Integrity Management of Non-Metallics

Jaarcongres PRDA
23 Mei 2023

Maud Haarsma, Corne Uytdewilligen
Shell Chemicals Park, Moerdijk

Pitch

- In the industry a variety of non-metallic materials are being used for several applications (piping, equipment, liners, gaskets, seals, hoses).
- Limited reliable and validated NDT available and no pass criteria for inspection and testing in standards/codes/methods.
- Standards and codes are hardly used due to not covering the whole design, a limited number of compliant fabricators, combined with limited knowledge with the CBI's.
- However... non-metallics are commonly applied in high HSSE risk services (like HCl, H2SO4, hypochlorite, caustic, alkyd resins and aromatics) and several serious incidents have happened in industry…!
- Be aware of potential construction defects, degradation mechanisms, risks, codes and standards, and have an integrity management strategy in place to use this great material safely!

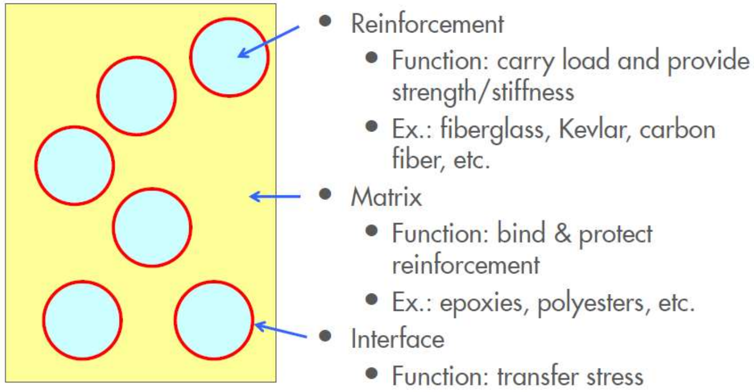
IF IT AIN'T STEEL, IT AIN'T REAL?

Content

- Introduction
- Overview degradation types / failures of non-metallics types
- Guidance on inspection and NDE techniques
- Share integrity management strategy
- Codes and standards

Introduction

- Non metallics are widely used in industry for pressure vessels, piping, storage tanks
- Composites: glass reinforced plastic (GRP, GRE)
- Dual laminates: GRP with thermoplastic internal liner like, Polyethylene (PE, HDPE), polypropylene (PP), polyvinyl chloride (PVC), polytetrafluoroethylene (PTFE)



- Pros and Cons:
  + Good corrosion resistance
  + Less expensive compared to (high) alloyed metals
  + Less weight compared to metals (1:5)
  - In general lower strength compared to ferrous materials
  - Flanges, nozzles, heads are vulnerable for handling

Overview of common non metallic degradation types / defects

- During design, procurement, installation:
  - Inadequate material selection (chemical resistance, service temperature)
  - Manufacturing defects, like delamination, blisters, voids, reinforcement less than specified (workmanship)
  - Mechanical damage due to transportation, storage
  - Joints: adhesive performance
  - Cracked flanges due to poor alignment

- In-service
  - Degradation due to chemical environment (diffusion)
  - UV radiation attack
  - Mechanical damage due to impact
  - Flanged joints:
    - Over-tightening leading to overstressing of joints and flange cracking,
  - Thermal degradation
  - Fatigue, i.e. pump vibration, inadequate support, regular over pressurization (by for example truck unloading)

Guidance on inspection and NDE techniques

- **Visual inspection:**
  - The most important inspection technique, if resin is transparent large areas can be inspected quickly within the laminate.
  - However, some of the most important defects such as poor bonding may require sophisticated NDE techniques.

- **UT/RT/HT/AE/TOFD/DSC/Thermography/Tap testing:**
  - All techniques that could be used to identify "defects" in the material but……..:
  - Acceptance or rejection criteria are not available as result of the performance based character of code.

- **Pressure testing:**
  - The hydrotest is considered to provide the best assurance (and is often more reliable than NDE) for assessing that the system has been properly fabricated and installed.

Integrity management strategy – design, procurement, installation

Flawless QA/QC is key:

- Project quality lead to understand these integrity risks during construction
- Well-defined and clear QA/QC plan
- Inspection Test Plans (ITPs) during fabrication and construction
- Handling/transportation plan should be developed (ISO14692-4) and implemented to avoid mechanical damage during transportation to site .
- Special attention on how to control environmental circumstances, while making a “field weld” laminate/cemented joint (temp- humidity, dewpoint).
- In case of buried piping a trance design plan should be made (considering a Proctor compaction test, backfill plan, soil free of stones, visual recognition of vulnerable pipelines and how to control and inspect for stresses from UG to AG lines).

Integrity management strategy – in service

Risk based integrity review can be applied:

- Collect equipment engineering and operating data
- Establish service life versus design life
- Find proof for the potential degradation / failure modes
  - Failures in the past? Understand why it happened?
  - Define risk profile (potential vs consequence)
- Example to apply strategy:
  - If service life > design life and degradation is observed → Replace
  - If service life > design life and no degradation → Continue service (include risk assessment)
  - If service life < design life and incompatible material or operated beyond design limits → Replace (FFS, risk based)
  - If service life < design life and (no) degradation occurs → Continue service (FFS, risk based) with IOW/DOW monitoring
- Update inspection management system (i.e. RBI) for equipment that remain in service

Defect types, acceptance criteria and corrective actions in standard

See Table A.1 of EN ISO 14692 for an overview of defect types in non-metallic pressure vessels, acceptance criteria and recommended corrective actions for the manufacturing, delivery, installation and operational phase (including recommended NDT methods).

Design codes for FRP Equipment (non pressure and pressure baring equipment and piping).

Tanks and vessel design code EN13121 part 1-4: (Pd 0-10 bar(g)/ Td -40/120C)

1. Raw materials- specification condition and acceptance criteria.
2. Composite materials, Chemical resistance.
3. Design and workman ship.
4. Delivery installation and maintenance.

Piping Design code EN ISO 14692 part 1-4: (Performance based code)

1. Vocabulary, symbols, applications and materials.
2. Qualification and manufacture.
3. System design.
4. Fabrication, installation and operation.

EN 13121

Tank and vessel design considerations:

Design and Hydrotesting an ATM tank were the liquid has a specific gravity >1.0, e.g. H_2SO^4 specific gravity is ~1,6 g/cm^3 . What does this mean for the stresses in the corner welds and bottom plates and annular ring. What will happen if a Hydrotest is executed with water, will the critical tank parts meet the stresses as filled with the medium?

Internal floating roof design and pitfalls:

- Bending.
- Personal qualifications.
- Electrical conductivity and electrostatic dissipative properties

ISO 14692- 1/4

Design and Qualification:

Note that this material is Anisotropic!

- **Performance based procedures.**
- Freedom of this approach is that manufactures are being encouraged to optimize their material selection and construction procedures.
- Within the (minimum) safety requirements acc PED if applicable, code ISO, ASME….
- Design of FRP piping system should represent the most severe anticipated conditions, experienced during installation and within the service life of the system (minimum 20 years).

- **Qualification program.**
  - Typical 1000Hr till 10.000Hr survival testing, @65°C for the piping and fittings to get the regression curve. (min 18 meas)
  - For low pressure water applications less stringent qualification programs could apply.
  - Based on the diameter and pressure range.
  - Based on an empirical de-rating factor Z, which is derived from tests ASTM D1599.

FRP project execution

Projects

- Experience in Shell with FRP pipe systems shows most problems (Joints, leakages) are mainly caused by inadequate system design and poor installation.
- To many interfaces in the execution phase of a FRP installation project, will lead to errors during system design and or installation. (recognition of load cases, cyclic, bending, vacuum, ect ect….)
- Single point of responsibility should be specified for FRP design fabrication and installation projects. FRP manufacturers have good understanding of the product capabilities they should take this responsibility.
- Minimize the number of FRP failures by adequate project execution and proven track records.

Life cycle cost FRP's

- **Material costs:**

  Diameter range 2"-3" : 3-4 times CS

  Diameter range 4"-16" : 2 times CS

  Diameter range >16" : 1-1.5 times CS

- **Installation costs:**

  20-25% lower than carbon steel (painted/coated) due to light weight and easy handling.

Pressure testing FRP systems

- Pressure testing shall be done in accordance with ISO 14692.
- Spool pieces shall be tested at 1,5 times the design pressure.
- Test pressure shall be raised over a period of 30 min or longer to 1,5 times the design pressure.
- Test duration 1 hr according the above, and 24 hr at 1,1 times the design pressure.
- Hydro test shall be done using a writing manometer, the resulting disk will be added in the manufacturing book.
- System draining after hydro testing is a critical activity, drain the system slowly reduce shocks, and make sure air is admitted at the top of the system. To prevent vacuum and buckling while draining.
- System burring is critical, insufficient soil coverage in combination with high water tables will result in buoyancy of pipeline.

Manufacturer, installation and inspection personnel qualifications

ISO 14692-4 Annex-C.

All personal involved in the fabrication installation and inspection shall be assessed in compliance with the code and by an independent organisation that works in full compliance with ISO/IEC 17024.

Joint instruction are manufacture specific –based to the qualification program- the training is therefore usually provided by the manufacturer. The training should consist a theoretical and practical exam and should be external verified by a competent person of a ISO 17024 organization.

Market developments

FRP liners (FFCP) Foldable Flexible Composite Pipe.

They find application in rehabilitation of steel and concrete leaking host pipes.

- Are liners capable of holding the internal pressure if the host is lost?
- Bends how many, and angle. (buckling of the liner vs hydraulic capabilities of the system)
- Inspection prior to insertion of the liner?
- Curing the system, hot water, or UV light?
- Consider a plan B, if liner insertion fails on installation.

Wrappings, leak box design?

- PRD 2.5
- ISO24817, ASME-PCC2.

End of Life assessment FRP systems

In general the design life of a FRP system is 20 years, what happens when it is over 20 years in service.

- If the system is operated at or close to the qualified system pressure (MPR) than the system could show some leakages weeping.
- If the system is operated 3% under the design system pressure than there could be some remnant life in the system, this could be up to approximately 10 years.
- Choose the system design pressure wise, based on the required design life and make sure that the execution of the hydrotest pressure is based on the qualified system design pressure.
- Take samples from the line and perform mechanical tests and compare the results with fabricators data.
  - Aging is not only the result of system design- vs operating pressure also occasional loads and frequency (cyclic)
  - Operating temperature, and temperature creep normally up to 30C below Tg.
  - Chemical resistance layer CRL intact? (Internal and External)

End