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« Ageing of hazardous installations »

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Lessons learnt from accidents involving ageing of industrial facilities

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The importance of ageing management to prevent accidents

- Facility **ageing is a normal process**, whose mechanisms are often well-known.
- **Ageing has to be anticipated and managed**.

- **In case of :**
  - design and dimensioning flaws or construction defects
  - underestimation of the effect of stresses due to inadequate monitoring or maintenance

  ageing can be accelerated, thereby leading to an increased probability of accident.

- A site containing old installations, or installations whose ageing is not properly managed, is more prone to experiencing an accidental situation.
- Even if it not be the root cause of an accident, deteriorated equipment can considerably exacerbate its effects.

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Analysis of accidents involving "installations ageing"

Analysis of accidents extracted from the "ARIA" (Analysis, Research and Information on Accidents) database

- Database operated by the BARPI, entity of the French Ministry of Ecology, Sustainable Development and Energy
- 46,000 summaries of accidents caused by industrial facilities and by transportation of hazardous materials

→ In France, more than 700 accidents involving ageing occurred since the creation of the ARIA database (1992), of which:

→ More than 500 in classified facilities

→ About 100 in pipelines (hazardous substances, gas, steam…)

→ About 30 associated with hazardous substances transportation (road, rail, sea…)

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Manifestations of ageing

Depending on the type and context of installation use, ageing can appear in a number of ways.

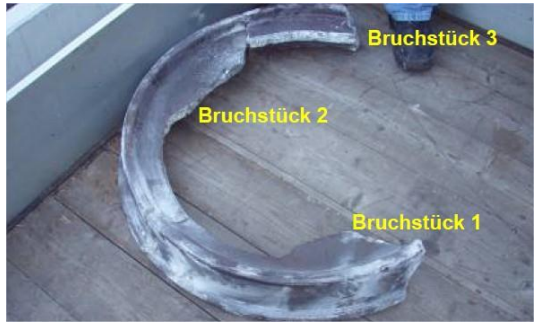
- The most frequently observed sign is **material degradation**, which can trigger :
  - the perforation of equipment, which can cause leaks in the surrounding environment or the accidental introduction of substances capable of disturbing processes
  - the weakening of potentially critical structural elements, such as anchorages or supports
  - the abrupt tearing of containers
  - the dropping of components
  - the collapse of large-scale facilities like silos or furnaces

- The other frequent symptom of ageing is the **malfunction** of electrical equipment, processes, treatment units…

Causes of accidents involving material degradation

- Corrosion is the first cause underlying accidents involving ageing of installations

- Fatigue is another recurrent cause



Accidents involving corrosion

- Corrosion mechanisms are determined by the environment, operating conditions and installation layout.
  - Maritime settings, dampness or acidic environments are especially prone to this phenomenon.
  - A change in surfacing or medium, individual contact points, interface between different metals all tend to cause corrosion.
- Industrial sectors most targeted by accidents are :
  - Chemistry
  - Transportation of hazardous substances
  - Refinery
  - Food processing
  - Flammable liquid storages
  - Gas production
- Accidents often involve large chemical or petroleum platforms or transportation pipes
- In more than 90% of cases, accidents lead to the release of hazardous/polluting substances to the environment

Accidents involving corrosion

- From the 200 corrosion-related accidents that occured in France during the last 10 years, **more than 50% relate to piping**.

- Accident probability is increased by frequent **difficulties in accessing the piping to inspect their condition** and the **significant length of sites** (or between sites) making monitoring difficult.

- Causes of piping corrosion can be :
  - **Internal** (action of a corrosive substance on a flawed coating, erosion affecting a bend or caused by compressor discharge…)
  - **External** :
    - Dripping from a pipe located above
    - Dripping via supports (racks or pipe supports)
    - Coating flaws (due to wear or works)
    - Corrosion under insulation (CUI)
    - Corrosion under the paint (paint joints)
    - Stress due to poor supporting
    - Corrosion affecting piping elements (flanges, valves, etc.)
    - Corrosion due to lack of passive protection in the case of underground piping

Corrosion : illustrative accident

ARIA 34351 – 13/03/2008 – 44 – DONGES

During the loading of 31,000 m3 of fuel oil into a ship at a refinery site, a leak on a pipe caused spreading in the Loire River Estuary. A team of over 750 spent three and a half months cleaning the 90 km of polluted banks.

The fuel oil pipeline showed a longitudinal opening, due to localised corrosion in the thermal insulation that was related to a water leak on a pipe running directly overhead.

Despite the **previous detection of several anomalies on this rack**, the operator failed to implement the measures made necessary by the river's proximity.

A number of **remedial measures** were imposed including : inspections on the site's other pipelines, permanent monitoring accompanied by a leak detection system and alarm relay for the pipelines running closest to the river.

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Accidents involving corrosion

- Apart from pipes, corrosion-related accidents can affect storages and tanks
- Most common cause identified : **internal corrosion caused by defective or missing internal coating**

- Failures affecting tanks often relate to **crude oil** and **diesel oil**
- At chemical facilities, the tanks involved are mainly **acid tanks**

Corrosion : illustrative accident

ARIA 32675 – 12/01/2007 – 33 – AMBES

The bottom of a tank containing 12,000 m3 of light crude oil opened. The retention basin withstood the effect of the ensuing wave, but 2,000 m3 of fuel still spilled out of the basin. 50 m3 of oil polluted 2 km of marshland ditches, infiltrating the surface water and flowing into the Garonne River. **In all, 40 km of riverbanks on the Gironde, Dordogne and Garonne were polluted.** The site operator pumped 6,000 m3 of product, proceeded with pollution cleanup steps in the vicinity and treated water fouled by the spill. Operating losses were estimated at €50 million.

A slight leak on the tank had been detected the day before around 5 pm. No procedure had been planned to deal with an emergency situation of this type. The operator had postponed until the next day the tank drainage step due to the risks potentially incurred by employees when having to block the floating roof seal on the tank at night. During this wait, water had been injected into the bottom of the tank.

In 2006, an inspection of the tank bottom had revealed corrosion and thickness losses of up to 80%. Repair work had been performed and followed up with an inspection.

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Corrosion : illustrative accident

ARIA 42401 - 05/07/2012 - 33 - BIGANOS

At 2:30 pm, inside a paper mill located 5 km east of Arcachon Bay, **a 5,000-m³ black liquor tank ruptured**. 4,000 m³ of this product at 85°C spilled over a 2 to 3-ha area within the mill. After destroying a low retaining wall, **100 m³ of product overflowed into the LACANAU and then the LEYRE Rivers.**

Production losses reached €10 million and pollution cleanup costs were valued at over € 1 million.

The tank showed signs of ageing and corrosion. The mill operator had scheduled complementary inspections on this tank for the end of July 2012 specifically to ensure its suitability for continued service.

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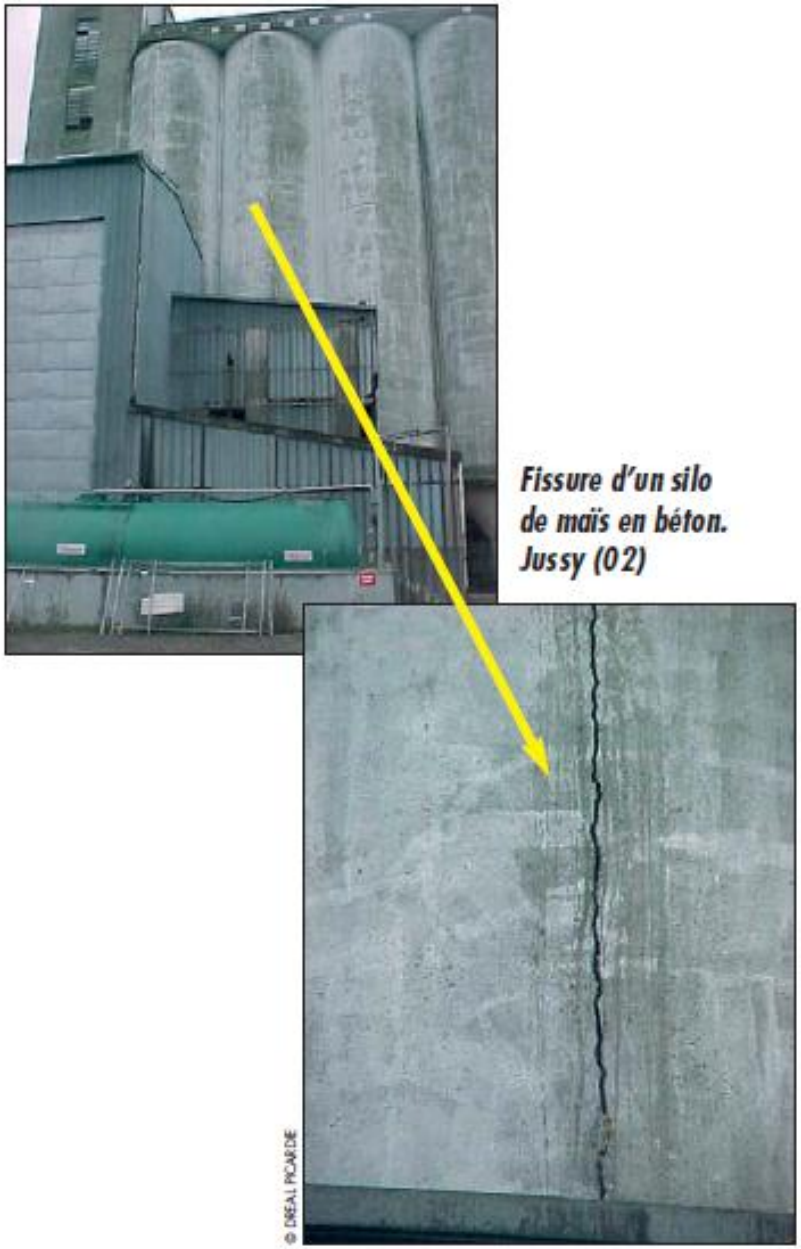
Corrosion : illustrative accident



Fissure d'un silo de maïs en béton. Jussy (02)

ARIA 23368, 20/10/2002 – 02 - JUSSY

In an agricultural cooperative, the concrete wall of one of the vertical storage cells of a silo built in 1963 cracked throughout a length of 25 m. About 100 tonnes of maize spilled over and destroyed a wall allowing access to the control facilities at ground level.

The inspectorate for classified facilities recommended the prefect to issue an emergency site shutdown order requiring an expert evaluation of the facilities. **Poor ageing of the reinforced concrete, with corrosion of the reinforced steel, is the cause of the accident.**

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Recurrent failures leading to corrosion

Inappropriate technical choices :

- Absence of protective coating against corrosion
- Incompatibility between products and materials
- Unsuitable ergonomics : installations non accessible for control
- Dangerous installations design : water pipe located above a thermal insulated pipe

Insufficient maintenance :

- Lack in maintenance
- Inappropriate non-destructive controls

Human errors :

- Default in assembly of a heat insulator
- Shock leading to the damaging of a protective coating

Possible corrective measures

- **Improvement of operation monitoring**
  - Updated pipeline network map, inventory of sensitive points
  - Trapdoors for inspection of thermal insulated pipes
- **Improvement of control procedures**
  - Regular thickness measurement on critical points
  - Leakage tests or hydraulic tests
  - Intensification of inspection programs
- **Modification of installations**
  - Use of more resistant alloys (hastelloy, inox)
  - Modification of protective coating material
  - Removal of risky tapping
  - Enslavement of equipment to safety measures
- **Modification of the process**
  - Change in parameters such as temperature, pH, product flow
  - Reduction of operating pressure of equipment

Accidents involving fatigue

About 30 fatigue-related accidents (most commonly due to excessive vibrations) recorded in France during the last 10 years.

Equipment involved includes :

- **Tanks**
  - fatigue cracking affecting a sulphuric acid tank (without any link to corrosion)
  - failure of a 1" tapping on a compressor back-up tank due to progressive cracking caused by vibration
  - tank fatigue following successive filling / emptying cycles leading to its cracking
- **Piping**:
  - failure of a tapping caused by vibration after a failure to reinforce the weld along a pump outlet line
  - failure of a small diameter drain pipe following successive vibration,
  - failure of a tapping linked to vibration,
- **Safety systems**:
  - Fatigue-related untimely opening of reactors' rupture disks (before their correct opening pressure is reached)
  - safety pin failure on electric generator units

Fatigue : illustrative accident

ARIA 32611 - 28/10/2006 - 76 - GONFREVILLE-L'ORCHER

In a plastics manufacturing plant, the **rupture of a 1" branch pipe on the discharge tank of a propylene gas compressor** caused the emission of a cloud of gas.

Examination of the broken branch pipe confirmed that the **rupture was in fact caused by mechanical fatigue**, i.e. by progressive cracking. The examination of the fracture surface showed that an initial cracking phase had occurred several years earlier. Progressive cracking had then continued until total rupture of the branch pipe through ductile fracture. **The blowdown pipe generated continuous mechanical vibration**, with the embossing on the equipment acting as a recess creating a local stress zone which led to generating the fatigue fracture phenomenon.

The design of the pipe was unsuitable for significant exposure to vibrations. The **inspection organised on the pipe was also inappropriate** (inspections of the "small branch pipes" did not take into account fatigue cracking at the thread roots, which is specific to a screwed assembly).

All of the branch pipes subject to vibrations were identified; the screwed assemblies were replaced where possible by a slip-on assembly. Furthermore, the operator modified the compressor so as to eliminate a fixed point that was detrimental in environments subject to vibrations.

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Possible corrective measures

- **Improvement of control procedures**
  - Increased inspection frequency
  - Identification of equipments subject to the same risks than those involved in an accident → implementation of large-scale corrective measures
  - Modification of inspection plans to take into account specific vulnerability to fatigue of some equipment (for example : risk of fatigue cracking specific to screwed assemblies)
  - Increased critical equipment' replacement frequency (for example : rupture disks)
- **Modification of installations and processes**
  - Changes in equipment design to make it more suitable for exposure to vibrations (elimination of fixed points ; replacement of screwed assemblies by slip-on assemblies)
  - Changes in operating procedures to limit stresses (for example : modification in a boiler's start-up procedure to limit both dilatation stresses and pressure surges)
  - Modification of operation parameters (calibration values…)
- **Training**
  - Training of maintenance staff to the caution to be taken when manipulating sensitive equipements to limit their weakening.

Conclusion on lessons learnt from accidents

The analysis of accidents reveals :

- Several of events in which the symptoms of facility ageing have not been anticipated or detected in a timely manner (sometimes in spite of many "warnings“).
- Verification campaigns can prove inappropriate or incapable of correctly measuring the speed of structural alterations, due to defective equipment or interpretation error.
- The implementation of facility renovation programs is sometimes scheduled too late or only insufficient temporary repairs are performed.
- Large-scale industrial platforms remain highly exposed to risks as a result of the large number of devices or piping involved.

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Conclusion on lessons learnt from accidents

- Need for awareness of the full extent of degradation possibilities + identification of factors capable of speeding the deterioration process.
- Some critical points deserve special attention : protective coating, structures, welds, supports, joints, tank bottoms…
- Control and maintenance efforts within inaccessible zones (subject to accelerated degradation) must not be overlooked.

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Conclusion on lessons learnt from accidents

Prevention should be placed into a comprehensive management approach aiming also at handling potential accident occurrence :

- Incorporation of early detection steps (visible equipment, frequent inspection visits, use of detectors, cameras, alarms, etc.)
- Limitation of potential effects (retention, catchment system for effluents originating at the site surface, water curtains, etc.)
- Organization of the intervention
- Evaluation of possible impacts and their mitigation
- Integration of lessons learnt from past accidents and incidents

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Conclusion

- Besides property damage and operating losses generated by an eventual accident, structural ageing represents a sizeable cost for industry.
- Taking preventive action serves to extend installation life cycle and to limit the occurrence of potentially catastrophic accidents.
- Given the ageing of Europe's industrial infrastructure within a number of major business sectors, placing emphasis on this thematic is key.

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Thank you for your attention

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