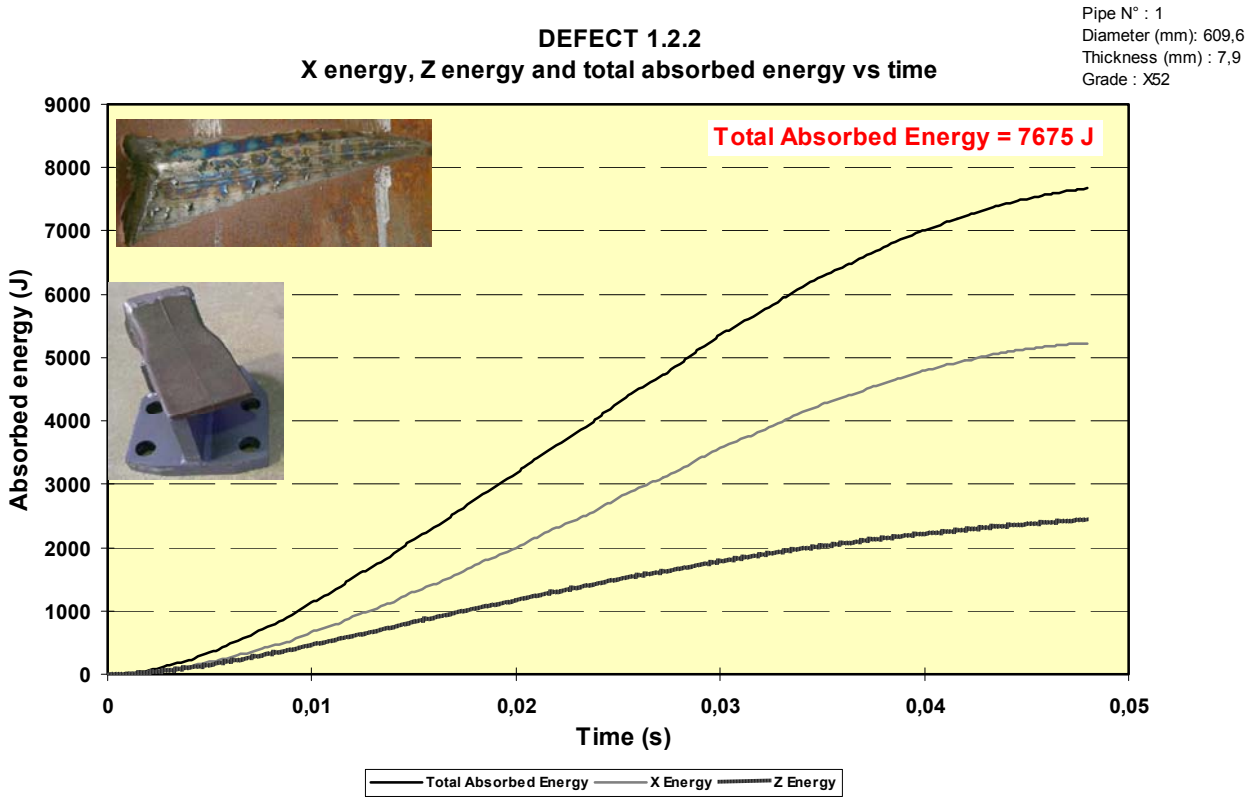
Defect 1.2.2

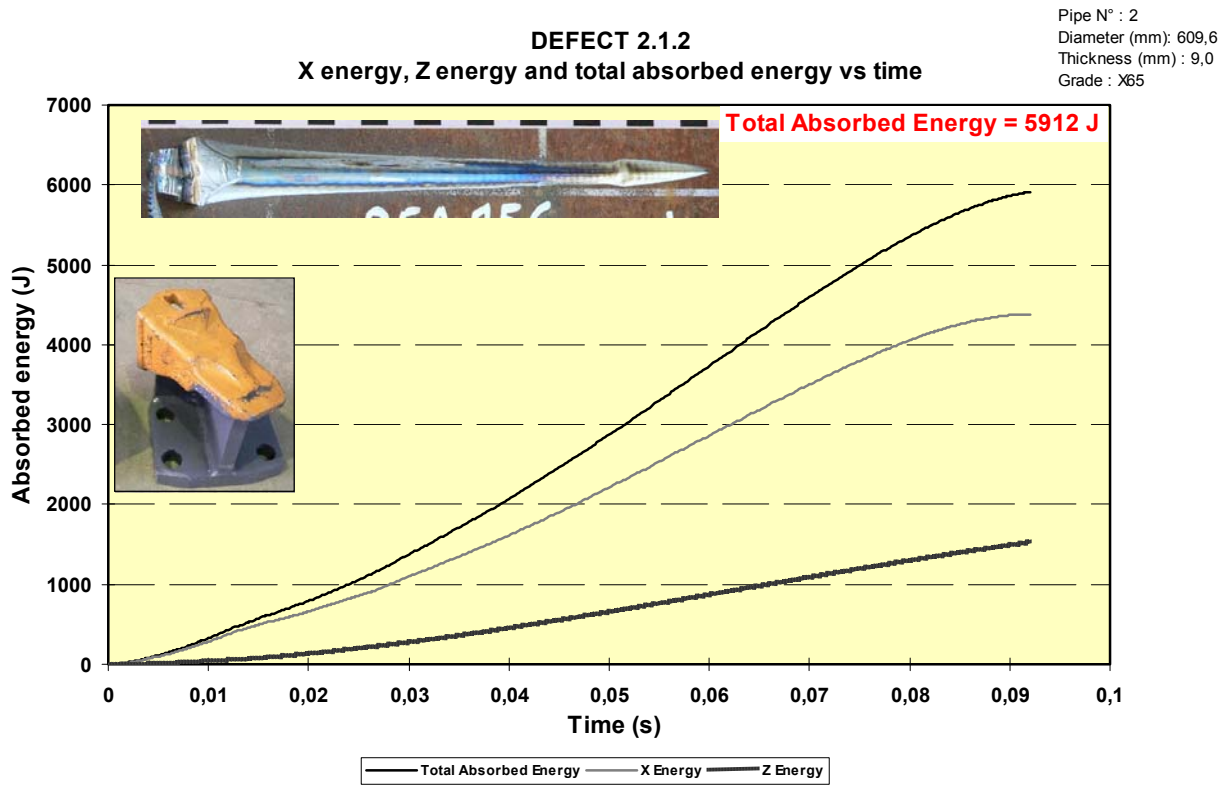
Tooth type	Impact angle α (°)	Drop Height (mm)	Additional Mass (Kg)	Internal Pressure (bar)
Esco	76	270	800	85

Defect 2.1.2

Tooth type	Impact angle α (°)	Drop Height (mm)	Additional Mass (Kg)	Internal Pressure (bar)
Cal44New	81	170	800	85

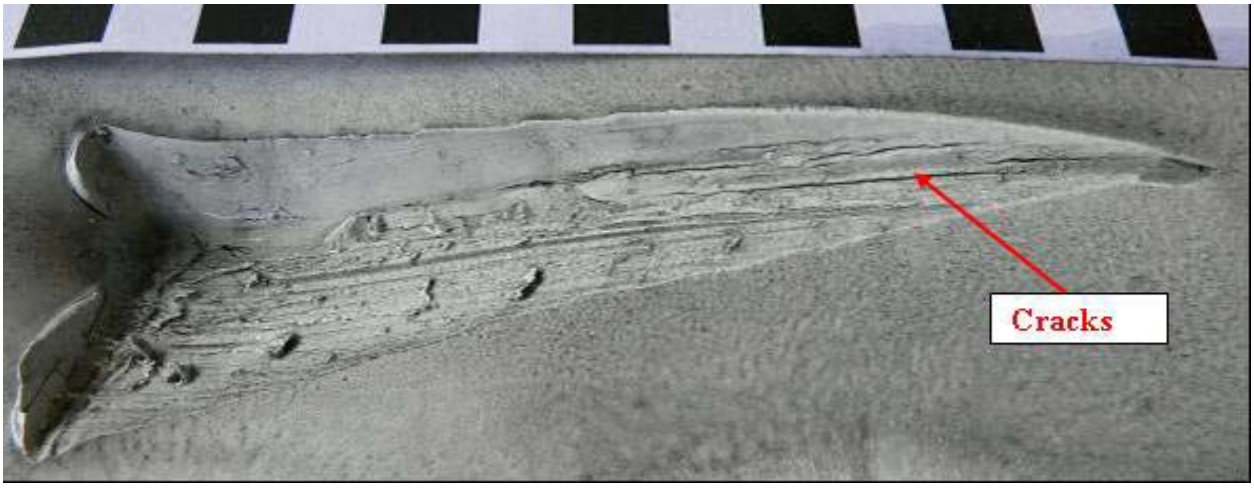
Energy absorbed by the defect creation



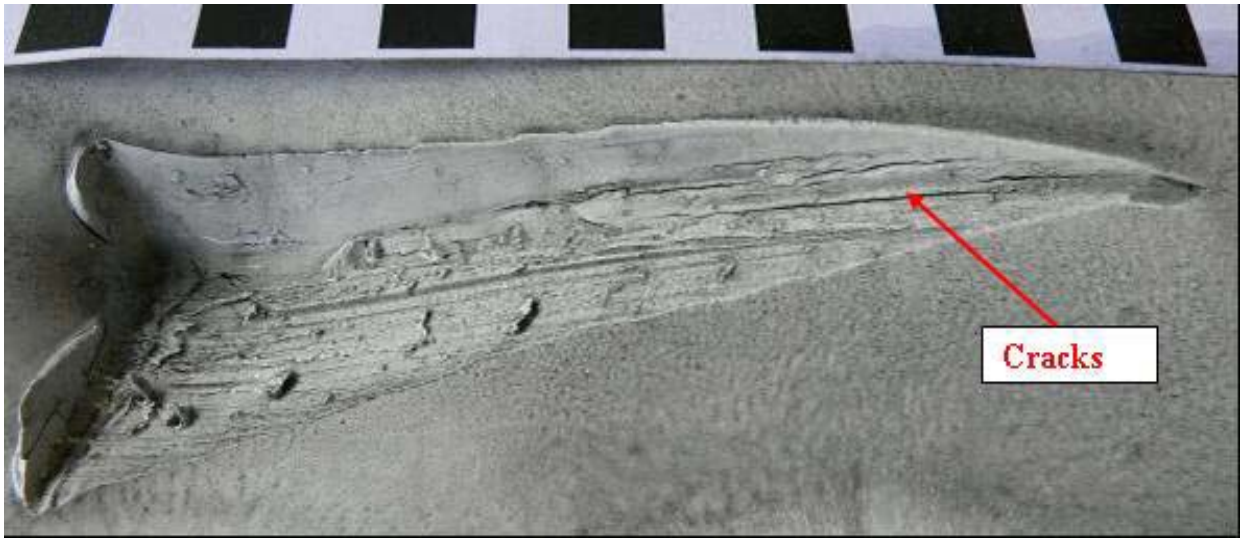


Detection of micro-cracks on gouge bottom

After the defect creation, magnetic particle inspection (MPI) was applied to identify potential surface micro-cracks in the gouge. Cracks appear in defect 1.2.2 and micro-cracks in defect 2.1.1.



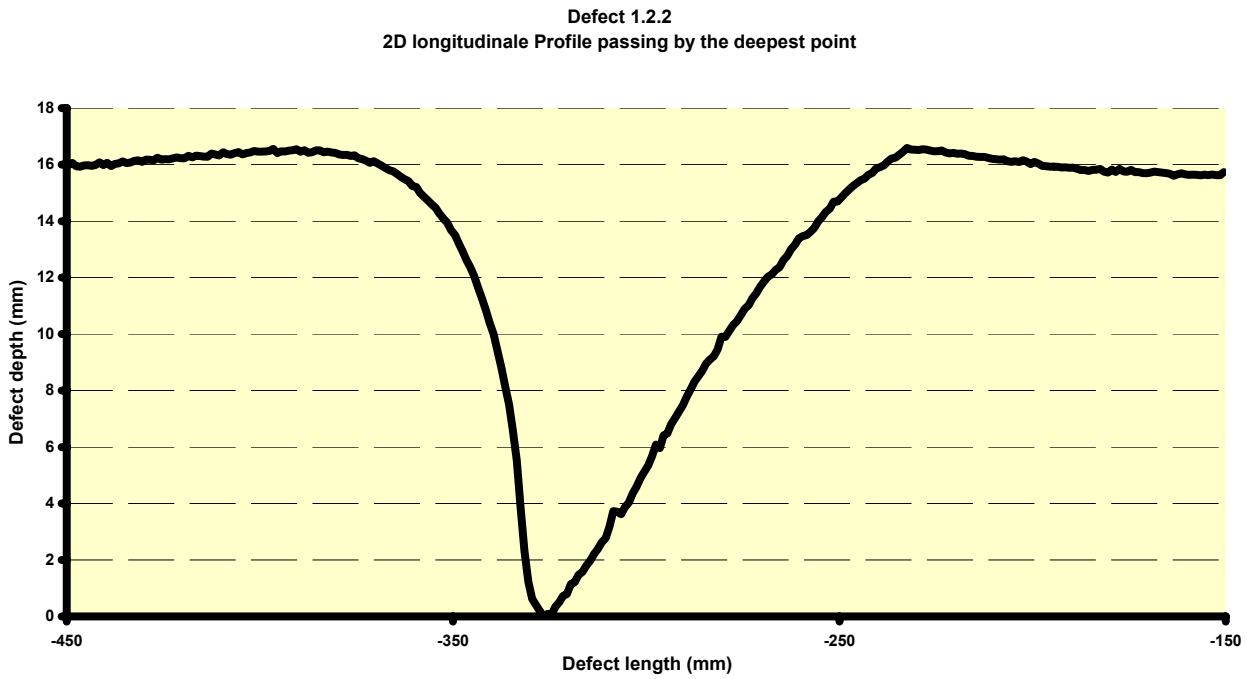
Defect 1.2.2



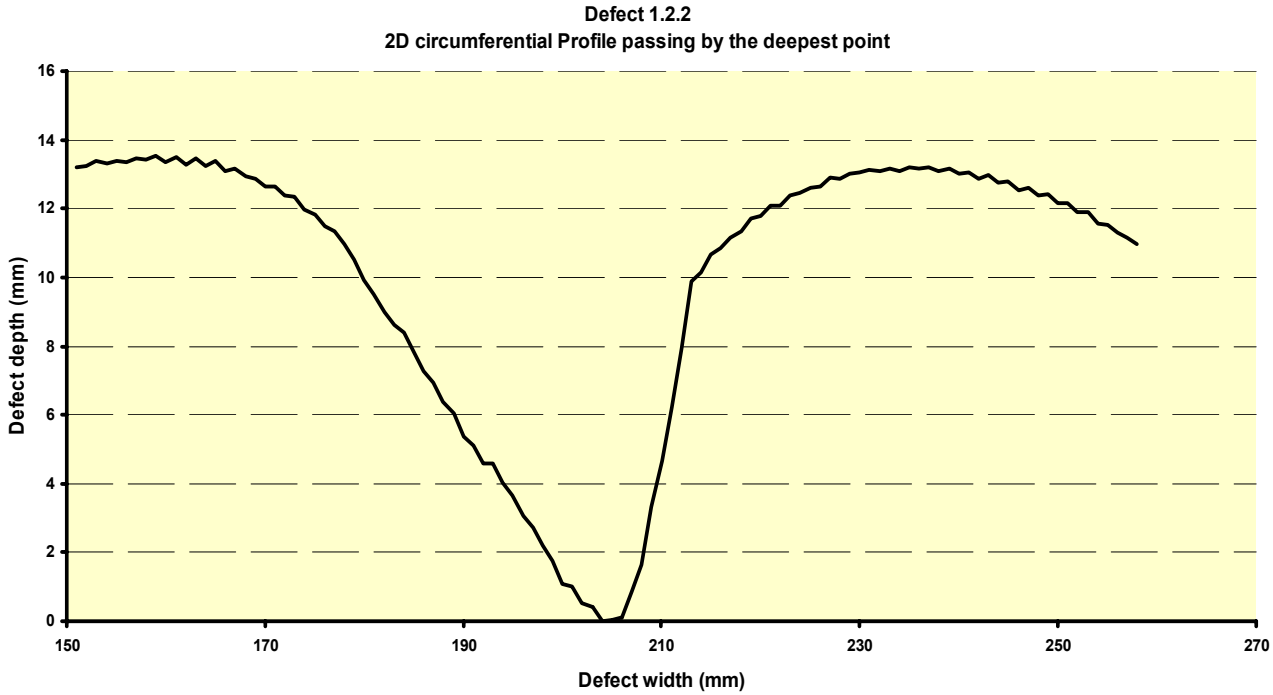
Defect 2.1.1

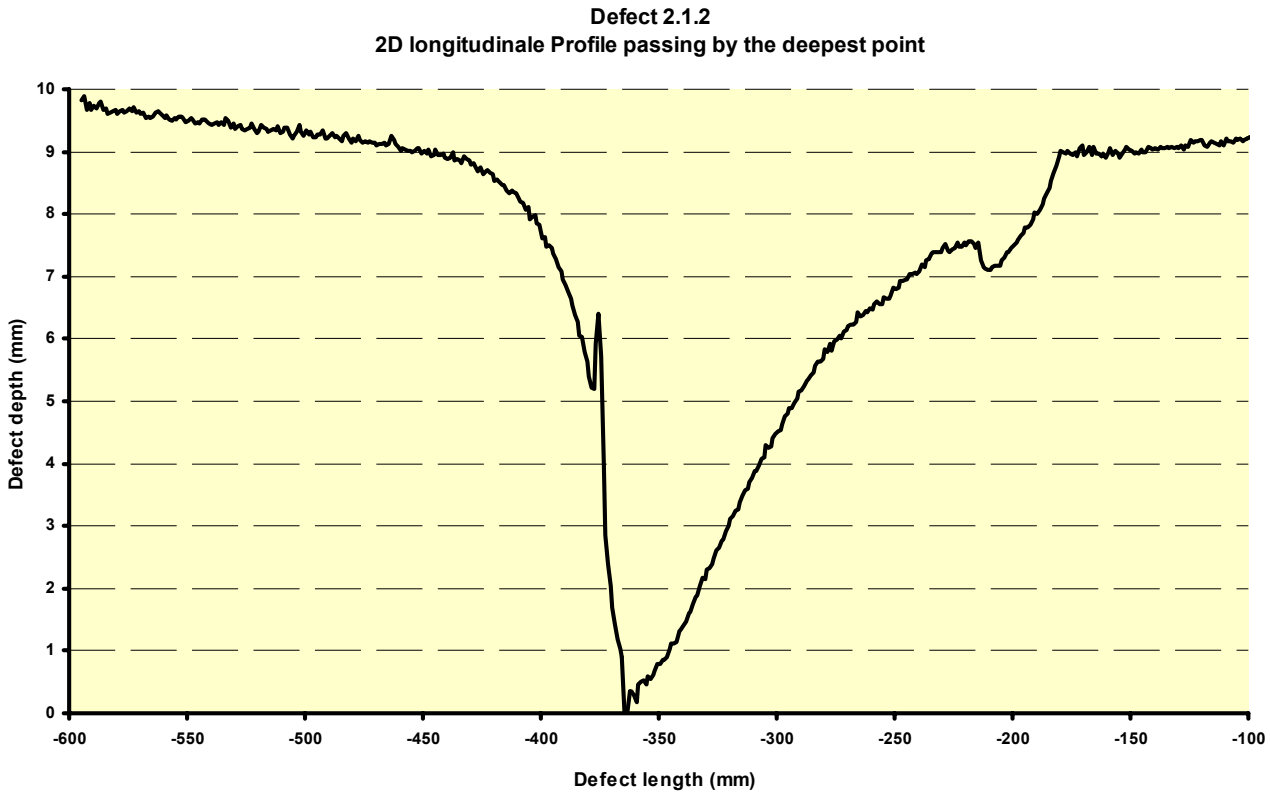
Defects Geometry

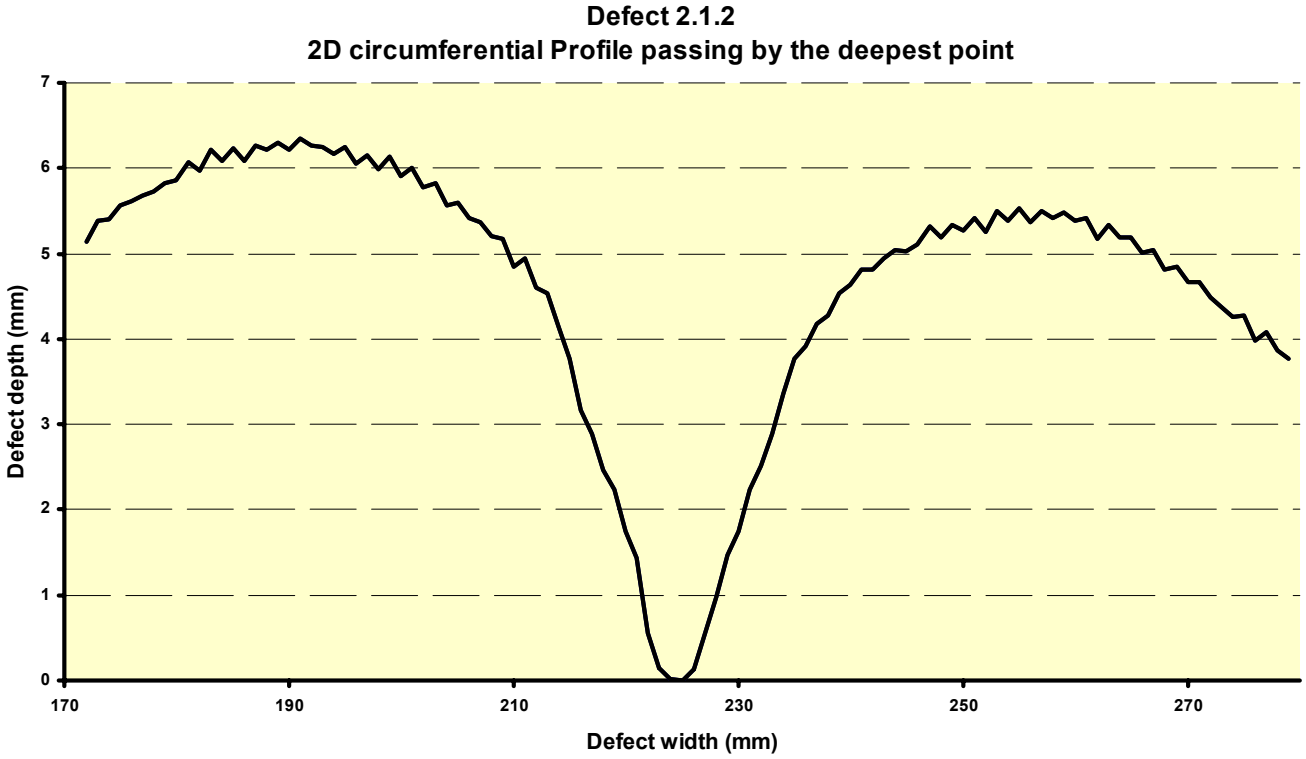
Defects were sized by 3D laser measurements. 2D longitudinal and circumferential profiles passing by the deepest point of the dent are given in the following figures.



Defect depth (nm) vs. Defect Length (nm)




Defect 2.1.2
2D longitudinale Profile passing by the deepest point
Defect depth (mm)
Defect length (mm)
10
9
8
7
6
5
4
3
2
1
0
-600
-550
-500
-450
-400
-350
-300
-250
-200
-150
-100


Defect 2.1.2
2D circumferential Profile passing by the deepest point
Defect depth (mm)
Defect width (mm)
7
6
5
4
3
2
1
0
170
190
210
230
250
270

Along the longitudinal axis of gouge center, residual thickness has been measured by US. Then, the gouge depths have been deduced as indicated in the schema below

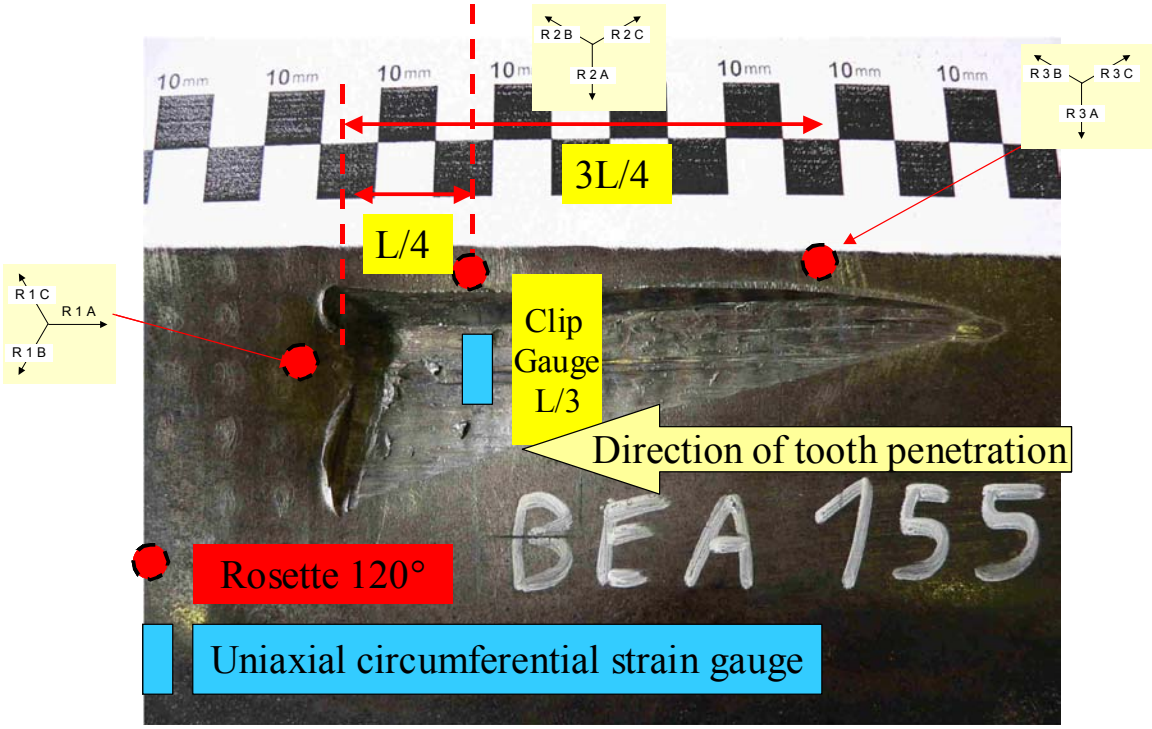
The main defect dimensions are gathered in the following table:

	Defect Type	Material	Test order	Gouge length (mm)	Gouge depth (%)	Dent depth (%)
Defect 1.2.2	2	Pipe 1	2	101	30	2
Defect 2.1.2	1	Pipe 2	2	166	19	1,3

Burst test – defect 1.2.2

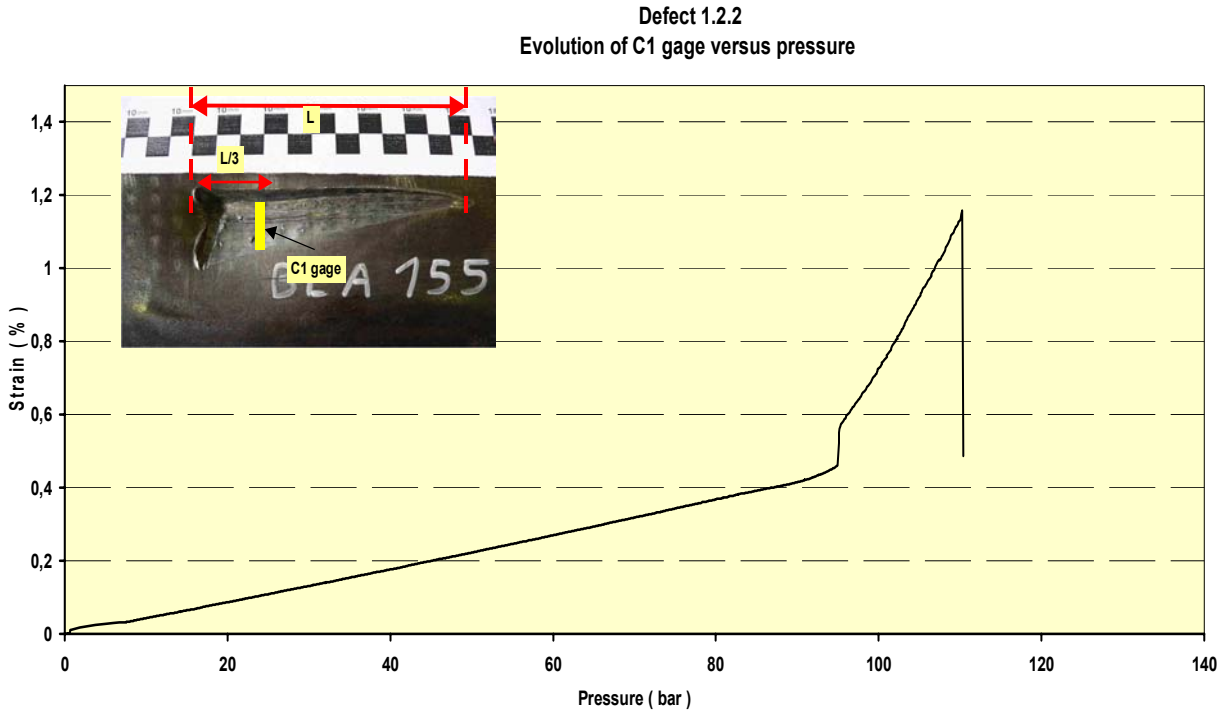
Defect 1.2.2 was instrumented by:

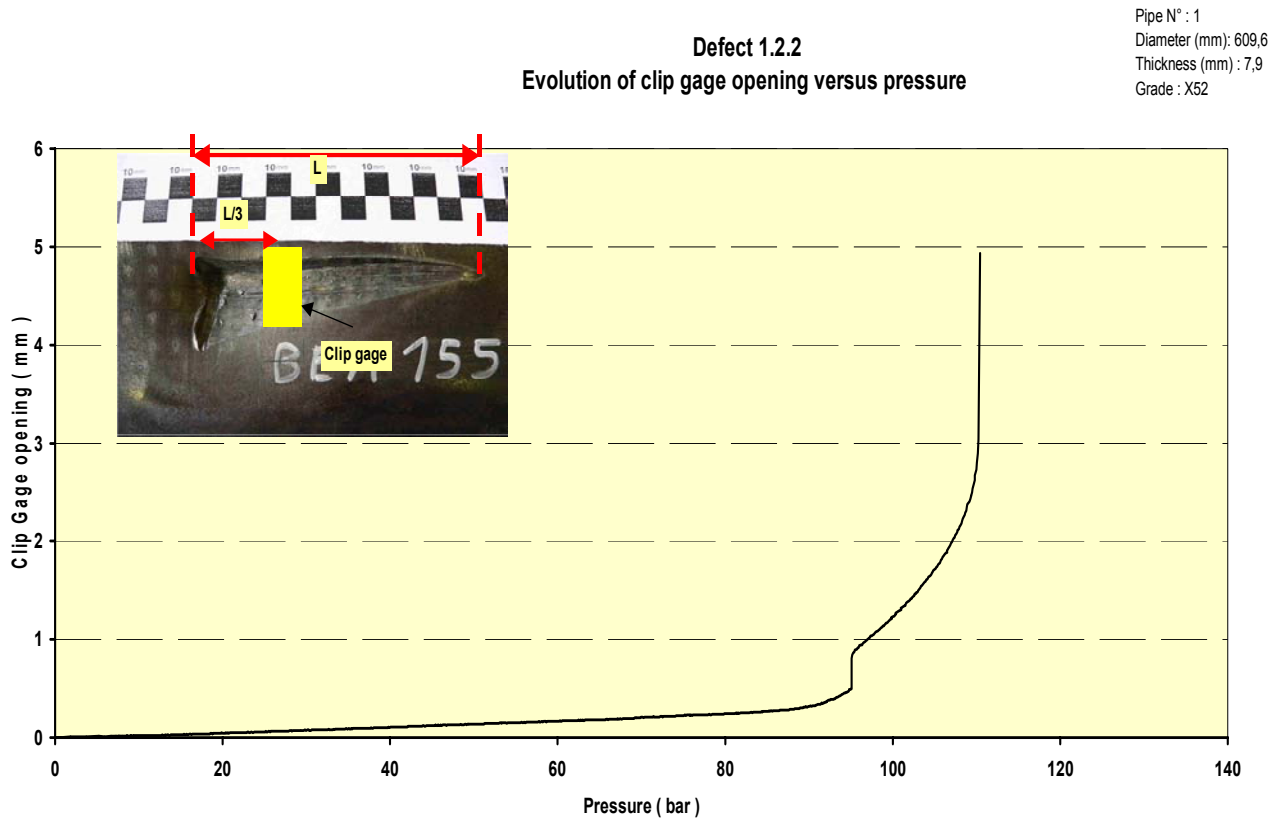
- 1 Clip gage;
- 1 uniaxial circumferential strain gauge in the gouge;
- 3 strain-gauge rosettes at the edges of the defect

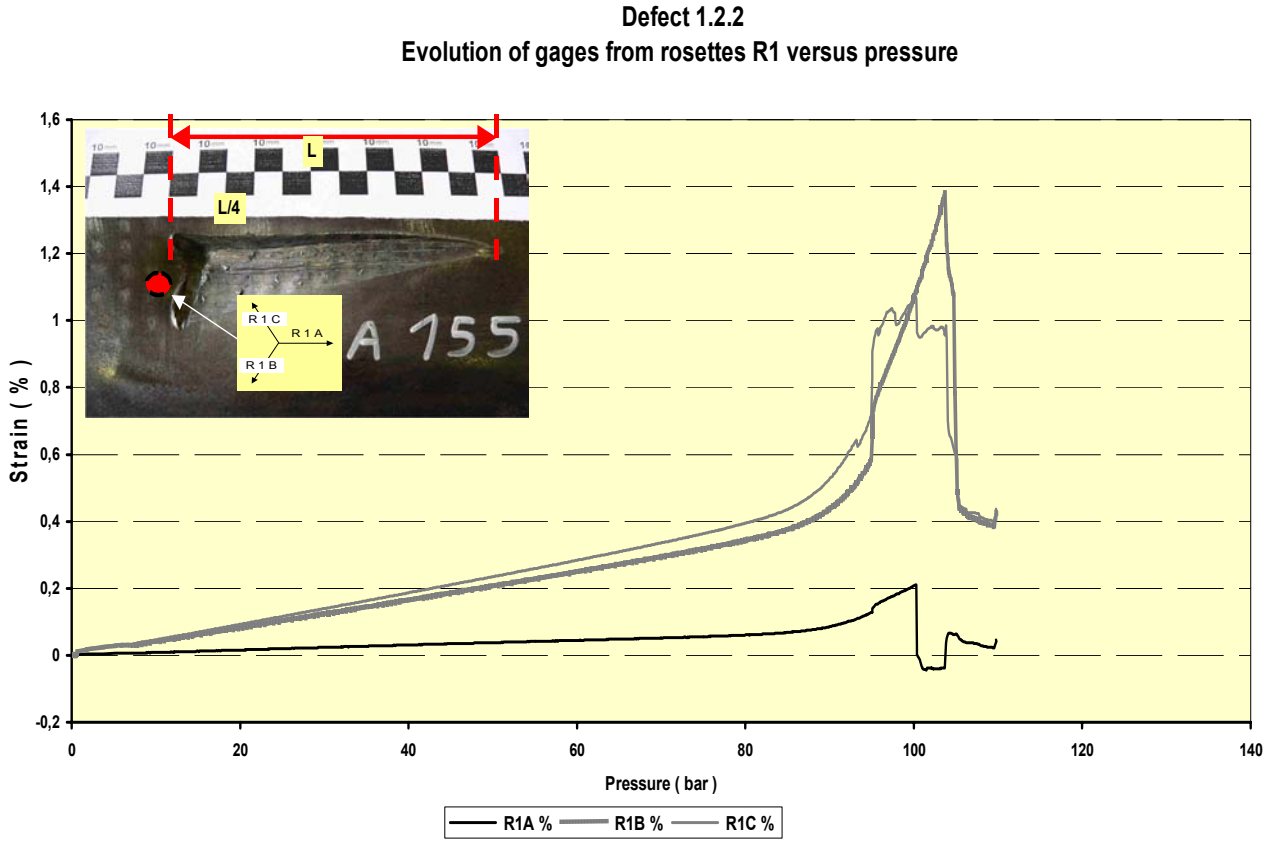


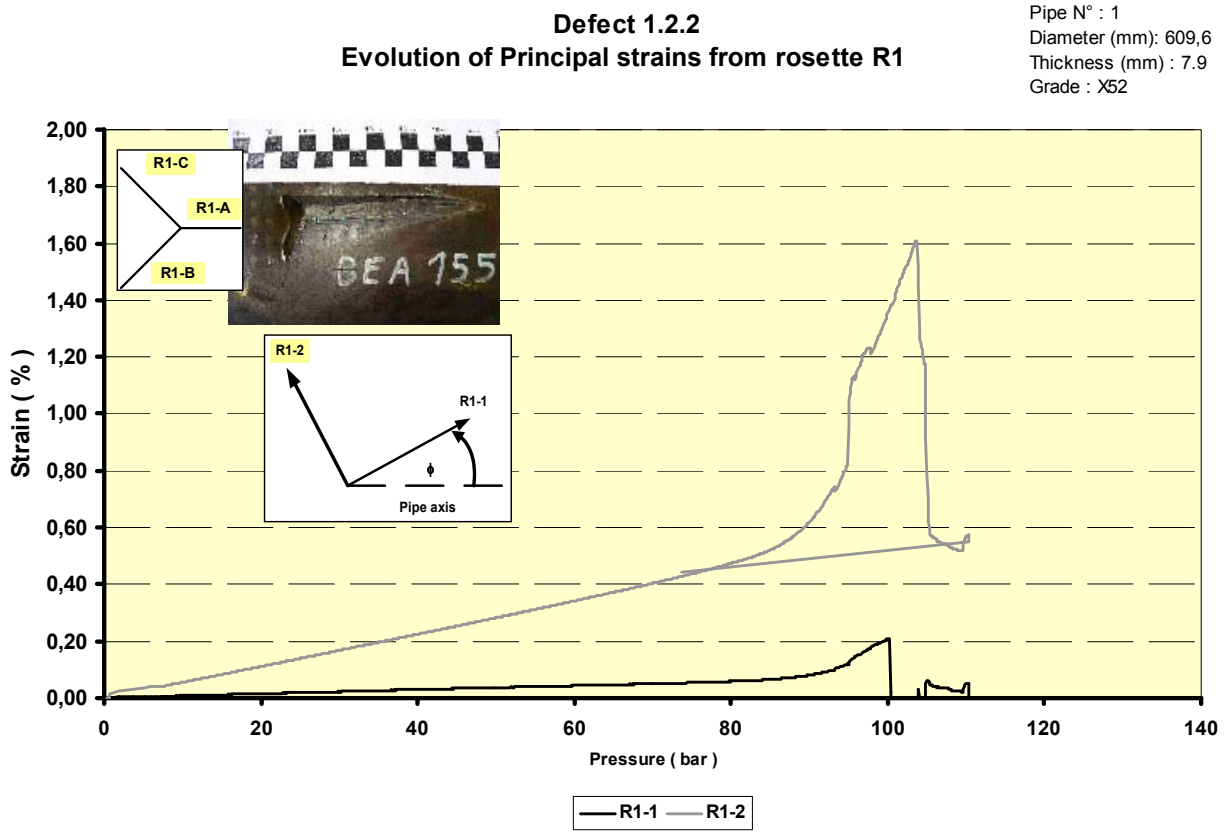
A monotonic increasing internal pressure was applied and the vessel burst in the defect at a failure pressure of **110 bar.** The failure is a slight opening in the gouge creating a leak, not a rupture.

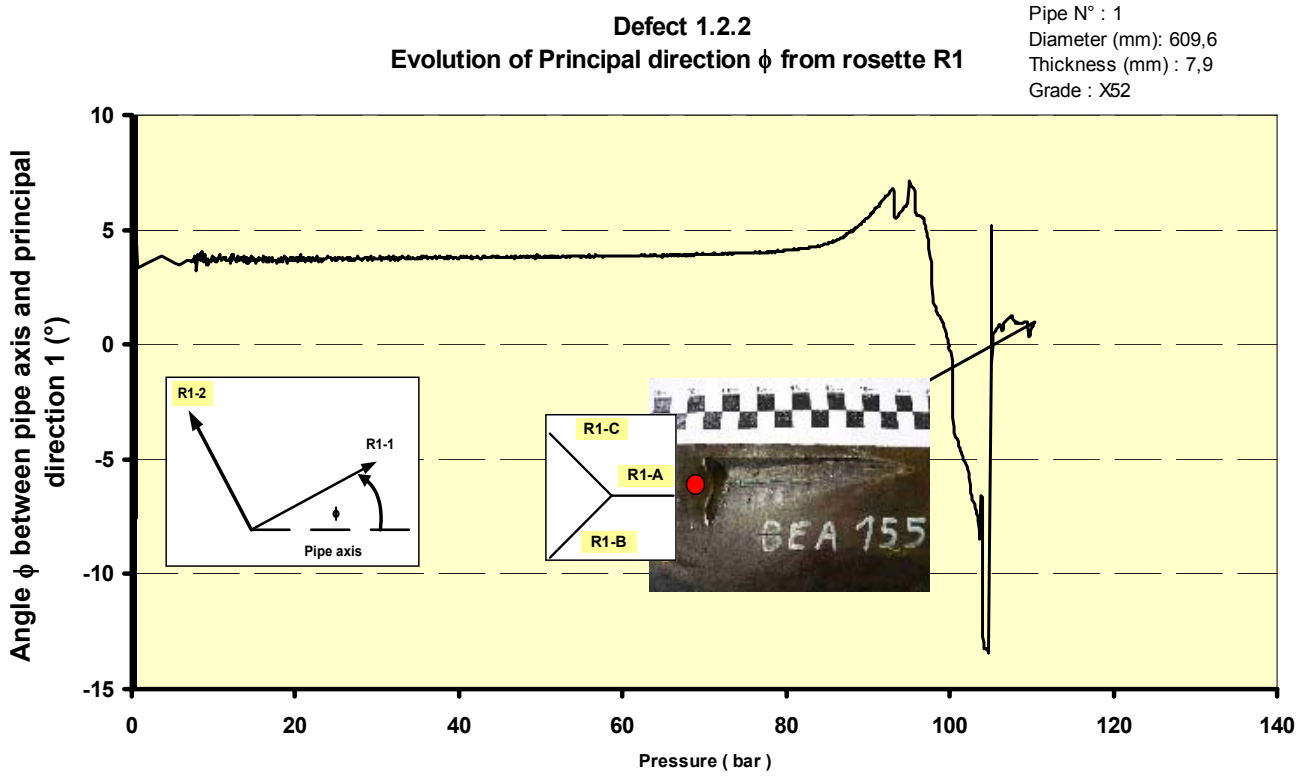
The following graphs provide the evolution of all instruments: clip-gauge, strain gauges, etc. versus internal pressure.

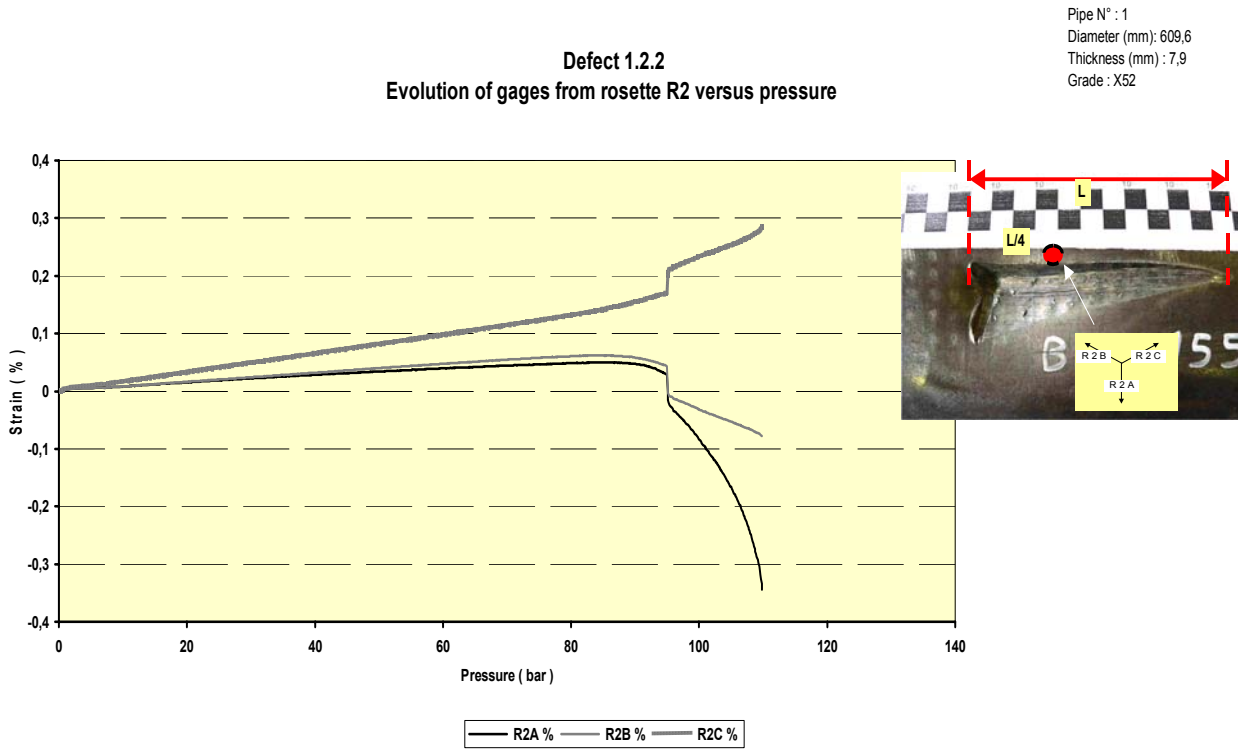


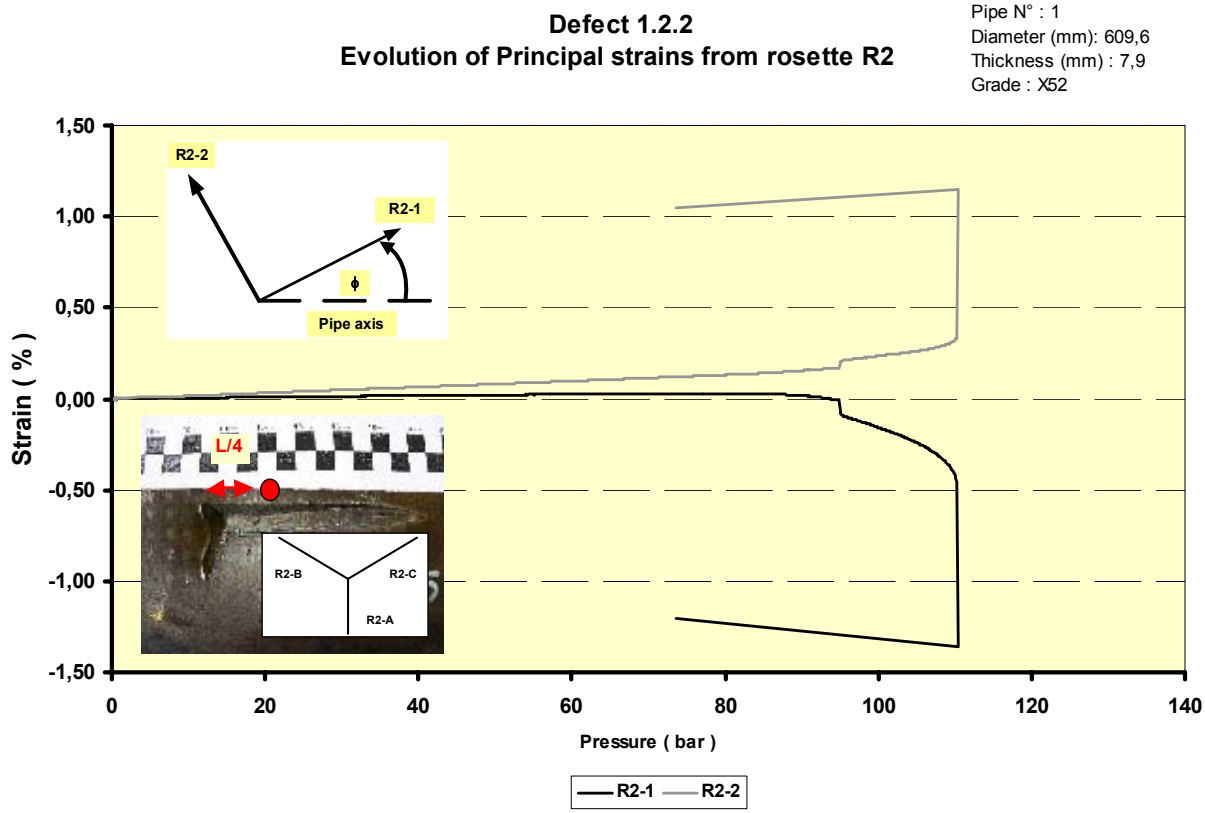

Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Defect 1.2.2
Evolution of clip gage opening versus pressure
L
L/3
Clip gage
Clip Gage opening (mm)
Pressure (bar)
0
1
2
3
4
5
6
0
20
40
60
80
100
120
140

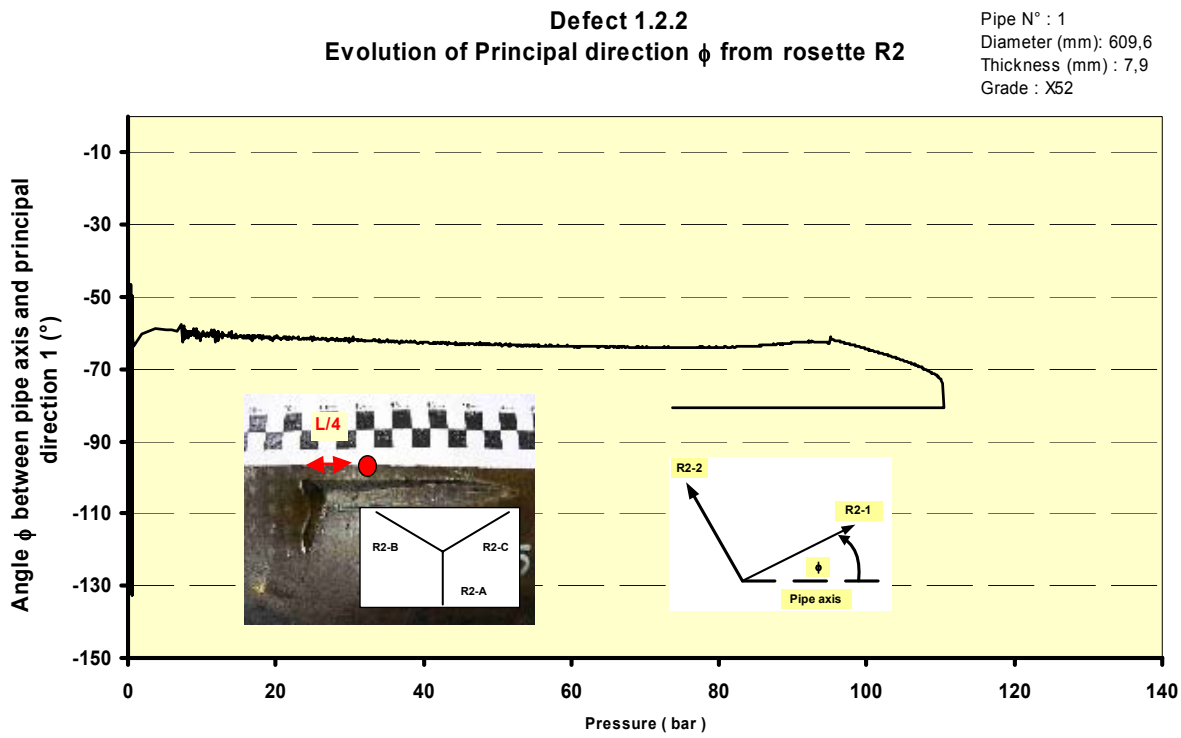

Defect 1.2.2
Evolution of gages from rosettes R1 versus pressure
L
L/4
R 1 C
R 1 A
R 1 B
Strain (%)
Pressure (bar)
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
-0,2
0
20
40
60
80
100
120
140
R1A %
R1B %
R1C %

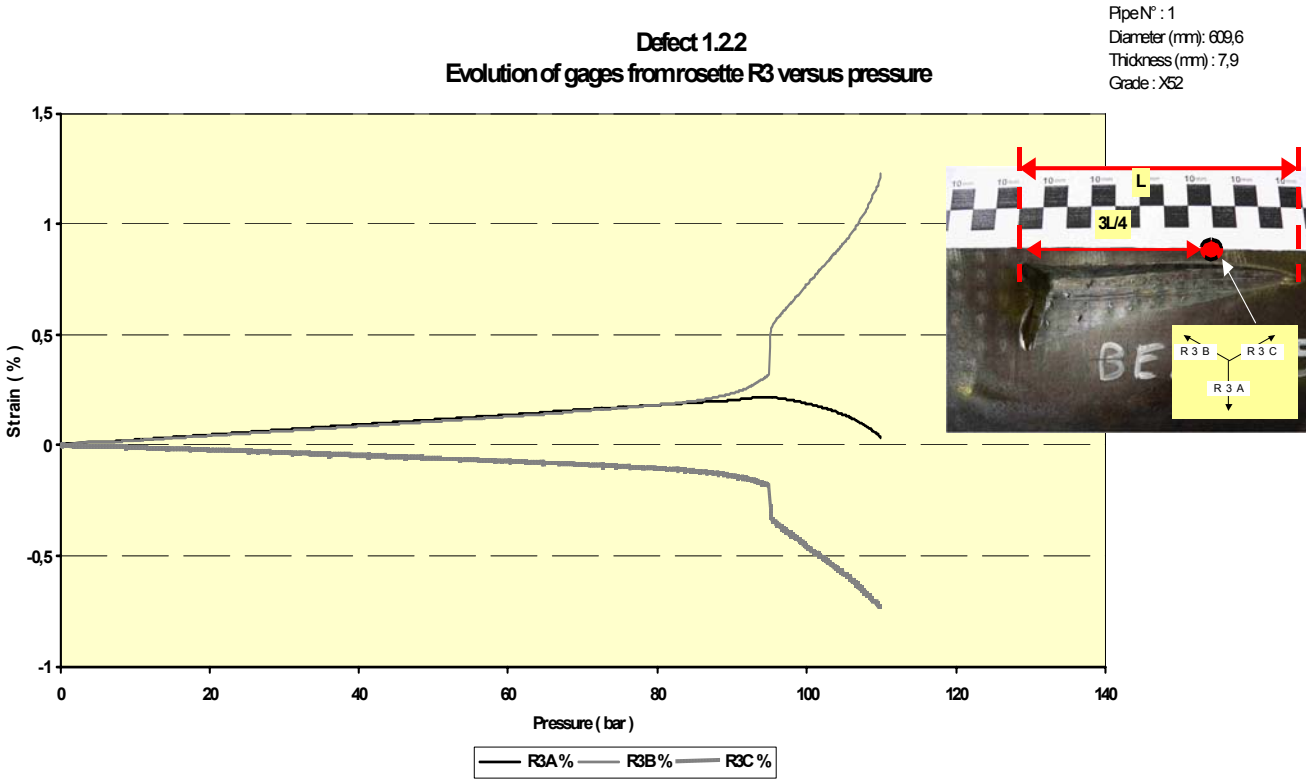

Defect 1.2.2
Evolution of Principal strains from rosette R1
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7.9
Grade : X52
R1-C
R1-A
R1-B
BEA 155
R1-2
R1-1
ϕ
Pipe axis
Strain (%)
2,00
1,80
1,60
1,40
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0
20
40
60
80
100
120
140
Pressure (bar)
R1-1
R1-2

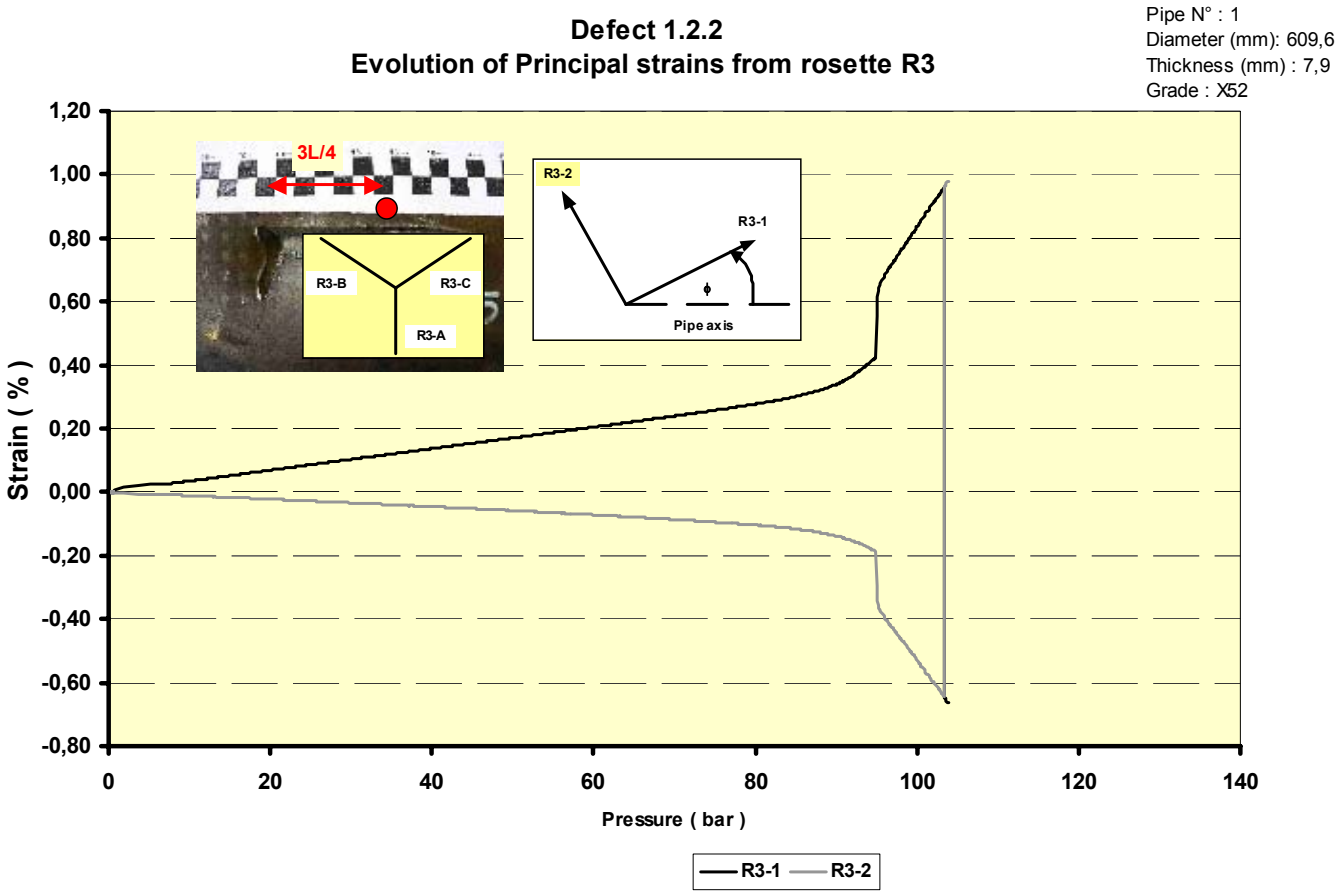

Defect 1.2.2
Evolution of Principal direction ϕ from rosette R1
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Angle ϕ between pipe axis and principal direction 1 (°)
10
5
0
-5
-10
-15
R1-2
R1-1
ϕ
Pipe axis
R1-C
R1-A
R1-B
BEA 155
0
20
40
60
80
100
120
140
Pressure (bar)

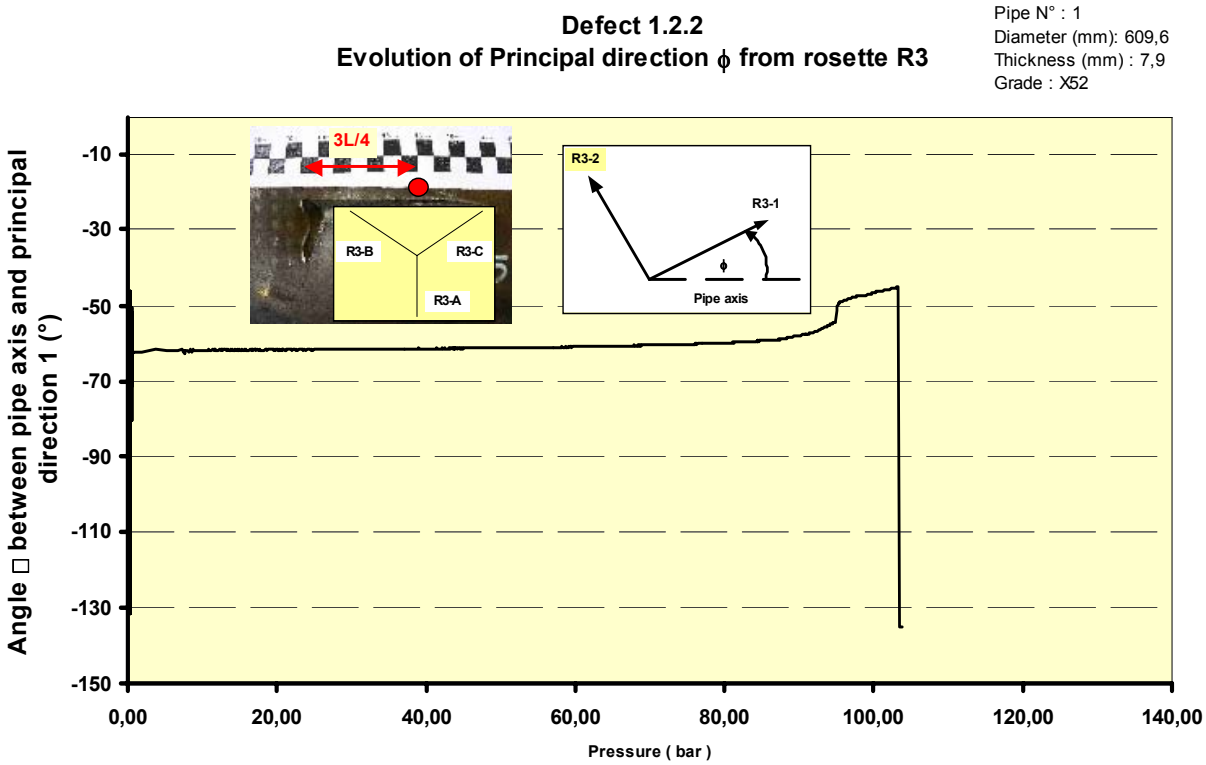

Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Defect 1.2.2
Evolution of gages from rosette R2 versus pressure
Strain (%)
Pressure (bar)
L
L/4
R2B
R2C
R2A
R2A %
R2B %
R2C %


Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Defect 1.2.2
Evolution of Principal strains from rosette R2
Strain (%)
Pressure (bar)
R2-2
R2-1
ϕ
Pipe axis
L/4
R2-B
R2-C
R2-A
R2-1
R2-2


Defect 1.2.2
Evolution of Principal direction ϕ from rosette R2
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Angle ϕ between pipe axis and principal direction 1 (°)
-10
-30
-50
-70
-90
-110
-130
-150
0
20
40
60
80
100
120
140
Pressure (bar)
L/4
R2-B
R2-C
R2-A
R2-2
R2-1
ϕ
Pipe axis


Defect 1.2.2
Evolution of gages from rosette R3 versus pressure
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
Strain (%)
1,5
1
0,5
0
-0,5
-1
0
20
40
60
80
100
120
140
Pressure (bar)
L
3L/4
R 3 B
R 3 C
R 3 A
R3A %
R3B %
R3C %

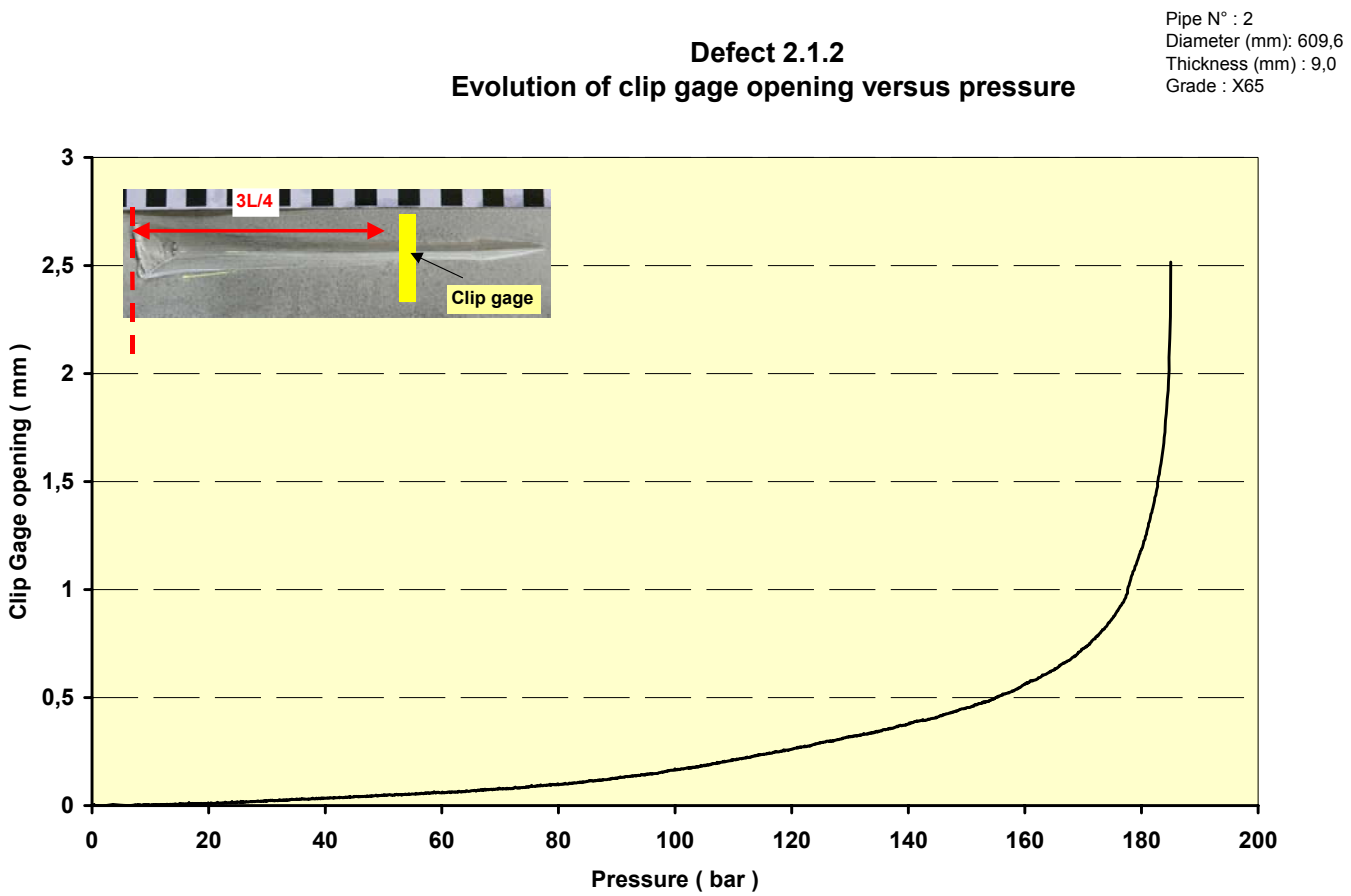

Defect 1.2.2
Evolution of Principal strains from rosette R3
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
3L/4
R3-B
R3-C
R3-A
R3-2
R3-1
ϕ
Pipe axis
Strain (%)
1,20
1,00
0,80
0,60
0,40
0,20
0,00
-0,20
-0,40
-0,60
-0,80
0
20
40
60
80
100
120
140
Pressure (bar)
R3-1
R3-2

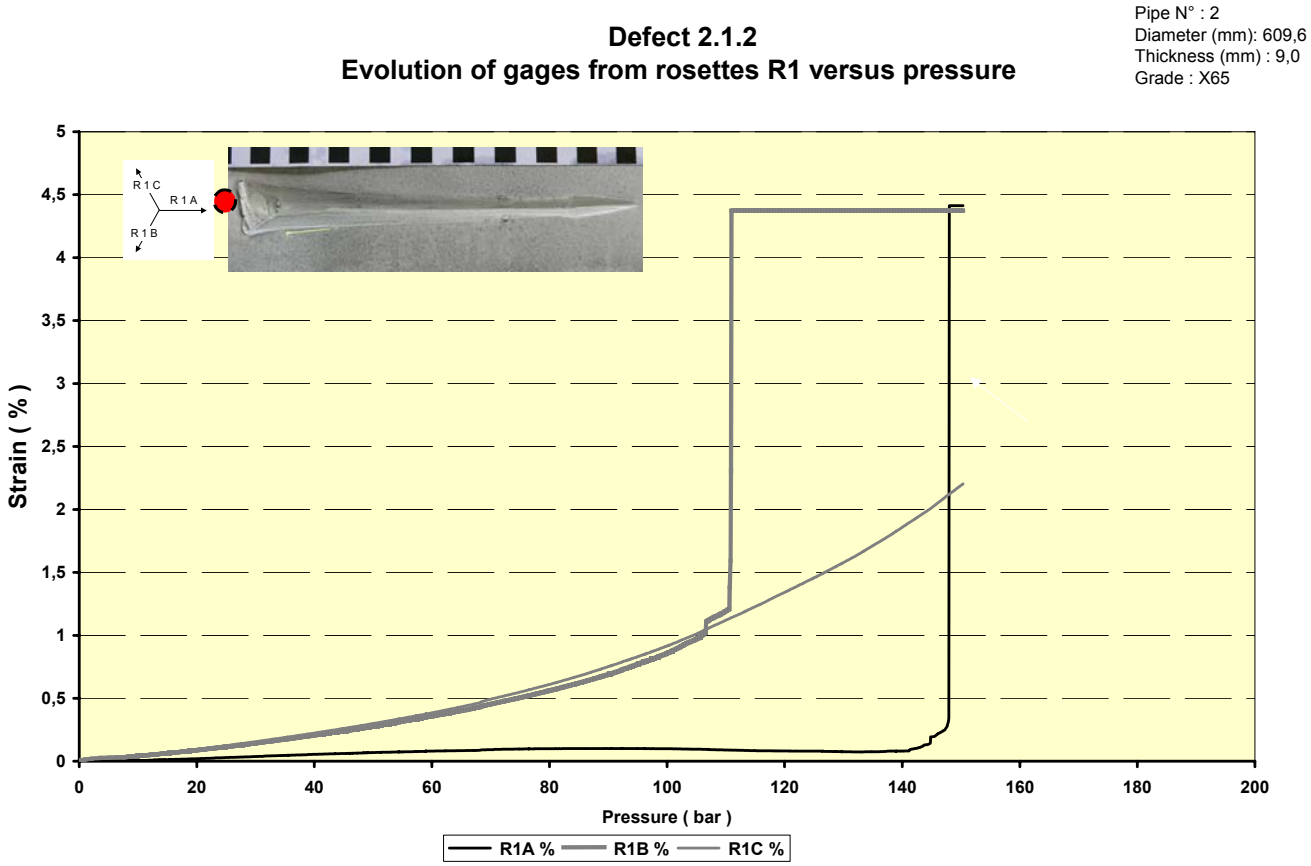

Defect 1.2.2
Evolution of Principal direction ϕ from rosette R3
Pipe N° : 1
Diameter (mm): 609,6
Thickness (mm) : 7,9
Grade : X52
3L/4
R3-B
R3-C
R3-A
R3-2
R3-1
ϕ
Pipe axis
Angle □ between pipe axis and principal direction 1 (°)
-10
-30
-50
-70
-90
-110
-130
-150
0,00
20,00
40,00
60,00
80,00
100,00
120,00
140,00
Pressure (bar)

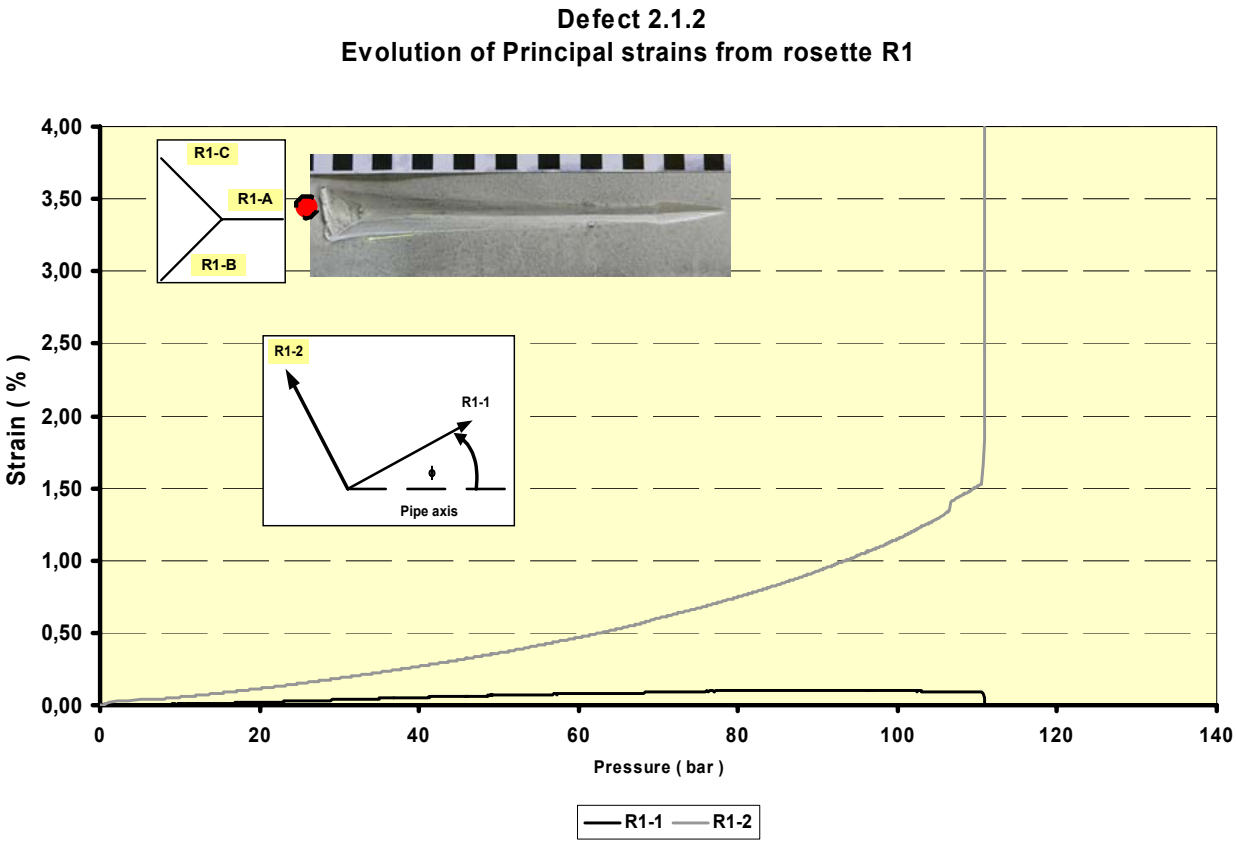
The strain-gauge positions are given in the following graphs. A monotonic increasing internal pressure was applied. The vessel burst in the defect at a failure pressure of 185 bar. The failure is a ductile rupture, in shear mode, as shown in the picture below.

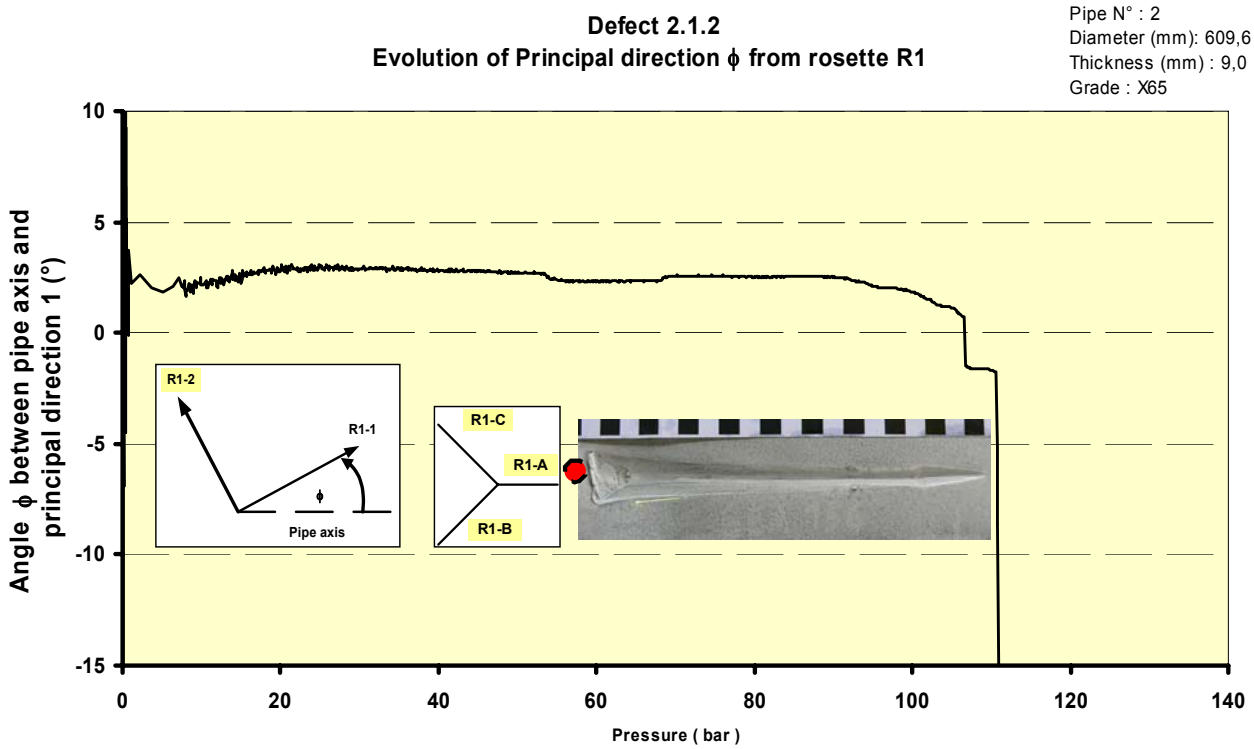
Rupture at 185 bar initiated in the defect

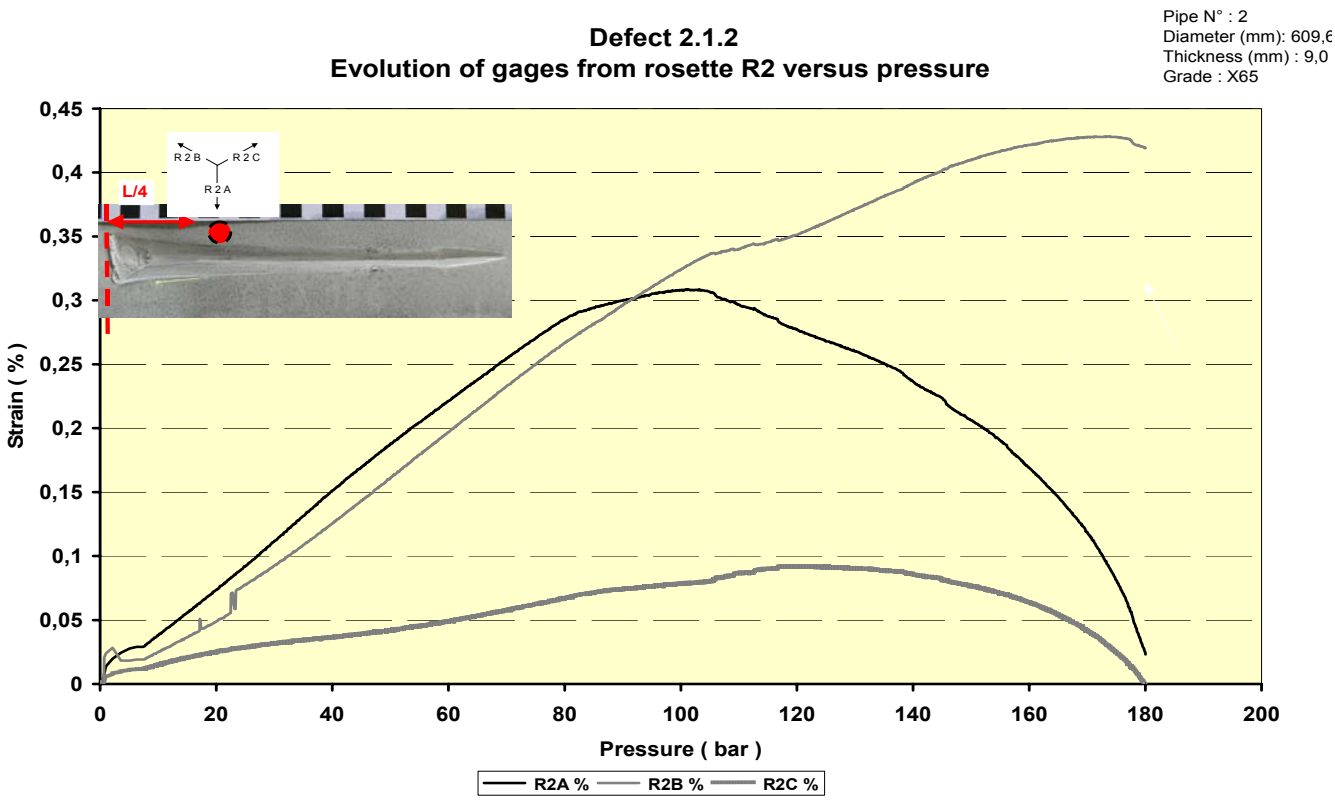
The following graphs provide the evolution of all instruments: clip-gauge, strain gauges, etc. versus internal pressure. Unfortunately, the circumferential strain-gauge failed at the beginning of test so the information from this strain-gauge is not available.

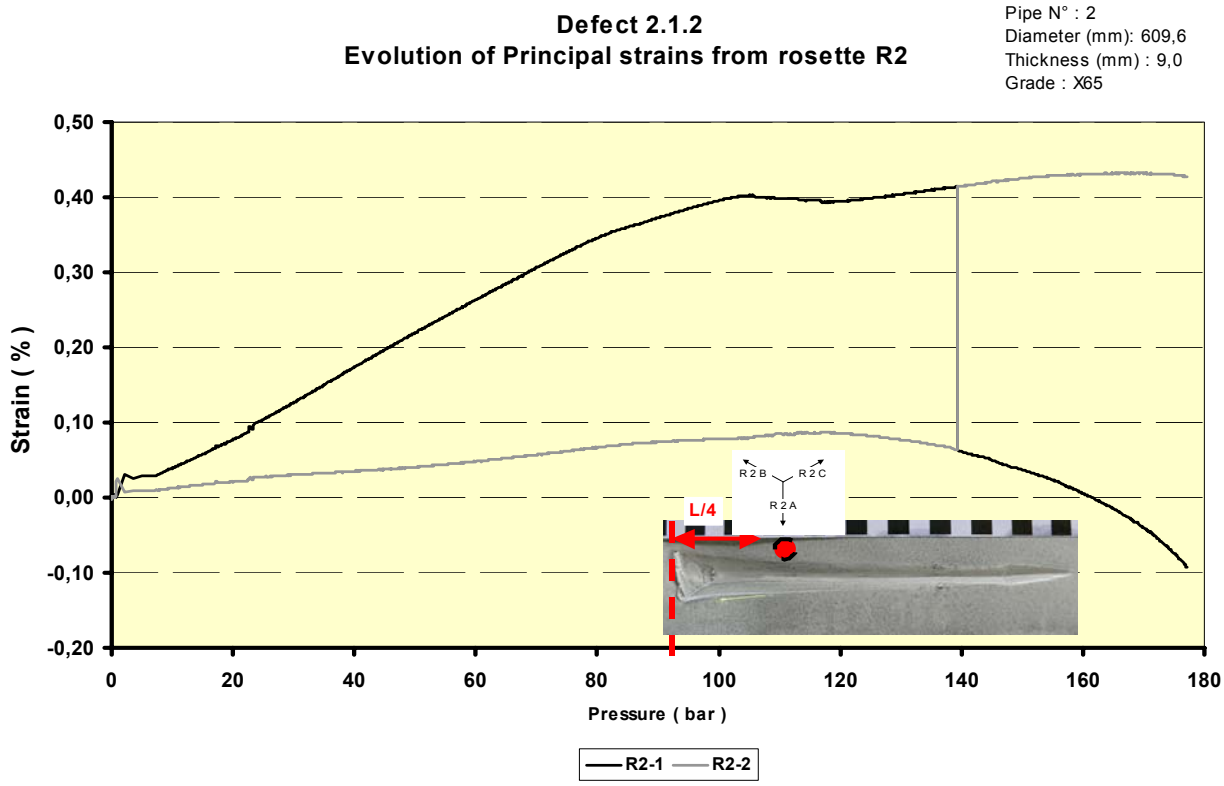

Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Defect 2.1.2
Evolution of clip gage opening versus pressure
3L/4
Clip gage
Clip Gage opening (mm)
Pressure (bar)
0
0,5
1
1,5
2
2,5
3
0
20
40
60
80
100
120
140
160
180
200


Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Defect 2.1.2
Evolution of gages from rosettes R1 versus pressure
R1C
R1A
R1B
Strain (%)
Pressure (bar)
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
0
20
40
60
80
100
120
140
160
180
200
R1A %
R1B %
R1C %

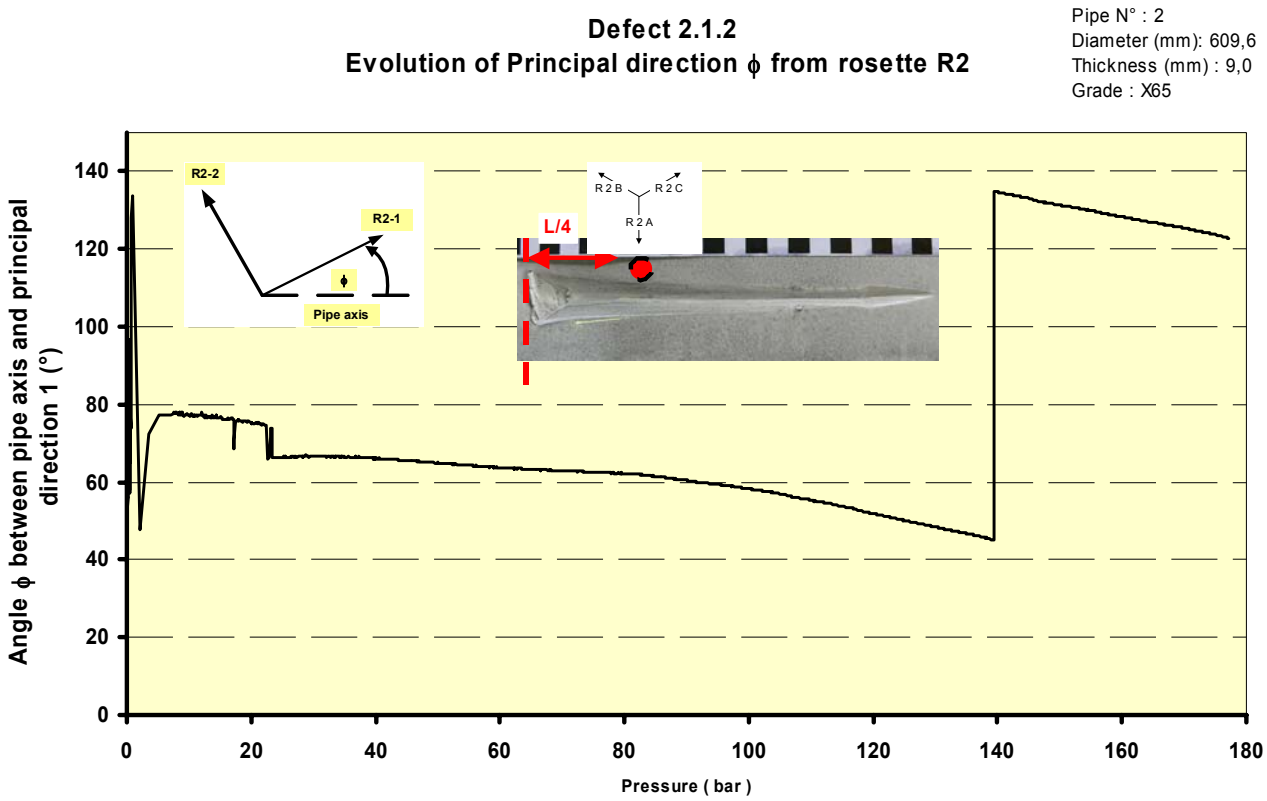

Defect 2.1.2
Evolution of Principal strains from rosette R1
Strain (%)
Pressure (bar)
R1-C
R1-A
R1-B
R1-2
R1-1
Pipe axis
R1-1
R1-2

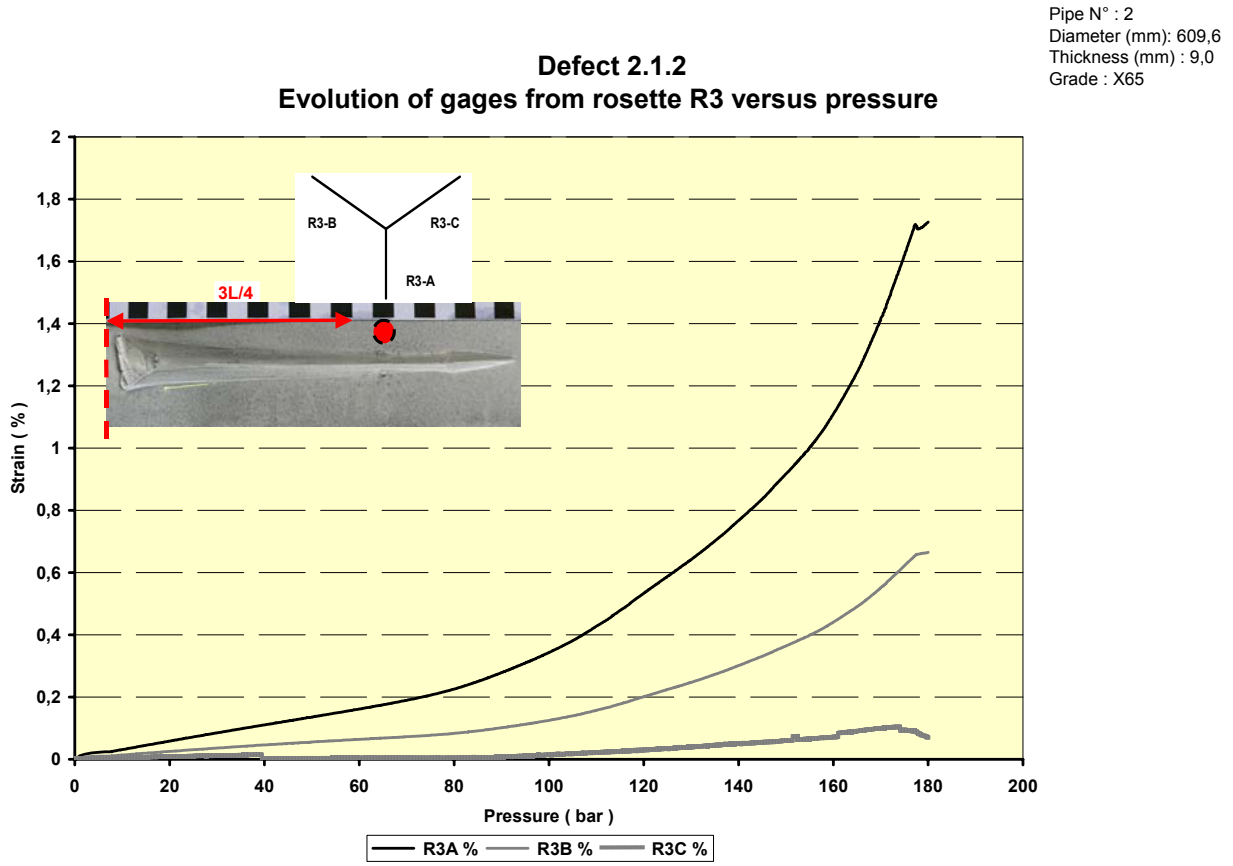

Defect 2.1.2
Evolution of Principal direction ϕ from rosette R1
Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Angle ϕ between pipe axis and principal direction 1 (°)
Pressure (bar)
R1-2
R1-1
Pipe axis
R1-C
R1-A
R1-B

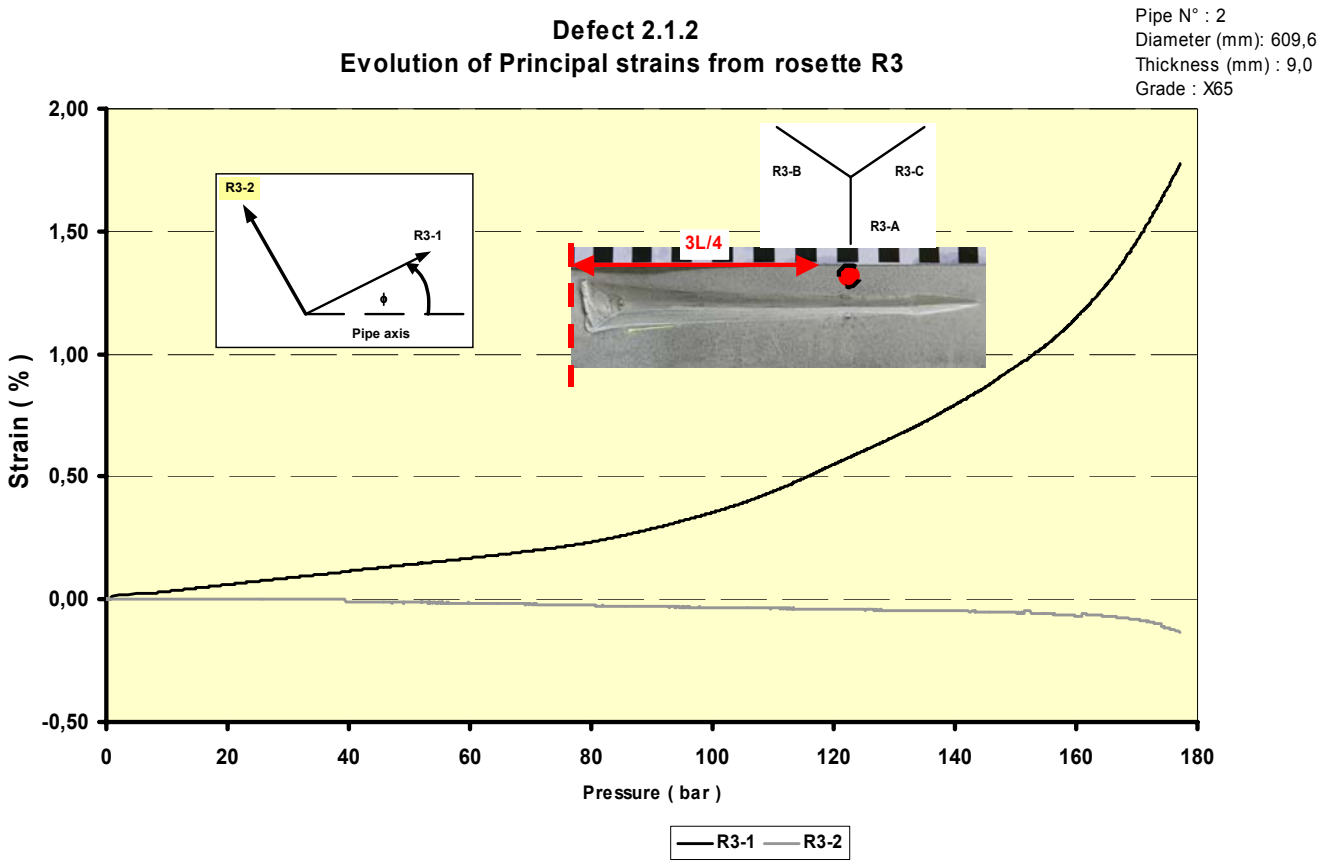


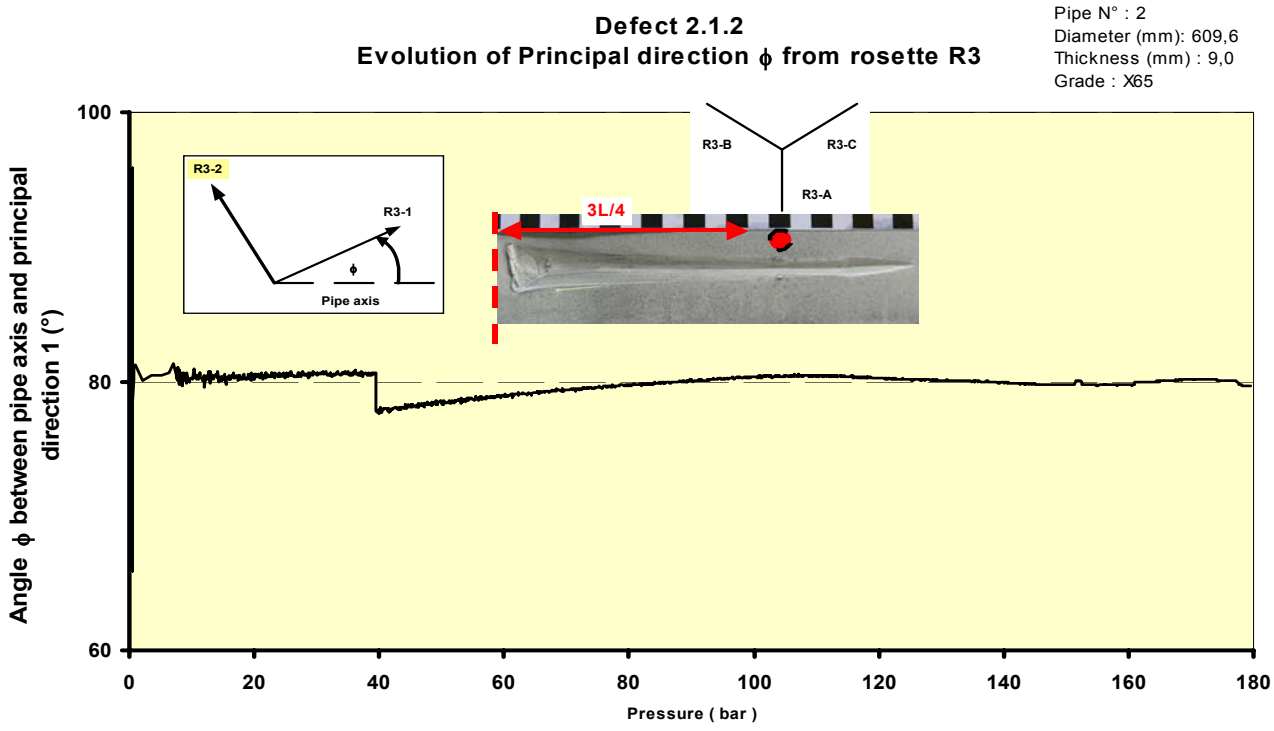


Note the 90° switch in principal directions, that results in an exchange of the strain gauge readings between gauges.


Defect 2.1.2
Evolution of Principal direction ϕ from rosette R2
Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Angle ϕ between pipe axis and principal direction 1 (°)
Pressure (bar)
R2-2
R2-1
ϕ
Pipe axis
R2B
R2C
R2A
L/4


Defect 2.1.2
Evolution of gages from rosette R3 versus pressure
Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Strain (%)
Pressure (bar)
R3-B
R3-C
R3-A
3L/4
R3A %
R3B %
R3C %


Defect 2.1.2
Evolution of Principal strains from rosette R3
Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Strain (%)
2,00
1,50
1,00
0,50
0,00
-0,50
0
20
40
60
80
100
120
140
160
180
Pressure (bar)
R3-2
R3-1
ϕ
Pipe axis
R3-B
R3-C
R3-A
3L/4
R3-1
R3-2


Defect 2.1.2
Evolution of Principal direction ϕ from rosette R3
Pipe N° : 2
Diameter (mm): 609,6
Thickness (mm) : 9,0
Grade : X65
Angle ϕ between pipe axis and principal direction 1 (°)
100
80
60
0
20
40
60
80
100
120
140
160
180
Pressure (bar)
R3-2
R3-1
ϕ
Pipe axis
R3-B
R3-C
R3-A
3L/4

Main Conclusions:

Principal strains and direction for defects 1.1.2 and 1.1.3

- Principal strains and directions were determined for previously performed defects 1.1.2 (Burst test) and 1.1.3 (Fatigue test).

Creation of defects 1.2.2 and 2.1.2:

- Two defects 1.2.2 and 2.1.2 were created respectively similar to defects 1.2.1 and 2.1.1.
- Total absorbed energies for the defect creations were recorded.
- 3D laser mapping and 2D laser profiles of the defects were determined.
- The defect 1.2.2 on pipe 1 is shorter but with a deeper gouge than defect 2.1.2 on pipe 2, as different aggression teeth were used.
- Magnetic particle inspection (MPI) revealed cracks in the gouge for defect 1.2.2, and also for defect 2.1.2 but rather microcracks, less numerous and less easy to observe.

Burst tests on defects 1.2.2 and 2.1.2:

- Both defects were instrumented in the same conditions with a circumferential strain gauge in the gouge, a clip gauge and 3 strain gauge rosettes.
- Defect 1.2.2 in pipe 1 failed by leak in the gouge at a pressure of 110 bar, whereas the defect 2.1.2 in pipe 2 led to a ductile rupture at 185 bar (in shear mode).
- For the both defects, all gages were interpreted including principal strains and direction for rosettes, except for circumferential gage of 2.1.2 which failed.

Preparation for creation of defects 1.2.3 and 2.1.3: Exploratory internal strain gauges

- To comply with the new project team request, strain gauges were installed on the internal wall of pipes before the defect creations under the expected impact zone, to record the strain evolution during the impact.

Business Status

The project remains well coordinated with the pipeline industry through the PRCI partnership on the project.

Schedule & Payable Milestones

Task 2 is slightly behind schedule due to identifying pipe and collecting cost/schedule data for the vintage pipe. Task 3 is behind due to capturing data as it becomes available from sources. Neither task will delay the overall schedule of the project.

Task No.	Task	Status	Scheduled Completion Date	Payable Milestone (Item No)
1	Project Kick Off Meeting and Subcontracting	100% Complete	8/31/2008	
2	Purchase & Characterize Pipe Material	60% Complete	11/30/2008	
3	Literature Review – effect of pre-strain and dent-gouge defect from field feed-back	70% Complete	11/30/2008	
4	Testing of Dents on Welds and Corrosion Features	0% Complete	11/30/2009	9
5	Testing of Dents with Gouges	20 % Complete	5/31/2010	10
6	Demonstration of Mech. Damage Model Performance	0% Complete	5/31/2009	
7	Industry Workshop	0% Complete	5/31/2010	
8	Project Management and Reporting	On-Going	5/31/2010	11

Issues, Problems or Challenges

- To improve the similarity between the created defects of the same type, the aggression tooth has to be examined after the impact test and reshaped to get as close as possible to the same geometry as initially before launching the following test to create a similar defect.
- For the next defects 1.2.3 and 2.1.3, a strain gauge was placed on the internal wall of the vessel in the area where the defect will be created, but before the defect creation. This gauge will record the strain evolution on the internal wall side of the defect during its creation and then during subsequent fatigue and/or burst test. This supplementary action with respect to the contract involved a delay of two weeks.
- The residual stresses in defects called x.x.1 are realized on the same vessel for a given material. This process avoids to waste material using the same vessel for different x.y.1 defects. The consequence is that the residual stress determination and the metallurgical characterization of these already created defects will be performed at the end of the defect creation process for a given material (Pipe 1, Pipe 2, or Pipe 3).

Plans for Future Activity

Planned activities for the project are presented below.

Task 2: Purchase & Characterize Pipe Material

Team is preparing a summary plan outlining the steel procurement justification and cost analysis. Results on pre-strain effect on toughness for pipe 1 material will be compiled as well as results of material characterization on pipe 2.

Task 3: Literature Review

Any new information on pre-strain effect on toughness and on realistic defects from field feedback will be captured as it becomes available from other sources, like conferences, workshops and results of other PRCI projects.

Task 4: Testing of Dents on Welds and Corrosion Features

Full scale testing of the plain dents in the test matrix will be completed with a start planned for the dents on corrosion features.

Task 5: Testing of Dents with Gouges

Evaluate results of defect creations for defects 1.2.3 and 2.1.3. Creation of defects 1.3.1 and 2.2.1 with internal strain gauges will be completed. Initiate metallurgical investigation of failed defects 1.2.2 and 2.1.2. Evaluate results of fatigue tests of defect 1.2.3 or 2.1.3.

PUBLIC PAGE

QUARTERLY REPORT

Project WP#339: Structural Significance of Mechanical Damage

For Period Ending: November 30, 2008

Contract No: DTPH56-08-T-000011

Prepared For: United States Department of Transportation
Pipeline and Hazardous Materials Safety Administration
Office of Pipeline Safety

Prepared By: Aaron Dinovitzer
Principal Investigator
BMT Fleet Technology Limited
311 Legget Drive
Kanata, Ontario, Canada K2K 1Z8
adinovitzer@fleetech.com

Mures Zarea, Rémi Batisse
Principal Investigators
GDF Suez R&T Department
361 Ave du President Wilson
B.P. 33, 93211 Saint-Denis, France
mures.zarea@gdfsuez.com
remi.batisse@gdfsuez.com

Mr. Ian Wood
Team Project Manager
Electricore, Inc.
27943 Smyth Drive, Suite 105
Valencia, CA 91355
ian@electricore.org

Mark Piazza
Team Technical Coordinator
Pipeline Research Council, International
1401 Wilson Blvd., Suite 1101
Arlington, VA 22209
mpiazza@prci.org

Public Page for Quarter Ending November 30, 2008

Project WP#339: Structural Significance of Mechanical Damage

Background

The primary objective of the project is to establish a detailed experimental database to support the development and validation of improved burst and fatigue strength models for assessing the interaction of mechanical damage with secondary features (gouges, corrosion, and welds). The use of this data to develop and validate mechanistic models will produce reliable tools to assess a wide range of mechanical damage forms, thereby increasing safety, reducing unnecessary maintenance, and supporting the improvement of pipeline standards and codes of practice.

Progress in the Quarter

GDF SUEZ created two combined defects "Dent - Gouge" one on a recent pipe specified as API X52 and the second on a recent pipe specified as API X65, both steels being characterized by a high level of ductility:

- Defect 1.2.2 on pipe grade X52.
- Defect 2.1.2 one pipe grade X65.
- The maximum gouge depths and dent depths (measured without internal pressure) are respectively of 30% and 2% for defect 1.2.2 and 19% and 1,3% for defect 2.1.2. The gouges are respectively 115 mm and 195 mm long. Theses values correspond to the defect types 1.2.1 and 2.1.1.

Burst tests were performed on both defects. Defect 1.2.2 burst at 59% of the burst pressure of defect 2.1.2. But the significant difference is the failure mode, by leak for defect 1.2.2 and by rupture for defect 2.1.2. After tests all instrumentation records were represented in graphical form, and principal strains and principal directions were determined from the strain gauges records.