Hose · Flexible pipe · Offshore · Oil industry

Bonded flexible pipes are suitable for various oilfield applications, and are used especially offshore, including deep water and harsh environment. They have specific advantages as risers and flow lines, or even floating high pressure lines for live crude oil transport in marginal fields, because of simple installation, without high mobilization costs. Mid-water oil export lines are protected from wave effects, offering longer lifetime than conventional oil suction and discharge hoses. Water intake systems can be custom designed for the given environment, offering high operational safety and easy installation. High pressure flexible lines can be preformed to fit tight configurations even in 3000 m water depth.

High Performance Flexible Lines for the Oil Industry

Bonded flexible pipe is a synonym of large bore, reinforced rubber hose. In the narrower sense it refers to medium and high pressure flexible lines. In this paper however we use this term in broader sense and include large bore low pressure flexible lines too. The hoses we discuss here range from seawater suction lines to choke and kill lines with a rated working pressure up to 103,4 MPa. The size of the flexible pipes covered ranges from 50 to 1000 mm (2” to 40”) or larger internal diameter. An overview of high pressure flexible lines was given 6 years ago at this conference [1], thus we will focus on newer developments and new applications.

In bonded flexible pipe the complete hose body structure is a composite where the continuous phase is vulcanized rubber, and the reinforcement is embedded and chemically bonded to the rubber. Often the coupling itself is chemically bonded [e.g. 2]. Typical bonded high pressure hose is shown in Figure 1.

The other family of flexible pipes is the unbonded flexible pipe, containing plastic liner and cover, as well as steel or composite reinforcement. Some features of bonded and unbonded flexible pipes are compared below:

- Bonded flexible pipes are usually produced on rigid mandrel, with limited individual length (about max 45 m). Long length high pressure rubber pipes [3,4], are not on the market anymore.
- Bonded flexibles have good corrosion resistance, since steel reinforcement is embedded in rubber.
- They are lighter than unbonded ones of the same size and pressure rating.
- Their coupling design is less complex, less expensive to manufacture, giving cost advantage in case of short hose assemblies.
- Their bending stiffness and other parameters can be varied even along the hose length.

- Bonded flexibles can be produced with rubber or plastic liner, giving more design options to meet the actual requirements.
- If the lining of a bonded flexible fails, there is only slow leakage through the bonded hose wall.

The main features of unbonded flexible pipes are the following:

- Unbonded flexible pipes are produced by mandrel-less technology, in long continuous lengths, often of several km.
- Unbonded flexibles have a less complex but more robust hose wall structure, with generally higher hydrostatic collapse and external pulling force resistance.
- The lower hose body cost compensates for the cost of the more complicated coupling design in case of longer flexible pipes.
- Unbonded pipes are produced with a plastic liner. The choice of suitable linings is narrow, presently most of them are produced with polyamide 11 or poly(vinylidene-fluoride).
- Plastic linings generally have better gas decompression resistance than elastomers.
- Lining failure in unbonded flexibles is likely to be catastrophic. If the lining of an unbonded pipe ruptures, then the unbonded hose wall will allow the internal fluid to pass through it, as opposed to slow leakage in bonded flexibles.

In this paper we will discuss new developments focused on certain applications, namely:

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- offshore gas, and live or treated crude oil transport,
- water intake systems
- flexible lines for deepwater drilling

Transport of live crude oil and gas in case of floating production facilities

In offshore oil production, as deeper and deeper waters are explored emphasis was shifted to floating production facilities from fixed platforms. Besides large fields with well developed but costly infrastructure oil (and occasionally gas) has been produced on marginal remote fields. The advantages of bonded flexible pipes make them especially economical in marginal fields. Since bonded flexibles are produced in limited length, they can be transported easier on sea and land.

Bonded flexibles can be installed with simple equipment, with cranes available locally without expensive mobilization of pipe laying vessels.

Another advantage of bonded flexibles is that their properties can be varied according to the requirement of the configuration, based on dynamic analysis results. The flexibles shown on Figure 2 were installed near the Philippines in 290 m water depth. It turned out in the course of dynamic and fatigue analysis that some critical points of the line require much higher bending stiffness, than that of the mainline flexible pipes. The requirement looked dramatic, compared to about 6 kNm⁻² bending stiffness of the mainline pipes short sections with bending stiffness of 150 kNm⁻² were required at a time when the mainline pipes were already in production. With the addition of four more cable layers, and changing the lay angle the requirement was met.

Bonded flexible pipes have been used as topside jumpers in floating production facilities for decades. (Jumpers are relatively short sections of flexible pipe, connecting rigid piping with relative movements, e.g. steel risers and a floating production platform)

Some old high pressure production and gas export jumpers (manufactured in 1995-96) were returned to the factory in 2009 for testing and dissection. Their internal diameter varied between 5,5" (140 mm) to 15" (386 mm), their design pressure was up to 21,7 MPa. All of them served at least 10 years in harsh North Sea or North Atlantic locations. They were successfully pressure tested to 2,5 times of their design pressure, which was the guaranteed burst pressure at the time of manufacturing. After dissection reinforcing cables were subject to tensile test, and still exceeded the breaking strength requirement of the new cables. This indicates that all the investigated flexibles were in good shape even after 10 years of offshore service (Fig. 3).

An example of recent development at ContiTech Rubber Industrial Kft. is the TauRoBend preformed bonded flexible pipe which is vulcanized to a curved shape (Patent pending), enabling easy installation in extreme tight spaces. A comparison of conventional and preformed 6" line installation is shown on Figure 4.

Another unique ContiTech development is high pressure floating production line. They transport live crude oil on some marginal fields in the Mediterranean from buoy to floating production vessels, and can be installed from simple supply boats, as shown on Figure 5.

Deepflo bonded flexible lines for oil export in deep water

In deepwater applications, especially in harsh environment, usual oil suction and
Discharge hoses may have limited lifetime. In order to overcome this limitation, Dunlop Oil and Marine (a ContiTech company) developed a new product family called Deepflo for the transport of refined gas free sweet crude oil. Deepflo lines can be installed as so-called mid-water hose, which means that the line is submerged to a depth, where waves have little effect, but it is not laid to the seabed, rather floating between the seabed and the surface. A typical configuration is shown in Figure 6. Deepflo lines are designed to last for decades in the subsea environment.

The main characteristics of Deepflo lines are given in Table 1. The new hose family can be manufactured up to 30" (750 mm) bore size. Both the rubber materials and the reinforcement were rigorously tested to demonstrate their aging and fatigue properties. The patented aramid containing hybrid reinforcement allows minimizing weight and maximizing flexibility in large bore constructions. Fatigue performance has been demonstrated on full scale hoses. The lifetime of the hoses is also depending on coupling corrosion. To prevent direct exposure of metal parts to seawater couplings can be moulded completely in rubber (Fig. 7).

**Water uptake systems**

Eddelbüttel & Schneider GmbH (a ContiTech company) developed a system for water intake of floating oil production facilities. The product is custom designed for every installation, and backed up with sophisticated dynamic analysis, fatigue, clashing etc. calculations. A specific feature of the rubber water uptake systems is their easy installation. Despite of the large bore size installation can be carried out with the crane of the vessel, without the need to mobilize expensive equipment.

The system found wide acceptance and is in use on several floating production units offshore Brazil, Angola and elsewhere, in bore sizes ranging from about 16” (400 mm) to more than 40” (1000 mm) (Fig. 8, 9).

**Flexible lines for deepwater drilling**

It was about 20 years ago when offshore drilling for oil reached the 1000 m water depth. Many of the drillships designed nowadays are suitable to drill in 3000 m water depth, which is a challenge also for the flexible pipe manufacturers. Various flexible
lines of ContiTech Rubber Industrial Kft. are used for deepwater drilling (Fig. 10). These include high pressure mud hoses (rotary, vibrator and mud jumper) up to 5” (127 mm) internal diameter and 51.7 MPa (7500 psi) working pressure, cement hoses with 3” (76 mm) internal diameter and 103.4 MPa (15000 psi) working pressure. All hoses meet the strict new requirements of API Spec. 7K Addendum 2 (2006). Rotary and vibrator hoses are baked up by high frequency, high temperature (100 °C) pulsation test too. If required, hoses can be built also for gas drilling.

Subsea blow out preventers (BOP) in deep water represent an even bigger challenge for the flexible lines. While in the past design temperature of max. 100 °C was generally accepted, often 121 °C max. operating temperature is required, as well as the capability to withstand at least for one hour at 177 °C internal temperature at full working pressure e.g. 103.4 MPa (15 000 psi). For deepwater subsea applications collapse resistance of the line is a requirement too (Fig. 11). The flexible choke and kill line developed at ContiTech Rubber Industrial Kft. for subsea application was thoroughly tested according to API Spec. 16C for 121 °C operating temperature, as well as for hydrostatic collapse resistance above 36 MPa, representing 3600m water depth, internal “survival” temperature exceeded 180 °C. A new unique feature of this pipe is that it can be manufactured as preformed TauroBend flexible line, to fit tight spaces on subsea BOP stacks. This possibility has an effect on the design of the BOP stacks themselves, they can be made shorter, because earlier the allowed bending radius of the flexible line was the limiting factor in the geometry of the top of the BOP.

Conclusion
- Bonded flexible pipes find widespread application both onshore and offshore in the oil industry
- Continuous intensive R + D is necessary to keep up with new technical challenges and regulations
- Hose lines used in oilfield applications are complex systems in terms of both structural parts and service conditions
- Effective design requires integrated analysis and engineering procedure
- Special simulation processes, structural and fatigue analyses using advanced FEA tools
- Design methodology shall fulfil the strict rules and standards recognised by the oil industry
- Each hose type is subject of complex design verification testing

References