

USE OF COMPOSITE MATERIALS IN OIL INDUSTRY

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Abstract: The most frequently used composites for fabrication of primary and secondary constructions within the oil industry are made of epoxy, phenolic or polymer matrix combined with glass, carbon or aramid fibers.

For fabrication of risers, thermoplastic polymers (polyethylene, polyvinylidene fluoride, and polyamide) are used, which are to be wound around steel reinforcement of riser. Polymer may be reinforced with glass or carbon fibers. Instead of thermoplastic polymers, epoxy matrix reinforced with carbon fibers may be used. The main challenge in this area of application of composite materials is to develop polymers whose operating temperature exceeds 120°C, as well as to completely avoid the usage of steel reinforcement.

In order to construct pipe systems for fluid transport and tanks for their storage, the most frequently used are GRP (glass reinforced plastic) composites, also known as fiberglass composites. Those composites are made of standard plastic matrix reinforced with glass fibers. Plastic matrix within GRP composites is most commonly made of epoxy resin (GRE pipes) or vinyl-ester (GRVE pipes) and rarely of polyester. Further development of this technology has resulted in the development of hybrid composites: thermoplastic pipes reinforced with GRE composite and RTP (reinforced thermoplastic pipe) thermoplastic pipes reinforced with glass, aramid or carbon fibers. The challenge in the production of composite drill pipes is the production of large diameter pipes.

Production tubings are usually made of GRE pipes or GRE pipes reinforced with carbon steel. The future of composite tubings lies in the development of epoxy resins that are able to maintain working ability during drilling at temperatures significantly higher than 100°C as well.

Secondary constructions used in oil industry are produced of epoxy, vinyl-ester or phenolic matrix combined with glass fibers.

Key words: composite materials, oil industry, primary and secondary constructions

1. INTRODUCTION

In order to meet increasing technical, technological and economic requirements imposed by oil industry in terms of development of new technologies and materials for fabrication of various constructions, the use of modern – composite materials becomes increasingly prominent.

Composite materials in the oil industry have found their application in fabrication of secondary constructions, such as: floor grates, footpaths of platforms, staircase railings etc. In housing modules of platforms, those materials find their application in manufacture of tanks, pipelines, and walls, refractory coats etc. For example, on the "Amoco Davy" platform at the North Sea about 16 t composite

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materials are used for those purposes (Composites for the Offshore Oil and Gas Industry, 1999).

Due to broad spectrum of properties that composite materials are showing, there is increasing interest for the application of composite materials for fabrication of primary constructions as well, such as: drill pipes, pipe systems for fluid transport, risers etc. One of interesting areas of application of those materials is also the manufacture of production installations on oil platforms. Such constructions have satisfactory strength, they are easy to install due to their small mass, and their lifetime is longer due to their corrosion resistance.

2. COMPOSITE MATERIALS FOR FABRICATION OF PRIMARY CONSTRUCTIONS

Due to especially advantageous relation "strength-mass", composite materials have found broad application in the production of primary construction in oil industry, especially for:

- manufacture of risers,
- manufacture of drill pipes and tubings,
- manufacture of tanks and pipe systems for fluid transport.

2.1. Risers made of composite materials

Risers are characterized by large pipe size and mass, which may be limiting factor when selecting the type of drilling installation, especially at places where the depth of water is high (over 1000 m). Therefore, risers made of composite materials are ideal substituent for steel because of especially advantageous "strength-mass" relation.

According to the study developed by the American company "Chevron", pipes with identical lengths made of composite and steel, at the same hydrostatic pressures, have the same crushing strength, although the mass difference is up to 65% to the benefit of pipes made of composite materials. For that very reason, the first researches in the field of manufacture of risers from composite materials date back to 1979, when "Aerospatiale" and "Institut Francais du Petrole (IFP)" have engaged in pioneer project and produced pipe with diameter of 10.2 cm, with fluid pressure resistance of 103.42 MPa (Composites World, 2008).

Thermoplastic polymers (polyethylene, polyvinylidene fluoride, polyamides) are most frequently used for the production of risers, which are wound around steel reinforcement of riser. Due to its corrosion resistance, polymer represents excellent insulation and protects riser against etching corrosion. If polymer is reinforced with glass or carbon fibers, it can take the part of axial and transversal loads from steel reinforcement. Risers designed in such way are flexible and they can be used at sea at depths of water up to 800 m, at pressures of 35 MPa and at temperatures of 120°C. The main challenge in this area of application of composite materials lies in development of polymers whose operating temperature exceeds 120°C, as well as in complete avoidance of steel reinforcement. In certain versions, instead of thermoplastic polymers, epoxy matrix reinforced with carbon fibers may be used. Economic cost

effectiveness of the use of composite materials for manufacture of risers is specially emphasized in projects where water is extremely deep (Lucas et al. 2009).

Risers are connected with special MCI (metal-to-composite interface) coupling, which is most frequently made of steel and titanium, designed in such way to be able to transfer loads from the body of composite riser onto metal coupling and vice versa, as shown in Figure 1



Figure 1– MCI coupling made of titanium at the ends of riser made of composites

The company "ABB Vetco Gray" has developed the unique model of MCI couplings for risers for drilling operations. Metal pipe is coated with filament made of composite material (epoxy matrix and reinforcement of carbon fibers). At the ends of the pipe such obtained, a metal/titanium coupling is mounted.

Production risers made of composite materials are most commonly made as CC (catenary composite) risers (Figure 2).



Figure 2–Composite risers for connection of active well onto production unit "Heidrun" platform, North Sea, 2001

The company "ABB Offshore Systems" produces high quality CC risers made of carbon fibers and thermoplastic. Their risers don't lose production capacity not even at flow of fluids with temperature of 160°C, pressures of 50 MPa and depths of water of 2000 m.

2.2. Pipe systems for fluid transport and tanks made of composite materials

For the manufacture of pipe systems for fluid transport and tanks for the storage thereof, most frequently are used *GRP* (glass reinforced plastic) composites, also known as fiberglass composites. Those composites are made of standard plastic matrix reinforced with glass fibers. Plastic matrix in GRP composites is most usually made of epoxy resin (GRE pipes) or vinyl-ester (GRVE pipes), and rarely of polyester. Winding of glass fibers at GRE pipes is done in one direction, under constant angle, as shown in Figure 3.



Figure 3 - GRE pipe – procedure of winding of glass fibers

GRE pipes are characterized by: high corrosion stability (no coatings are needed), high value of "strength/mass" relation (much higher than with steel), small mass (1/6 of the mass of the equivalent steel pipe, 1/10 of the mass of equivalent concrete pipe), electrical non-conductivity, dimensional stability, chemical inertness and smooth pipe surface. Operating pressure lies within broadband from atmospheric pressure up to 40 MPa. Maximum operating temperature is slightly higher than 100°C (progress in production of epoxy resins resistant to temperatures up to as much as 160°C is expected) (Fiberglass Pipe Design, 2006).

GRP composites have also found large usage in manufacture of stationary tanks of various diameters and heights, used to storage water, glycol, waste etc (Figure 4).



Figure 4 - GRP storage tanks

Further development of this technology has resulted in manufacture of hybrid composites: thermoplastic pipes reinforced with GRE composite and RTP (reinforced thermoplastic pipe) thermoplastic pipe reinforced with glass, aramid or carbon fibers.

The advantage of hybrid composite systems lies in the fact that they are more flexible, so that they may be wound onto drums. Therefore, except for the manufacture of pipe systems for fluid transport, they are also used for pipe systems for drilling operations (Cadei, 1998).

2.3. Drill pipes and tubing made of composite materials

Those pipes are also known as *CDP* (composite drill pipe). They are characterized by relatively small mass and significantly higher resistance to torsional stress when compared to steel drill pipes.

The company "Lincoln" produces drill pipes from composite materials for horizontal drilling made of combined carbon and glass fibers in epoxy matrix (Figure 5). They are used for drilling of narrow, so called "slim" wells. They are flexible and easy to use. Connectors at the ends of pipes, male and female, are standard API connectors coated with composite material – which enables connection with steel pipes, where appropriate (Composites World, 2008).



Figure 5 - Composite drill pipes laid on platform

The challenge within the segment of the production of primary constructions made of composite materials lies in the construction of drill pipes with larger diameters that have the possibility to meet requirements of a dynamic environment such as drilling. Especially active in this field is "U.S. Department of Energy (DOE)", who form many years now finances pilot-projects in this field.

Flexible GRE and RTP pipes can be wound onto drums, and they are used when drilling – especially on ERD (extended reach drilling) projects and horizontal sections of wells.

Composite materials are also used for fabrication of tubings for the extraction of fluids from deposits and for water injection in order to upgrade production. They are made of GRE pipes or GRE pipes reinforced with carbon steel.

The future of composite tubings lies in the development of epoxy resins, which are able to maintain operating ability during drilling at temperatures significantly higher than 100°C.

3. COMPOSITE MATERIALS FOR FABRICATION OF SECONDARY CONSTRUCTIONS

Composite materials have also found broad application in fabrication of secondary constructions within the oil industry, such as: housing modules, railings on floor grates, footpaths on platforms, constructions for the protection against fire and explosion etc.

Depending on their purpose, those elements are usually produced of epoxy, vinyl-ester or phenolic matrix combined with glass fibers. Epoxy matrices are characterized by good mechanical characteristics and they are used when cheaper polyester matrices cannot reach the expected operating ability. Vinyl-ester matrices have good strength and chemical characteristics. Phenolic matrices are characterized by good heat resistance and they have small emission of toxic vapors in contact with fire. The use of composite materials for those purposes is reasonable, because those structures have high corrosion resistance, have small mas, they are easy to mount, and the degree of safety at work is higher etc.

Some examples of the use of composite materials for fabrication of secondary constructions in oil industry are shown in Figures 6-10.

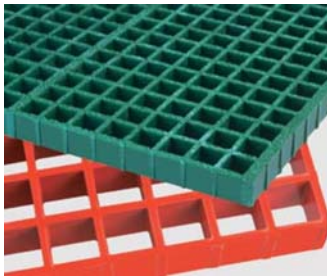


Figure 6 - Regular treads



Figure 7 - Reinforced treads

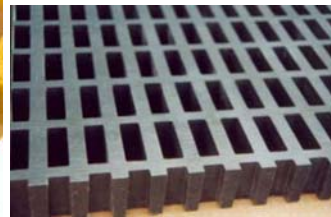


Figure 8 - Big load treads



Figure 9 - Staircase



Figure 10 - Different types of fiberglass profiles

Floor gratings are most usually made of glass fibers and phenolic matrix due to heat resistance, but epoxy matrix, which has better mechanical characteristics, may

also be used. The advantages of constructions made in this way is in their good resistance to all corrosive substances and chemicals, their small mass, easy installation, larger safety at work, easy maintenance.

Figure 11 shows the fire extinguishing facility (Maracaibo, Venezuela), where steel installations were replaced with fiberglass pipes "Green Thread 150/250" of the company "Smith Fiberglass".



Figure 11 - Replacing of steel installations with fiberglass pipes in Maracaibo bay

4. CONCLUSION

Today, the use of modern – composite materials in oil industry becomes more and more prominent. Due to the use of them, mass of construction is reduced up to 80%.

Composites are already greatly used for the production of pipe systems for fluid transport, pressure vessels, drill pipes and their couplings, tanks for fluid storage, risers, pipes for "coiled drilling" installations, partitions on platforms for the protection against fire etc.

Use of carbon fibers as reinforcement elements when fabricating composites – due to their high strength – is very important in oil industry. According to the researches of the company "Spencer Composites Corp" from 2009, the use of composites for fabrication of primary structures in oil industry should, in the near future, reach: 67-74.5 kg/m – for risers for drilling operations; 15-18 kg/m – for production risers; 9-10.5 kg/m – for "choke" and "kill" ducts; 3-7.5 kg/m – for auxiliary ducts.

Basic advantages of the use of composite materials when compared to conventional materials – steel – are: reduction of mass of primary and secondary constructions, introduction of new technologies (for example installation of conducting infrastructures into drill pipes), better physical and chemical characteristics (corrosion resistance, buckling strength), longer life time of the construction (for example within 25 years carbon fibers lose 2-10% of initial strength), easy installation of the construction, higher safety at work, minimum maintenance.

Further researches and development in the field of use of composite materials in oil industry are directed toward development of new composites with better physical and technical characteristics for increased operating temperatures and pressures but without significant increase in production costs.

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