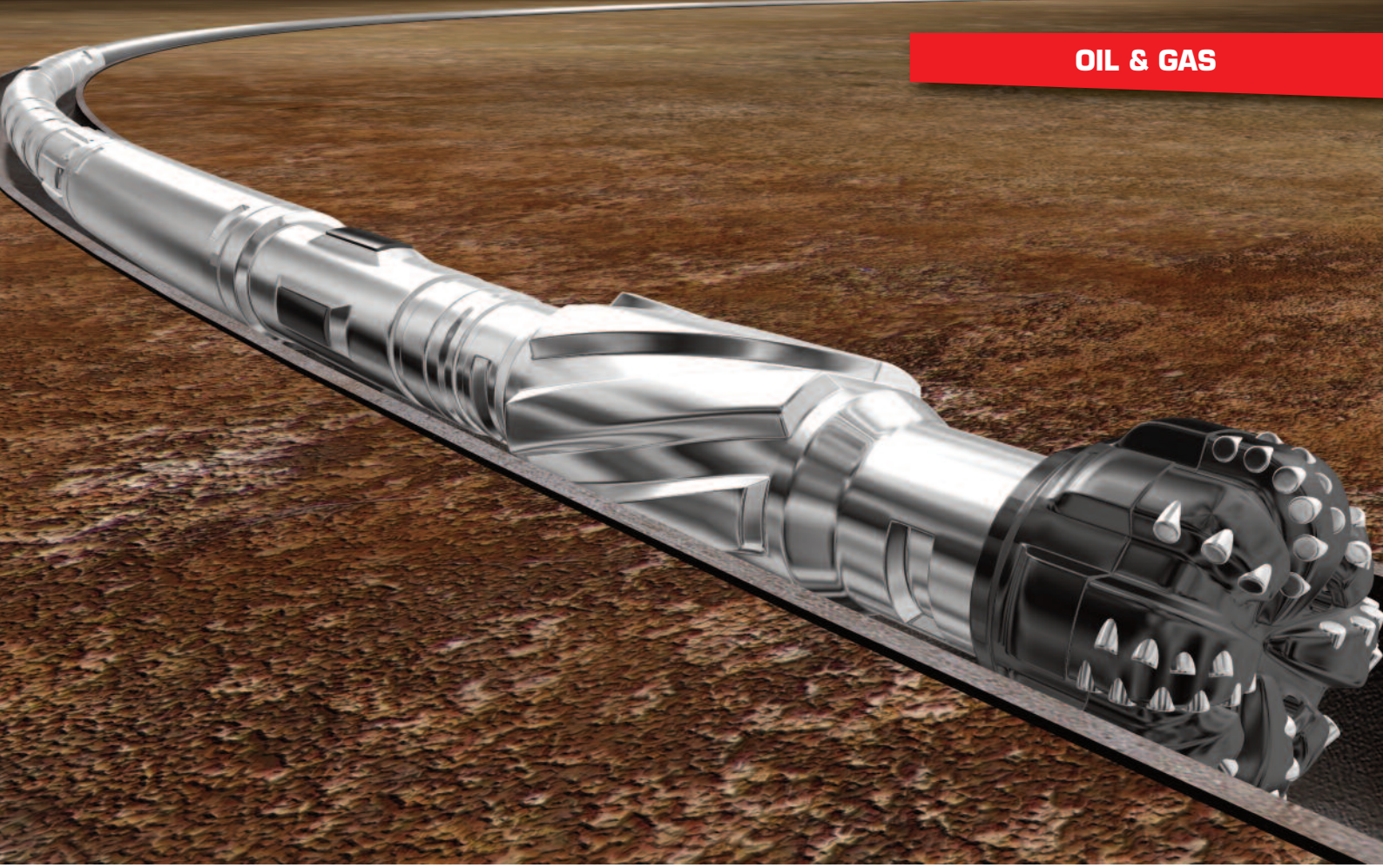


Non-magnetic drill string components produced by Schoeller-Bleckmann Oilfield Equipment AG.

The future of corrosion resistant steels and alloys in the oil and gas industry

Despite efforts to promote renewable resources, oil and gas will continue to be the backbone of energy supply for the next decades to come. As conventional available reserves have largely been exhausted, more difficult fields have to be explored and enhanced oil recovery methods have to be utilized in existing fields in order to keep up with the accelerating demand for oil and gas. The era of easy accessible oil and gas has ended!

By Wolfgang Lipp, Managing Director at SMI – Steel Market Intelligence, Austria and Sean Shafer, Consulting Manager at Quest Offshore Resources, Houston, Texas, USA

The share of total oil and gas production from offshore areas has increased significantly during the past decades, and the rapid growth of ultra-deepwater production is expected to continue well into the future. Oil and gas production is more challenging today as service conditions have become increasingly severe, e.g. higher temperatures, higher pressures, sour fields (high hydrogen sulphide content) with high carbon dioxide levels. All these

challenges require advanced technologies, improved equipment and high performance materials in order to ensure the smooth and especially safe production of oil and gas.

This is where Corrosion Resistant Alloys (CRAs) are coming into play, as they are better suited to meet increasingly demanding requirements in exploration and production. Thus, the demand for special alloy steels, stainless steels and nickel alloys for upstream oil and gas applications has grown substantially and this trend is expected to continue.

Types and selection of CRAs in the oil & gas industry

CRAs are typically defined as stainless steels and nickel alloys. In addition to typical CRAs, special alloy steels are also widely used in the oil and gas industry. Alloy steels and stainless steels account for around 95% of the tonnage used but the 5% of nickel alloy tonnage contributes 25 % of the total value.

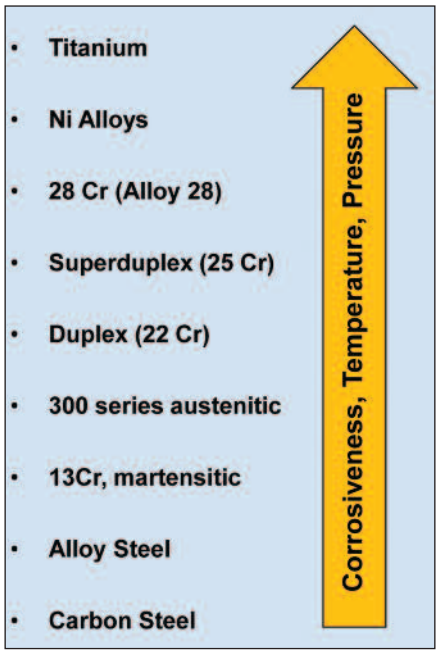
The demand and selection of CRAs is driven by the production/reservoir conditions (sorted by importance):

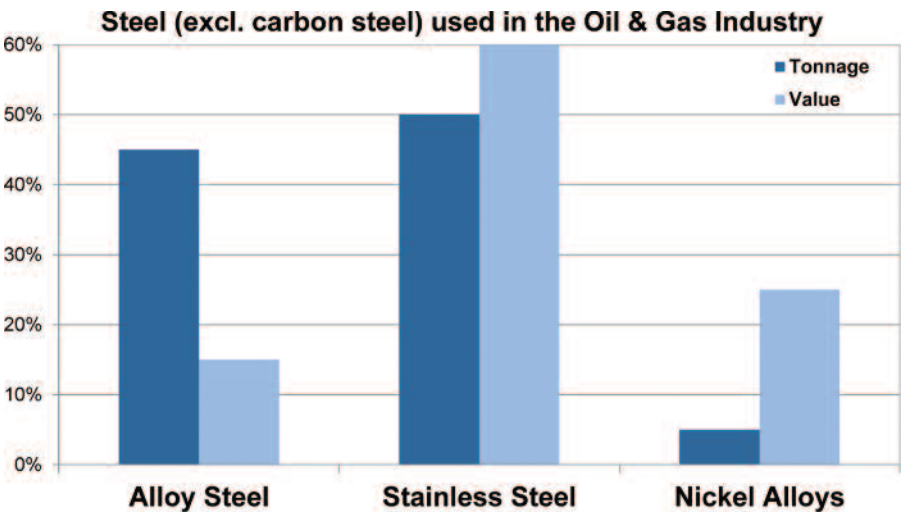
1. Corrosiveness (hydrogen sulphide, carbon dioxide, chloride)
2. Temperature
3. Pressure

Corrosion engineers calculate the expected corrosion rate per year, which is then multiplied by the design life. When corrosion is expected to exceed a certain level, either CRAs are selected, or carbon steel with a higher wall thickness. Instead of solid CRA material, cladding or weld overlay can also be applied on carbon or alloy steels. Another option to fight corrosion is the use of chemical inhibitors or cathodic protection.

Whilst safety is the number one criterion, the selection of the material also depends on the calculated life cycle costs. Although CRAs require higher capital investment in the beginning, they may well be the cheaper option in the entire life cycle as they have to be replaced less frequently, require less maintenance and do not need chemical inhibitors.

The following picture shows the steel selection tree for oil and gas projects. Obviously, carbon and alloy steels are used whenever possible as these are the lowest cost materials. However, as operating conditions become more severe, higher grade materials have to be used step by step and there is no alternative to CRA materials.





In order to be more specific, the following table shows the most widely used steel grades in the oil and gas industry:

- Alloy Steel: 4145H, 4130, 4140, 4330, 8630, F22
- Martensitic: 13Cr, Super 13Cr, 410, 420, F6NM
- Austenitic: 316, 304, 321, 317L, Nitronic 50/60, 904L, 254SMO (6Mo)
- Duplex: 2205, 2507, LDX2101
- PH Grades: 17-4, 15-5, 13-8
- Ni Alloys: 825, 625, 718, 925, Alloy 28
- Non Magnetic: special chromium manganese austenitic grades

CRAs are required in all product forms including 3D-forgings, rolled rings, forged and rolled bars, seamless and welded tube and pipe, clad pipe, plates, sheet and strip.

Applications for CRAs in the oil & gas industry

Special alloy steels and CRAs are required for a wide range of applications, especially for offshore production. They are used for drill string components, tubing and casing, downhole completion equipment, wellheads, blowout preventers, subsea trees, manifolds, riser systems, flowlines, jumpers, umbilicals, valves, pumps, topside processing equipment, etc. Here are some examples are listed:

- Components for directional and horizontal drilling are made of special non-magnetic steels which are forged on a rotary precision forging press followed by extensive machining. The bottom hole assembly consists of drill collars, MWD and LWD tools, mud motors and the drill bit.
- Seamless tubes are used for tubing and casing (OCTG). Depending on the fluid composition either 13Cr, superduplex or nickel alloy grades are selected. Cold working is required to achieve the required strength.
- Welded clad pipes are often selected as a lower cost alternative to solid CRA for flowlines, pipelines and steel catenary risers. They consist of a carbon steel host pipe and a CRA

liner (e.g. 316L, 825, 625). Two different technologies are available: metallurgical and mechanical bonding.

- Instead of rigid flowlines and risers, flexible pipes can also be used. The carcass of these pipes is made of cold rolled coils. The main grades are 316L, lean duplex, duplex and superduplex.
- Large size forgings are required e.g. for blow-out preventers and subsea trees. They are usually made of alloy steel (e.g. F22, 8630, 4130) and a nickel alloy weld overlay (grade 625) is applied on all process wetted areas to prevent corrosion. Smaller forgings, e.g. for valve bodies, are often made of duplex grades.
- Large size, thin wall, welded pipes are used for piping for LNG projects (mainly 304L and 316L). Cryogenic transfer lines for LNG consist of Invar (Alloy 36) or 9% nickel steel. Invar is also applied for membranes of LNG tankers.

Macro trends and drivers

The use of CRAs in the oil & gas industry is being driven by two very different but rapidly growing sectors of the industry: onshore shale in the U.S. and offshore (especially deepwater) worldwide. Onshore shale gas production has seen an explosion in the U.S. in the past five years, led by massive changes in drilling and completions technology. Advances in horizontal drilling and hydraulic fracturing especially have unlocked these previously inaccessible resources transforming the U.S. onshore market, with the share of horizontal drilling rigs active in the U.S. increasing from under 10% to over 60% in less than 10 years. The strains placed on down hole equipment coupled with the corrosiveness of shale gas and the high pressures of oil shale have led drillers to higher quality materials.

Offshore, especially in deepwater, multiple trends are pushing operators towards increased use of CRAs in the industry leading to higher baseline demand. Offshore capital expenditures from 2013 to 2017 are expected to be over USD 1.2 trillion, a 57% increase from the previous five-year period. Deepwater expenditures alone are projected to be over USD 800 billion, increasing nearly 60% over the previous five years. Deepwater expenditures are being led by two sectors, deep and ultra deepwater oil production in the U.S. Gulf of Mexico, Africa and Brazil and gas production especially in Asia for liquefied natural gas (LNG) production in both onshore and floating plants.

In deep and ultra deepwaters, producers are facing higher reservoir pressures and temperatures in new developments while at the same time surveying the lessons learned from existing frontier deep and ultra deepwater developments. Increased concerns about safety as well as data on the performance of existing developments is pushing operators led by the oil majors and large national oil companies to specify higher grades of steels especially in subsea equipment. As wellhead pressures increase to 15,000 psi and beyond, temperatures climb towards 350 degrees and corrosion inducing contaminants including carbon dioxide and hydrogen sulphide are increasingly found in well streams, the need for higher quality materials including stainless steel and nickel alloys is expected to continue to grow.

While the shale revolution has drastically lowered natural gas prices in the U.S., the rapidly growing energy needs in Asian markets (including China, Japan, Korea and India) coupled with fears concerning nuclear power have led to increases in LNG prices for the region. The growing demand for LNG is leading to massive amounts of investment in new or expanded LNG plants, with over 200 million tonnes per annum of new LNG production capacity expected to come online from 2013 to 2017. Much of the gas for these developments will be sourced offshore, with liquefaction taking place either onshore or increasingly in floating facilities. Although most current LNG developments are in relatively shallow waters (under 500 meters), most offshore LNG is being produced with subsea technology, often including long distance tiebacks of unprocessed well streams. In most cases the gas carries high levels of impurities, leading to a very corrosive environment for the steel in contact with the well stream. In addition, environmental regulations in areas like Australia are very tough and a long maintenance free lifetime of the equipment has to be guaranteed. All these push the operators to specify higher quality materials, including nickel alloy cladding on both subsea hardware and pipes as well as solid stainless pipes.

Led by offshore and shale production, the oil and gas industry is expected to require increasing amounts of stainless and specialty steels to unlock the available resources in the face of increasing technical challenges. For producers who are willing to invest the time and resources needed to meet the demanding standards of the oil and gas industry, opportunities to increase sales in this industry should abound.

About SMI

Wolfgang Lipp

SMI – Steel Market Intelligence GmbH was established in January 2008 as an associate company of SMR – Steel & Metals Market Research GmbH with the purpose of providing the special steel industry with continuously updated off-the-shelf market reports. For more details, please visit the website www.steel-intelligence.com

About Quest Offshore Resources

Sean Shafer

Quest Offshore Resources specializes in analyzing the technology trends key to the upstream oil & gas industry. Quest is able to provide a myriad of strategic subscription data products, specialty reports as well as client-directed consulting services.

Do you want to know more about the future of CRAs in the oil and gas industry?

SMI and Quest have just published an in-depth market report about the use of CRAs in the oil & gas industry. This report is a unique combination of Quest Offshore's detailed oil & gas project database and SMI's in-depth knowledge about the stainless and specialty steel industry.