

# Qualification of composite systems for the repair of pipelines and risers

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## Coating failures and corrosion of the pipes

Severe degradation of riser coatings and pipe coatings have been experienced on the pipelines operated in the Delta of Mahakam

- riser coatings failures are generally due to bad application. Severe corrosion was observed on the risers
- pipeline coating and field joint coatings were the results of inappropriate coating selection, bad application, ageing and mechanical damages. Severe corrosion and leaks have been experienced.



2 - Références, date, lieu



## Complexity of the pipe repairs by composites

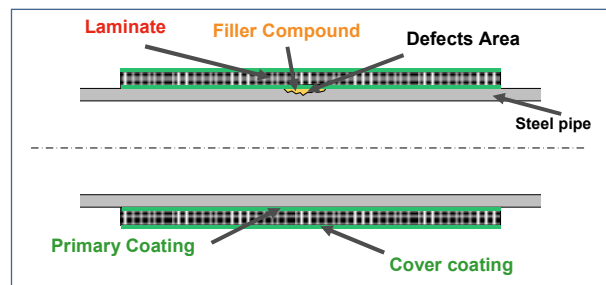
- ▶ About 200 repairs to be carried out on the risers and pipelines in a difficult environment.
- ▶ The coating on the risers, pipelines and at field joints are different (3LPE, 3LPP, Solid PU, FBE, Neoprene, EPDM, Coal tar enamel...) Repairs systems should be compatible with the existing coatings.
- ▶ Repair systems should restore the mechanical integrity and protect the pipelines and risers against corrosion.
- ▶ It was decided to qualify different composite systems



3 - Références, date, lieu



## Repair by composite systems – principal



4 - Références, date, lieu



## Main components of composite systems

Component	Function	Material
Circumferential reinforcement	Holding pressure, tension, flexion	Composite sleeves Tape, wrap in glass fibre or carbon Kevlar rope.
Filler / load transfer agent	Transmission of the load from the corroded pipe surface to reinforcement	Resin, mastic
Adhesive	Adhesion of reinforcement	Resin

5 - Références, date, lieu



## Domain of application of composite repair systems

- Non penetrating defects
- Maximum thickness loss shall be less than 80% of the initial thickness.
- In any case the minimum thickness is 2mm
- External defects only (dents, pitting, localised corrosion, gouges, blisters, lamination,...)
- Not acceptable for crack repair

6 - Références, date, lieu



## Total Indonesia requirements

### Repairs systems should be suitable / applicable :

- ▶ For steel pipes and risers with thickness losses up to 80%.
- ▶ For temporary repairs (2 years) and permanent repairs (20 years)
- ▶ For all diameters of pipe and riser
- ▶ For operating pressures up to 100 bars
- ▶ For operating temperatures up to 100°C
- ▶ On pipeline in operation (at reduced pressure)

Application should be simple and quick

7 - Références, date, lieu



## Qualification of available systems

### ▶ In 2004, four products were selected for testing

- Clockspring,
- 3X Reinforcekit
- Strongback
- Fortec

The objective of the testing was not to select the best one but

- To evaluate the gap between the performance of the existing systems and our requirements
- Then to work closely with manufacturers to improve the characteristics of the repair systems and to complete them by additional components if needed (application of anticorrosion coating, for example)

8 - Références, date, lieu



## Characteristics of the selected composites

### Resin impregnated fiber tapes: Fortec and Strongback

- Homogeneous structure
- Can be used on piping / pipelines of different shapes (elbows...)
- Characteristics can be adopted for high temperatures, underwater applications....



9 - Références, date, lieu



## Characteristics of the selected composites

### Prefab sleeves: Clockspring

- First generation composite repair. Widely used.
- It is comprised of 8 wraps of composite, a high-strength filler material and an adhesive
- Applicable mainly on straight pipe sections



10 - Références, date, lieu



## Characteristics of the selected composites

### Encapsulated systems: 3X Reinforcekit

- Wound up Kevlar rope + formwork + resin filler
- Straight pipe section only



11 - Références, date, lieu



## Challenges

### ▸ Structural behaviour

- Mechanical resistance and adhesion between different layers/ components
- Mechanism of the load transfer from the pipe to the repair system (failure mechanism)
- Resistance to impact

### ▸ Environment

- High temperature resistance (disbonding, deformation, accelerated ageing)
- Corrosion resistance (disbonding, crevice corrosion)

### ▸ Long term behaviour

- Ageing
- Fatigue (cyclic pressures)

### ▸ Application

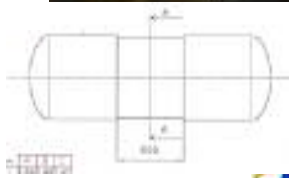
- Surface preparation
- Quality of the applied system and reproducibility
- Possibility to repair, repair procedure

12 - Références, date, lieu



## Test program

- Applications of repair systems were carried out in Eupec facilities in France by the manufacturer/ supplier of each system
- All tests were carried out in Eupec facilities according to procedures proposed/ agreed by Total.
  - Pressure test of pipes having circumferential machined defects (remaining thickness is 20% of initial wall thickness)
  - Impact test
  - Adhesion tests before and after ageing in sea water at 100°C during 1000 hours. Adhesion tests were carried out for the evaluation of adhesion between repair system and steel and also between repair system and PP, PU, EPDM (overlap areas)
  - Cathodic disbonding tests



13 - Références, date, lieu



## Results



### Pressure test

- Failures were generally circumferential, due to axial load created by End Effect. **Failures occurred before reaching the burst pressure.**
- It seems that the repair systems were developed to hold the hoop stress (circumferential). They do not take into account of the axial stress.
- Axial load is mainly hold by the remaining cross section of the steel at the defect. **Premature failure is unavoidable.**



14 - Références, date, lieu



## Results

### Adhesion test

- Generally good adhesion to the steel before and after ageing for the systems having anticorrosion coating (>2.5Mpa after ageing)
- There is almost no adhesion to PP, PU, EPDM (< 1Mpa) as expected
- Some systems have limited resistance to high temperature (severe deformation and disbonding at 100°C). During ageing, the adhesion strengths decrease from 9 – 10 MPa to 1-3 MPa.



15 - Références, date, lieu



## Results

### Cathodic disbonding tests

- Some systems have no anticorrosion coating. Consequently, resistance to cathodic disbonding is very low.
- With anticorrosion coatings, results are acceptable in most of cases (increase of radius is 1 et 5mm)
- Some systems fails completely at 65°C (disbonding)



16 - Références, date, lieu



## Final qualifications

**Following qualification program with 4 products, Total continued cooperation with manufacturers**

- To improve the performance of the proposed systems
- To define the limits (especially temperature) and domain of use of each system
- To complete the repair systems with suitable anticorrosion coatings.

**Significant improvements have been achieved with all four products tanks to very positive cooperation.**

17 - Références, date, lieu



## Feed back from operations

- ▶ **Indonesia: Strongback have been used. Qualification tests for Clockspring and Fortec in 2007**
- ▶ **Yemen: 3X en 2006 and Clockspring en 2008 on the 10" export line**
  - **Some systems are sensitive to UV**
  - **Application procedures to be improved**
  - **Presence of a local agent / qualified applicator is important**

18 - Références, date, lieu



## Since qualification program of Total....

- ▶ Several working parties have been working on the subject for few years (PRCI, ISO, ..)
- ▶ ISO working party is preparing ISO 24817 related to pipeline repairs by composite materials

### Testing program:

- Resistance to axial load
- Resistance to ageing at high temperature

**ISO document does not cover corrosion aspects.**

- ▶ Total prepared a specification for composite repairs. It is in line with ISO 24817. Some additional requirements are included (adhesion, cathodic disbonding, subsea application, fatigue test etc).



19 - Références, date, lieu



## Other available systems on the market

More than 10 systems were identified

- ▶ Clockspring, Strongback, 3X, Fortec. Total continues to work on these products.
- ▶ Some systems were already used by Total : IMG and Armorplate. They will be qualified case by case considering temperature and the corrosivity of the environment.
- ▶ Other systems that can be qualified by a second qualification project or by a joint industrial project or working party: DML, Diamond Wrap, Spider Wrap (Aquawrap), Fibaroll, Technowrap (Aquawrap), Permawrap



Total is working with Fortec for submarine application.

20 - Références, date, lieu



## Conclusions

### ► General comments

- There is no universal system. Each system has its domain of application.
- Product data sheets provide general information and it is not a guarantee of performance for 20 years. Each system is to be qualified considering type of defects, environment and mechanical requirements.
- Most of the systems do not take into account corrosion aspect. If needed the repair system is to be completed with an anticorrosion system

21 - Références, date, lieu



## Conclusions

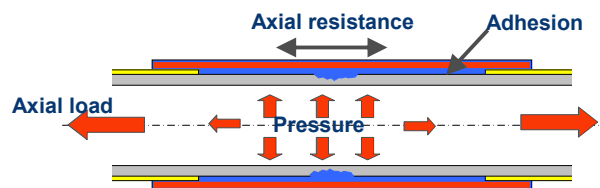
### ► Mechanical resistance

#### Existing systems are acceptable for:

- Buried pipes as axial loads (including end effect) are supported by the soil and supports
- Unburied pipes with limited circumferential defects as axial loads (including end effect) can be supported by the unaffected part of the pipe cross section (to be evaluated case by case)

#### Some improvements are needed for unburied pipes with circumferential defects

- axial loads including end effect should be taken into account in the design by bidirectional reinforcement,
- adhesion to the steel and transmission of the load should be improved.



22 - Références, date, lieu



## Conclusions

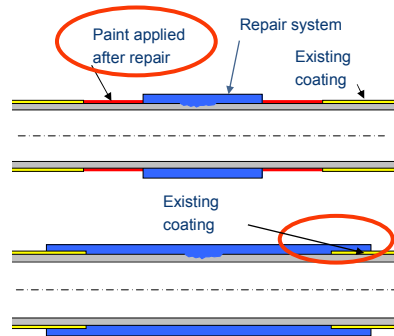
### ► **Anti-corrosion protection**

The continuity of the anticorrosion protection is not provided by most of the proposed systems. The adhesion of the repair system to the pipe coating or protection of the interface by another anticorrosion coating should be investigated.

#### Atmospheric zone

#### **Minimum requirement if no water wetting is expected**

- No overlap between the paint applied after repair
- No adhesion to the existing pipe or riser coating



23 - Références, date, lieu

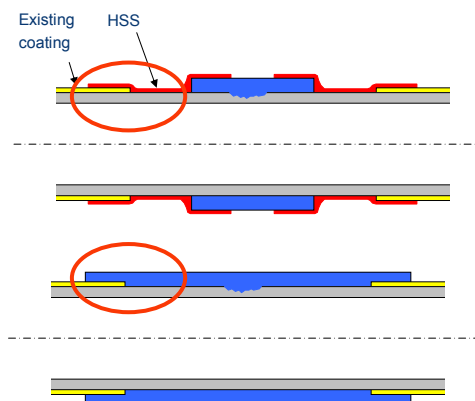


## Conclusions

### ► Splash zone or buried zone

Adhesion to the existing or repair coating and painting

- No adhesion between the heat shrinkable sleeve and the pipe coating. More works are needed.
- Adhesion to the existing coating is to be improved for the immersed zone.



24 - Références, date, lieu

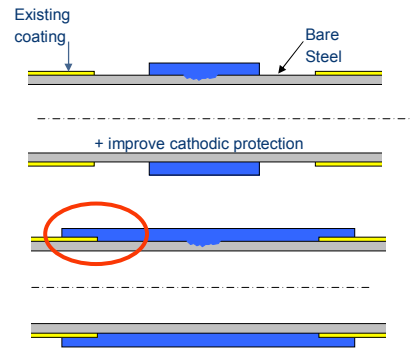


## Conclusions

### ► Immersed zone

If no overlap between pipe coating and repair system, bare surface is not repaired. It is protected by cathodic protection

If overlap between repair system and pipe coating, adhesion to the pipe coating is to be improved on the overlaps or overlap area is to be removed



25 - Références, date, lieu



Thank you....

26 - Références, date, lieu



## Total specification GS EP PLR 310

### ► Qualification of the composite repair systems according to ISO 24817. QA/QC defined by ISO standard

- Design methodology, materials and product qualification
- Qualification of the applicator
- Installation procedures
- Inspection after application
- Traceability

### ► Product data sheets for each system

### ► Additional requirements

- Pull-off test (similar to Total corrosion specifications)
- Cathodic disbonding (similar to Total corrosion specifications)
- Tensile test if the pipe is subject to axial load (mainly unburied pipes).
- Subsea application (if applicable)
- Fatigue test (pipe subject to important cycles of shutdown / start up)

