



Coiled Tubing String Failures – Past and Present

ICoTA Canada Breakfast Technical Session May 30th 2018

Tomas Padron – Coiled Tubing Research & Engineering



Outline

- What is a CT string failure and examples
- Why doing CT string failure analyses
- CT string failure analysis process
- CT failure statistics
- Main ideas

CT String Failures

- Knowledge and control of fatigue performance
- Improvements in materials and manufacturing processes

Within the company:

- CT failures are analyzed and causes established
- CT failures statistical data



What is a CT Failure?

- CT failure:
 - Loss of pressure integrity of the tubing during service and before the predicted fatigue life has been exceeded.

 Any condition that renders the string not safe to be used.



It's only a failure if you don't learn something

What is a CT Failure? – Examples

Pinhole

Partial Fracture

POOH – PLT run

RIH – Milling

Total Fracture

Pulling to free string Cleanout



2-3/8" OD – CT90



2" OD – CT90

What is a CT Failure? – Other examples



Why doing CT strings failure analyses?

 Make decisions / take corrective actions based on data and not guesses or "gut feelings"



Why doing CT strings failure analyses? – Example

Failure Sequence- Date	Manufacturer	Diameter (in.)	Grade	Days of Service	Runs – Wells	Max. SFL used (%)
First April 9 th 2013				26	22 - 7	36
Second May 6 th 2013	A			47	25 - 6	36
Third May 18 th 2013		2	90	24	14 - 6	29
Fourth May 20 th 2013	В	2	30	14	11 - 4	17
Fifth July 5 th 2013				41	22 - 7	50
Sixth July 24 th 2013	A			11	9 – 3	34

All six failures were associated to MIC (fluid contaminated with bacteria)



"Solutions" initially proposed without any failure analysis:

- "Bad quality" pipe change manufacturer
- Change the string Grade to YYY
- Limit the fatigue life used to XX%
- Others

Real solutions:

- Treatment of surface equipment
- Treatment of circulating fluids
- Between-wells stagnant fluids treatment

CT failure analysis:

Logical process of examination to establish the failure cause(s) based on evidence collected and the use of engineering principles.





Failure analyses are not done with a black box

We don't use crystal balls either !!!!



Failure Report

- Most common CT failure analyses include the following stages:
 - Sample(s) collection/preservation
 - Collection of data regarding failure/CT string
 - Visual/stereoscopic examination
 - Dimensional inspection
 - Metallographic analysis



Results analysis and report preparation

- Some additional analyses that are required for some particular cases:
 - Energy-Dispersive Spectroscopy (EDS)
 - Scanning Electron Microscope (SEM) Fractography
 - Tension tests
 - Others: Charpy test, corrosion tests, etc.



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CT string failure analysis process – Sample(s) collection / preservation



Level: L2 - Procedure Tier: GLB - Globa Document Type: Procedure Sub Element: Operations Doc Number: OPS-GLB-En-101452 Rov. A Effective Date: 3/4/2015

2.5.3.8 Procedure for Collection of Field Samples of Coiled Tubing In The Event of a Failure



1.2 Sample Collection

- Cut at least 1 foot on either side of the failure location. Use a tubing cutter or saw to do this, NOT a cutting torch. The up-hole end should be labeled U1 and the downhole end D1.
- Cut 7 to 8 foot samples on either side. Use a tubing cutter or saw to do this, NOT a cutting torch. Each end of the sample should be labeled U2 - U3 and D2 - D3.

			-		
U3	U 2	Ul	D1	D2	D3

Figure - 1 Required Sample Marking







Data about the failure: date, failure type, job, operation, well and customer, tubing depth, any additional information



Failure Report

Date Printed: 5/11/2018

Reel Number: TA-22022	String Length: 21,047.00 ft	
String Number:	Outside Diameter: 1.75 in	
String Description: Tapered	Current Volume: 40.567 bbl	
String Material:	District/Boat:	
Accumulated Fatigue: 1.320 %	Total RIH Distance: 41,293.00	ft

Cause Of Failure:			9/25/2017 10:00:54 AM
Failure Type	Pin Hole	Operation	Stationary
Failure Place	On the Reel	Job Type	Unspecified
Tubing Depth	13,385.83 ft	Job Ticket No.	
RIH Weight	0.00 lb	Location	
POOH Weight	0.00 lb	Customer	
Overpull Lavoff Weight	0.00 lb	Reel No.	TA-22022
CT Pressure	0.00 psi g	Core Diameter	90.000 in
WH Pressure	0.00 psi g	Core Width	86.00 in
Fluid Rate	0.00 bbl/min	Flange Diameter	156.000 in
Fluid Type	Water Based		

Comments: Leak was found when fluid was pumped into CT string for pressure testing. Failure of string to be defined after the metallurgic test.



Date

09/20/1

Revision 1 20 Feb 13

ed after installation and fina

12 0.86 0.012 0.002 0.34 0.28 0.19 0.62

Approved By

Signatur

vmond Goodman

RU. Gradman

String records:

- First job date / Most common job
- Average fatigue used / Fatigue used at failure location
- Long term storage periods and corrosion protection activities

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Job parameters and operational limits (mainly for overload/buckling failures)





CT string failure analysis process – Visual/Stereoscopic Examination

• One of the most important stages – In many cases gives good evidence on the cause of the failure – What to look for during this stage?:

Mechanical damage



External Corrosion

Internal Corrosion



Necking and 45° fracture propagation



Fishing -2" - CT90

Small longitudinal splits

Pressure Testing 2-3/8" –

CT100

Optiport



Confirm the presence of a bias weld



 \sum



OD Milling – 1-1/2" – CT90

Fracture origin

Fracture origin



Fishing – 1-3/4" – CT90



Figure 4. Detailed view of the "flat" portion of the fracture shown in Figure 3b. The following features can be observed:

- Ratchet marks at the outside diameter (small white arrows), indicative of multiple fatigue cracks starting at the outside diameter.
- · Thumbnail cracks starting from external pits (darker areas enclosed by dotted lines and block arrows).
- Some light marks concentric towards the OD can be observed (small green arrows), indicating propagation by fatigue from the OD.

All these features indicate that the fracture started at this location (fracture origin) from multiple fatigue cracks that propagated from the outside diameter at external pits.

CT string failure analysis process – Dimensional inspection

Verify the pipe condition regarding OD, ovality, wall thickness. Acid corrosion





Acid job – 1-1/2" – CT80

Up-hole direction Up-hole Up-hole

Location	Down-hole end (1)	1	2	3	4	5	6	7	8	9	10	11	12	Up-hole end (1)
Thickness measured (in.)	0.121"	0.111	0.107	0.101	0.083	0.068	0.056	0.056	0.082	0.087	0.105	0.120	0.120	0.133

(1) Measured at approximately 12" from the central portion on each side

Cleanout - 1-3/4" - CT90

External abrasion

• With the information gathered from the previous stages normally there is a good idea of what caused the failure.



Check pipe microstructure is OK: Q&T 20 µm Bias Weld

• Mechanical damage: confirm plastic deformation at damage:



Pipe crushing

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• Corrosion: corrosion depth / metallurgy at corrosion:



• MIC: pitting shape: normally "cavernous", deep, and very aggressive:



• Manufacturing flaw:





Environmental cracking: •



Caustic cracking

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• EDS: corrosion products / foreign particles



CT string failure analysis process – SEM Fractography

• SEM fractography: confirming fracture propagation mode: brittle (cleavage/intergranular) or ductile (dimples).

Cleavage on secondary crack (after opening) – MIC failure





Cracks on dimple on connection – Elongated dimples (shear) on cracks

CT string failure analysis process – Tension test

SPE 38412

Determining the N A. Crabtree, SPE, BJ Se



- 3.d. Conduct one unloading and reloading cycle at approximately 0.8% of strain to obtain the elasticity modulus as schematically shown in Figure 11.
- 4.b. Determine the Yield Strength by intercept of the tensile curve with the 1% offset line drawn at the angle of the elastic reloading line obtained in step 3d.



Figure 11. Schematic showing a full body tensile test procedure for determining Yield Strength and modulus of elasticity of bent pipe.

length

mun universions and mark

CT string failure analysis process – Tension test



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CT Failures Statistics – Terminology

Storage-corrosion: corrosion damage caused by the accumulation of corrosive fluids (within or outside the string) while it remains in storage for long periods.



Internal storage-corrosion example

Acid internal-corrosion example



Corrosion-operations: corrosion damage caused by the action of fluids pumped or the well environment during operations

CT Failures Statistics – Terminology



Mechanical damage: premature fatigue failure that starts at external damage caused by mechanical means.

Manufacturing flaw: premature failure associated with issues originated during the manufacturing process



"Cold weld" example

CT Failures Statistics – Terminology

Human error: failure associated with errors during the string operation.



Buckling







MIC (Microbiological influenced corrosion): corrosion failure due to the presence of certain specific type of bacteria within the fluid in contact with the pipe.

CT Failures Statistics – Period 1994-2005



- CT Failures trend is similar for the CT industry
- Main causes: Corrosion / Mechanical damage / Manufacturing flaw / Human error
- These causes represent around 80% to 90% of CT failures

CT Failures Statistics – Period 2006-2017 vs. Previous Periods



4 main CT failures causes have remained the same:

- Corrosion (≈ 30%)
- Mechanical damage (≈ 30%)
- Manufacturing flaw
- Human error

⁽¹⁾ All Others includes: fatigue, erosion, H2S failure, field welding, ext. abrasion, unknown

Main Failures Causes Review: **Corrosion** (**≈30%**)



Main Failures Causes Review: **Corrosion** (≈30%)

- Mitigation measures Storage-corrosion:
 - Eliminating residual fluids
 - Application of corrosion inhibitors (internally/externally)
 - Records kept within the string management system

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Real #: 8600 Core Diameter: 8630 Core Width: 8630 Flange Diameter: 15500 String #: 10000 Current Volume: 33000 Tubing 0.0.: 1.7500 TCAVLO.D:: 0.0000	Task Type: Corrosion Protection Date Entered: 2015/02/17 Maintenance Date: 2/17/2016 Maintenance Time: 15:53 HH:MM County: Comment Comment	Diginating Real Real Real Core Diameter: 86.0 in Core Widtr: 88.5 in Flange Diameter: 155.0 in	1
Accumulated RH Distance: 97656.4 m RH Distance: 18.972 % ■ OK Maint = 2017/11/2011 ■ OK Maint = 2017/01/002 1 ■ OK Maint = 2017/01/002 1 ■ OK Maint = 2017/01/0103 ■ OK Maint = 2017/01/0103 ■ OK Maint = 2016/002/01 1 ■ OK Maint = 2016/002/01 1 ■ OK Maint = 2016/01/18 00: ■ OK Maint = 2015/002/15 16: ■ OK Maint = 2015/002/15 16: ■ OK Maint = 2015/002/15 14: ■ OK Maint = 2015/002/15 14:	C Internal C External Inhibitor Type Steelgard RP (50 days) Treatment Fluid Volume Pump Rate 1.00 bbl 0.50 bbl/min Flush N2 Rate N2 Volume N2 Rate 40000.00 scl 800.00 scl/min	Effective for (days) 60	

Main Failures Causes Review: Mechanical Damage (≈30%)



- Normally caused by the action of the surface equipment.
- Can be very diverse.
- Stress/strain concentration point

Main Failures Causes Review: Mechanical Damage (≈30%)

Most frequent types of mechanical damage (2006-2017):

Damage:	Longitudinal Plowing Mark (LPM); Freque	ncy: 46%
General Appearance	Detailed view	Longitudinal Section
Part Part	T	OD 1 mm D

Damage: Transverse Notch; Frequency: 30%					
General Appearance	Detailed view	Longitudinal Section			
	TV Inn	OD d <u>1 mm</u>			

Main Failures Causes Review: Longitudinal Plowing Marks (LPM)



Main Failures Causes Review: Longitudinal Plowing Marks (LPM)

Frequently associated with worn gripper blocks



Main Failures Causes Review: Longitudinal Plowing Marks (LPM)



Some mitigation actions for LPM:

- Replacing "smooth" gripper blocks based on OEM recommendations
- Coating gripper blocks with tungsten carbide
- Inspect gripper blocks prior mobilization for the presence of debris in the grooved gripper blocks

Main Failures Causes Review: Manufacturing Flaw



Main Ideas

• CT Failures occur and in many cases it is worthy to perform failure analyses to establish the cause(s) based on data/evidence



Main Ideas

CT failure analysis:

Logical process of examination to establish the failure cause(s) based on evidence collected and the use of engineering principles.



Most common CT failure analyses include the following stages:

Failure Report

- Sample(s) collection/preservation
- Collection of data regarding failure/CT string
- Visual/stereoscopic examination
- Dimensional inspection
- Metallographic analysis 🖼
- Results analysis and report preparation

Main Ideas

- Data allow inferring that the main CT Failures causes are similar for the CT industry.
- No significant change was observed on the CT failures causes for the periods 1994-2005 and 2006-2017:
 - Corrosion
 - Mechanical damage
 - Manufacturing flaw
 - Human error
- These causes represented around 80% 90% of the CT failures



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Thank you

Questions?

