Materials used in Offshore Underwater Drilling of Oil and Gas

Introduction

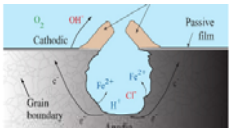
Here we would be discussing the various materials that can stand up to the challenge of offshore under-water drilling & can find their use in different structural & functional components & equipments in such oil exploration missions.

- Wells can range at a depth of 2000 to 3000m.
- There is a high cone of Hydrogen Sulphide and there can also be elemental Sulphur present at high concentration of H2S, which increases the corrosiveness of the environment. (H2S, organic acids, chloride, CO2, Mercury)
- Monolithic ceramic materials do not have fracture toughness and may be employed as coatings:
  - Monolithic alloys of Fe-Ni-Co-Cr, Mo-W
  - Also coatings of diamond like carbon (DLC)

Challenges in Offshore Under-water Drilling & material requirements

- Materials for structural components & construction of offshore oil drilling platforms capable of withstanding harsh oceanic environment.
- Materials for oil pipeline construction capable of transporting capable of transporting corrosive & hazardous materials under high stress environment while submerged under ocean.
- Advanced Robotics technology is required for operations like trenching on the sea floor, construction of sea pipelines, etc.
- Heat expansion, possible leaks from gasket, threaded joints, welded portions should also be taken into account for constructing a submerged pipeline. So, the chosen materials should have desirable properties in that regard too.

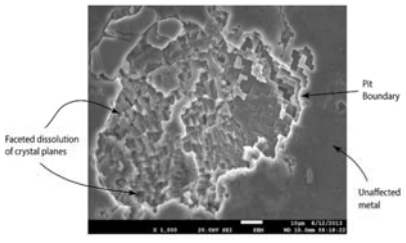
Resisting Corrosion from Sea-Water



As many structures in regard to offshore oil drilling has to resist the corrosiveness of Sea Water, understanding the mechanism of corrosion & thus preventing it of utmost importance.

The seawater acts as an electrolyte, and the different potentials between different parts of the steel structure cause metal ions to move from the surface of the structure and diffuse into the electrolyte solution. Here, they react with oxide and hydroxide ions to form corrosion products (see the figure above). The presence of dissolved oxygen is also an important concern. Because dissolved oxygen is greater near the water's surface, it imposes a greater corrosive over-potential in the vicinity of this region as compared to the metal further under the surface.

Pits can thus form on the metal surface along with corrosion along joints, imperfect weldings resulting in irregular erosion font. Increased non- uniform stresses & structural anomalies resulting from these reactions can lead to fractures & failures. **The rate of corrosion depends on microstructure of the materials.**



Electron micrograph. Image courtesy of C. Feng and S. Policastro, NRL.

Methods of Resisting Corrosion

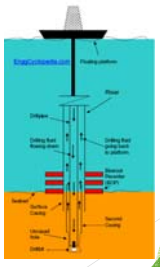
- Impressed Current Cathodic Protection: Applying external current to steel to prevent the surface from being anodic.
- Sacrificial Anodes: In this case, the steel structure is electrically connected to a less noble metal, such as aluminum, that acts as an anode. The metal is "sacrificed" by slowly corroding as the steel structure acts as a cathode and is protected from corrosion.
- Protection by painting: Painting the ship isolates the steel from the corrosive media. The paint must also be resistant to the marine environment and the application strictly controlled to ensure full and effective coverage of the steel. Regular inspection and repair of the coating may be necessary to achieve reliable and lasting protection.
- Using corrosion resistant alloys & ceramics: Depending on design factors including the severity of the application and the levels of strength, damage tolerance, reliability, safety and life required, components and systems can be manufactured from composites, or from stainless steels of increasing resistance, or from copper based alloys such as cupro-nickel or nickel aluminum bronze, nickel alloys or titanium, using these materials exclusively or in conjunction with each other or less resistant alloys.

FLEXIBLE RISER WALL STRUCTURE

Flexible risers has wide range of functions. Its for gas and oil, water injection, gas lift, oil or gas export, etc.

In a typical cross section of flexible pipe wall structure:

- Stainless steel carcass: inner most layer of pipe.
- Thermoplastic liner: Sealing layer made from thermoplastics.
- Carbon steel pressure armor: Its is to resist the hoop stress due to internal pressure.
- Annulus: The section between the linear and the external sheath is pipe annulus
- Carbon steel tensile armor, two contra-wound layers
- Thermoplastic outer sheath Polymer tape, which is used to minimize friction and wear between layers of armor, is not shown. Additional layers of material with low thermal conductivity may be applied in order to obtain specific thermal insulation properties of the pipe.



Pipelines

- Stainless steel :
  - Stainless steel is used for the carcass structure, which is in contact with the fluid in the bore due to it's resistance to corrosion. Standard grades are generally used, 304, 316 and similar as due to their desirable properties for stress/strain fatigue, corrosion resistance & tensile strength.
  - Alloy composition includes elements Magnesium, Chromium, Nickel, Molybdenum, Nitrogen, copper, Titanium, Selenium in varying proportion.
- Carbon steel :
  - Carbon steel is used for pressure armor and for tensile armor due to their greater hardness than stainless steel. The profiles are produced by rolling and/or drawing. The main criterion for selection of material grade(proper carbon steel) is whether the product flow is "sour" (containing H2S) or "sweet".

Contd.,

- Super martensitic alloy grades common for all stainless steels is a minimum content of 11% Chromium. S13Cr steels have typically 11-12% Chromium. The microstructure is austenitic at temperatures beyond ca 900°C. Rapid cooling suppresses the formation of ferrite and martensite is mainly formed. Chromium helps in making steel more resistant to corrosion by forming a layer of Chromium Oxide.
- Super martensitic stainless steels are normally divided into three types
  - Lean grade, 11Cr2Ni
  - Medium grade, 12Cr4.5Ni1.5Mo
  - High alloyed grade, 12Cr6Ni2.5Mo

Advanced Material

In the last couple of decades there have been a number of stronger, lighter and Multi-functional materials developed in the laboratory

- Nano Crystalline Materials
- Bulk Metallic Glass
- Diamond like Carbon

Nano Crystalline Materials

- Conventional Metallic alloys- 10 to 100 um
- (NC) materials grain size
- Compared to their micro crystalline counter parts Ni metals in general exhibit high yield strength and hardness, excellent wear resistant and enhanced super plasticity fracture and fatigue are found to be superior as well.
- They are mostly limited to coating & thin films due to ultra small grain sizes, thick cross sections are not possible
- Hardness, toughness compelled with better corrosion & wear resistant used in value seats & stems, components of compressor or pump and surfaces such as riser tensioning system, where wear & corrosion resistance

Bulk Metallic Glass (BMG)

- Any metallic alloy can form a glassy state by extremely rapid solidification
- Because of the absence of grain microstructure well defined crystal defects and chemical in homogeneities, BMG's posses outstanding mechanical properties compared to their crystalline counter parts,
- Much higher tensile strength & hardness
- Lower young modules
- Low internal friction & wear coefficients
- High Fracture strength & superior fatigue but they are brittle & lack plasticity under tension
- Low fracture toughness & low impact resistance

BGM USES:

- Used in values and springs, strengthened edges of tools, wear resistant surface of drill head, high corrosion resistant coating, pipes of mass flow meter, precise miniature parts of pressure sensors etc.,

Diamond Like Carbon (DLC)

- It indicates a variety of amorphous carbon materials containing a significant fraction of SP3 electron configuration in carbon-carbon bonds
- Which gives it similar mechanical properties as that of diamond
- DLC are mainly used as hard, low friction, long lasting, wear and corrosion resistant coating material
- It is used in Automobile industry as a reliable tri biological coating

Some Other Materials

- Self-Assembled monolayers are organic molecules that have strong chemisorption to metal surface and spontaneously aligned to form a monolayer, which makes SAM's and inexpensive and versatile surface coating
- Shape memory alloy could be used as critical component of safety values are other applications trigged by temperature Variations
- Titanium Alloys have been explode as light weight, highly corrosion resistant alternative to CRA, ideal for applications of drilling risers or high pressures heat exchangers. The data of titanium alloy is dependent upon the scale of availability at reduced cost.

Thank You!!!