DEVELOPMENT AND TESTS OF A RISER IN COMPOSITE MATERIAL

Sérgio Ricardo Milki de Sousa, sergiomilki@uol.com.br
COPPE/PEM - Mechanical Engineering Program, Universidade Federal do Rio de Janeiro, Technology Center, P.O.Box 68503, 21945-970, Ilha do Fundão, Rio de Janeiro - RJ, Brazil.

Armando Carlos de Pina Filho, pina-filho@deg.ee.ufrj.br
Department of Graphic Designing, Polytechnic School, Universidade Federal do Rio de Janeiro, Technology Center, bloco D, sala D-101, 21949-900, Ilha do Fundão, Rio de Janeiro - RJ, Brazil.

Max Suell Dutra, max@mecanica.coppe.ufrj.br
COPPE/PEM - Mechanical Engineering Program, Universidade Federal do Rio de Janeiro, Technology Center, P.O.Box 68503, 21945-970, Ilha do Fundão, Rio de Janeiro - RJ, Brazil.

Abstract. *The current system of risers used by petroliferous companies is expensive, demanding mechanisms of traction and fluctuation of high cost, with projects performed by considerations of fatigue. Risers constructed with composite materials presents advantages when compared with conventional risers in steel. They are more light and better thermal insulators; they have more resistance to the fatigue and corrosion. Such characteristics improve the system of platform in structural and mechanical terms, facilitating the extraction of oil in deep waters. The objective of this work is the study of risers manufactured in composite material. We will present details about the project of riser, some characteristics and test results, as well as a finite element analysis using ANSYS, showing the riser in composite material as a viable alternative to the current system with risers in steel.*

Keywords*: composite materials, oil, manufacture processes, riser.*

1. INTRODUCTION

The development of rigid risers in composite material was started in 1979. The use of these risers present a great potential of cost reduction in the oil platform. They are more light and better thermal insulators; they have more resistance to the fatigue and corrosion. Such characteristics improve the system of platform in structural and mechanical terms, facilitating the extraction of oil in deep waters.

Functionally, composite risers must have a similar performance to the metallic risers. Generally, the functions are: to control the fluid and pressures in the oil well; to cover the duct that transport the fluids to the reservoir, and from the reservoir; to guide the drill and tools to inside the oil well (Fisher *et al.*, 1977). In these functions, composite risers do not need special equipment or handling techniques.

To become the production cost more competitive, the body of the composite riser can be a hybrid structure (Fig. 1), composed by carbon fiber and glass fiber in an epoxy mold. This material is applied in the surfaces of the wall of the duct to maximize the resistance to the external pressures, as well as the resistance to damages and impacts. The carbon layers of longitudinal winding in composite riser supply rigidity and resistance to axial loading.

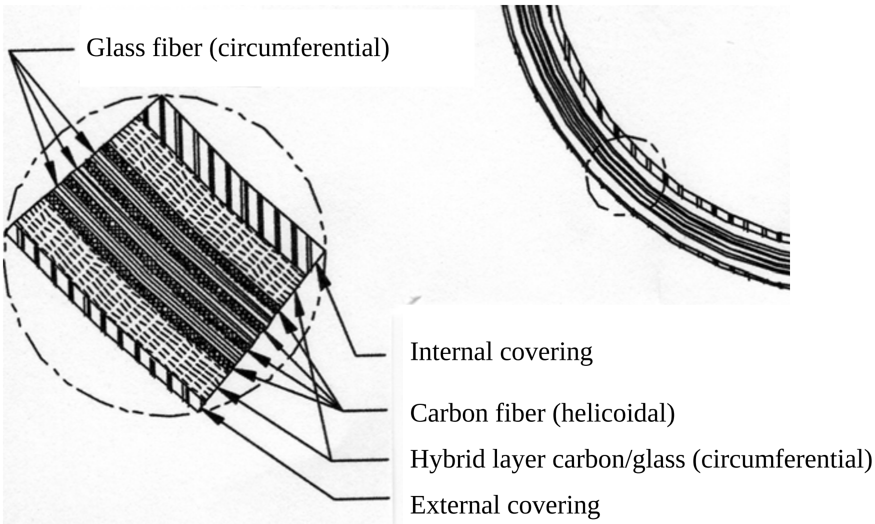

Figure 1. Composition of the riser wall (Baldwin *et al.*, 1997).

The most tests with risers (approximately 90%) take into consideration traction forces combined with pressures. In accord with analysis performed by Baldwin *et al.* (1997), the rupture by axial traction occurs in the interface metal-composite around 3747 KN (Fig. 2).

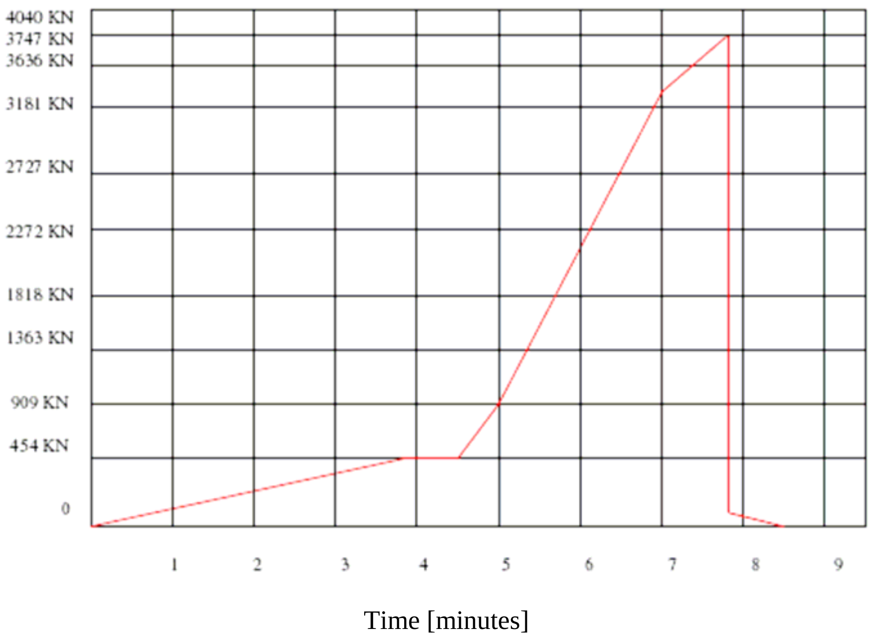

Figure 2. Graph Traction x Time for composite riser (Baldwin *et al.*, 1997).

Pressure tests with combined effect show 50% of defects in the interface metal-composite, and 50% of defects in the bodies of the risers around 84 MPa (Fig. 3). In order to establish industrial confidence in the behavior, the composite riser was tested under conditions of static fatigue (rupture tensions). One of the objectives of these tests was to establish the permissible values of resistance, dependent of the time, for laminated composites with different possibilities of defect (Baldwin *et al.*, 1997).

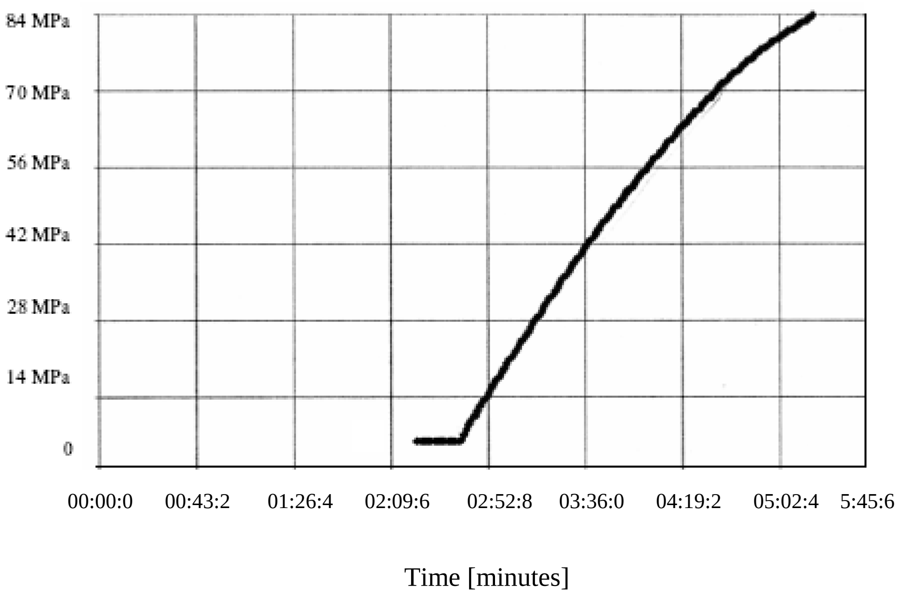

Figure 3. Graph Pressure x Time for composite riser (Baldwin *et al.*, 1997).

The results of the cyclical tests of fatigue are given by S-N curves. The inclination of the fatigue curves depends on the type of material (carbon or glass) and the failure mode (traction or compression). In Fig. 4, the inclination of the line of lifetime shows the loss of resistance with the time.

For the meaning of the fatigue curve, the selected value is the average of the resistance in the temperature based on the data of the final static tests (Johnson *et al.*, 1998).

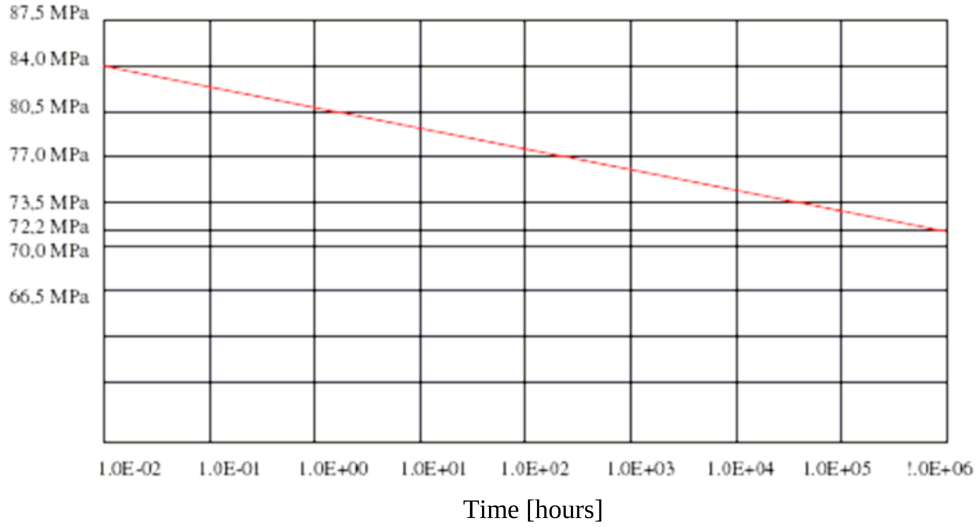

Figure 4. Static fatigue (rupture tension)(Baldwin *et al.*, 1997).

2. METHODOLOGY

In the analysis of the risers, we apply the finite element methods, more specifically, the ANSYS 8.1 program. We consider a simplified model of the riser as a vertical cylinder fixed in the extremities: the top of the oil well and the top of the riser (Fig. 5).

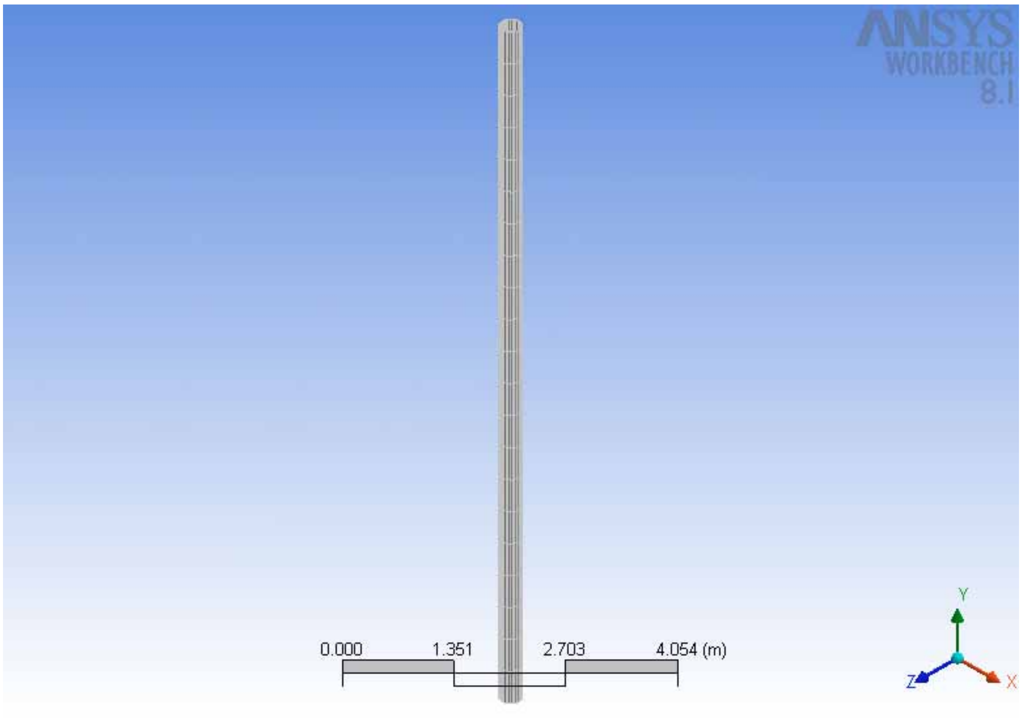

Figure 5. Structure of the riser.

The ANSYS program has a mesh generator which allows refining the mesh automatically. The generator determines the appropriate size of the mesh in a particular region. Thus, a adequate mesh will used in the accomplishment of the tests (Fig. 6). Reticulated elements with six degrees of freedom for node was used for discretization of the riser. These elements have three angular degrees of freedom and three linear degrees of freedom, making possible to consider resistance to the flexion of the lines.

The refinement of the mesh is very important to the tests. A mesh not refined, with small number of elements, can prejudice the results. Thus, the mesh must be refined to represent, with precision, the real structural behavior of the system. In this work, we have a mesh with 1281 elements and 5891 nodes.

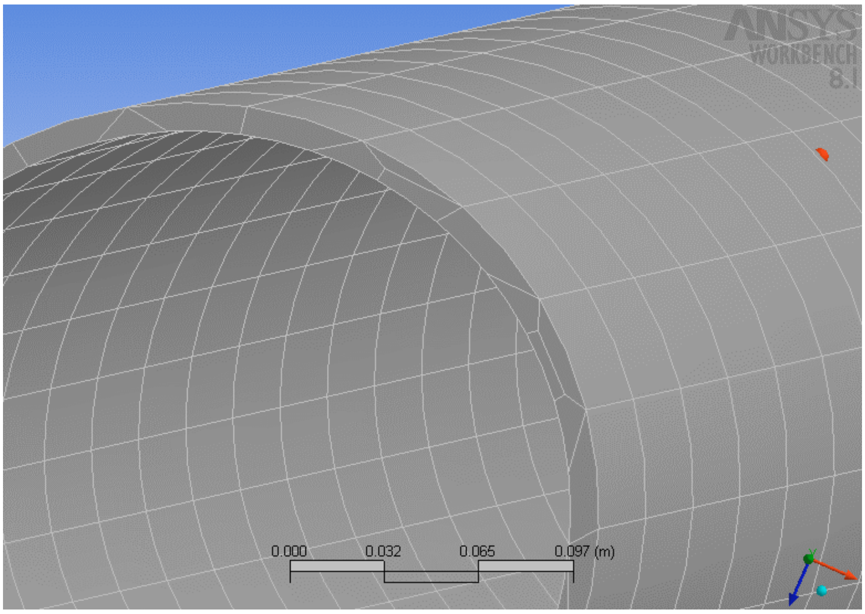

Figure 6. Riser with the refined mesh.

In order to obtain comparative parameters with the analysis performed by Gonzalez (1990), we use a modeling with axis-symmetry, and not taking into consideration non-linearity. The analyzed riser has external diameter of 0.40 m and internal diameter of 0.384 m, and was placed in a depth of 1000 m, being submitted to a distributed triangular loading (marine flows) and axial traction of 3747 KN (Fig. 7). Other data include: wave velocity equal to 0.33 m/s, specific weight of the water equal to 1000 kg/m^3, and dragging coefficient equal to 1.2.

Observe that in the analysis of Gonzalez (1990), the composite riser was not tested, and the used method for analysis was Newton-Raphson.

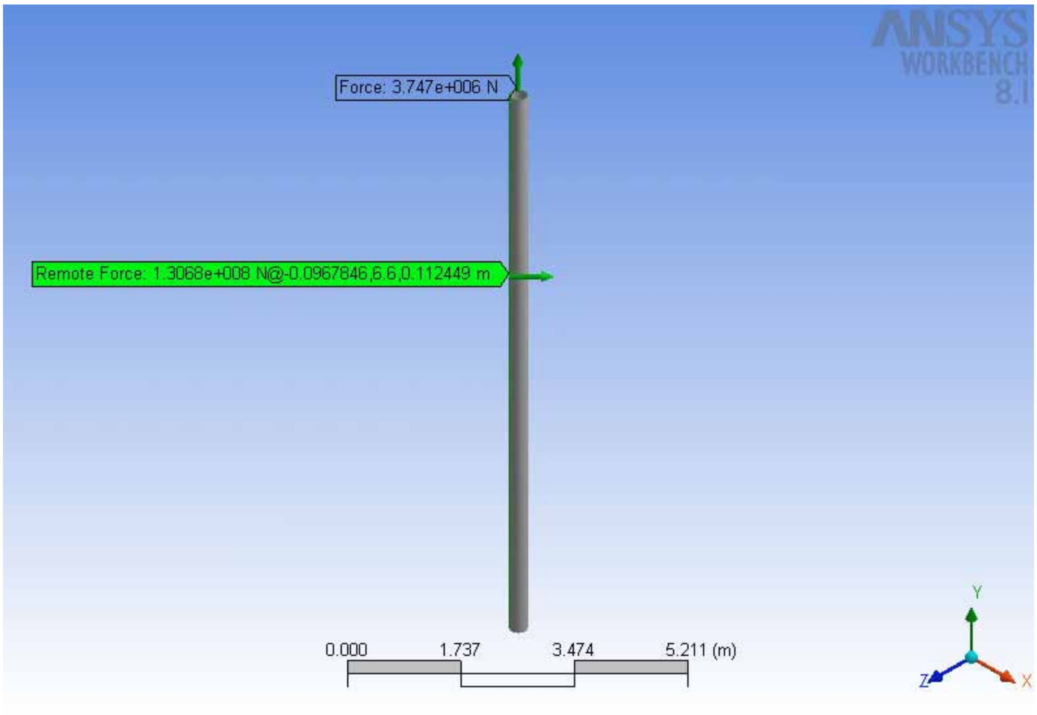

Figure 7. Riser with the applied tensions.

3. RESULTS AND DISCUSSION

From criterion of the maximum distortion, used by the ANSYS program, we observe in Fig. 8 the maximum resultant tensions for steel riser, which occur close to the top of the oil well (1.482 x 10^5 MPa) and close to the top of the riser (1.903 x 10^5 MPa). Figure 9 presents the steel riser with a maximum deformation equal to 18.612 m.

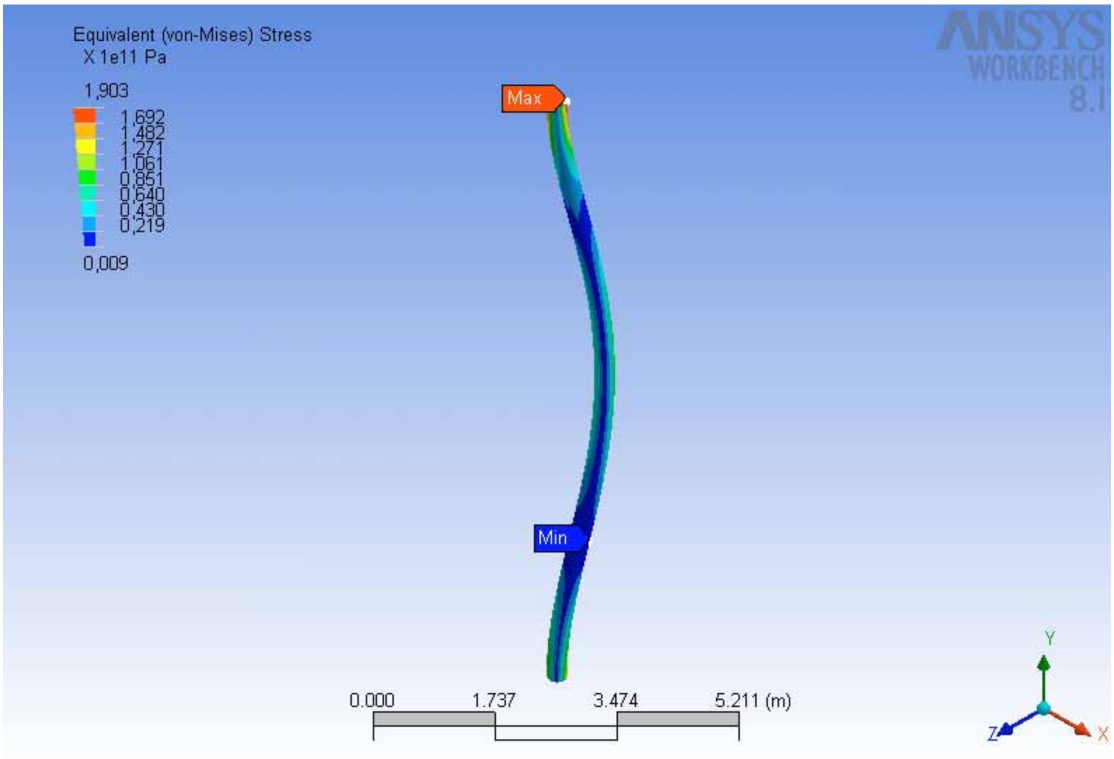

Figure 8. Steel riser with resultant tensions.

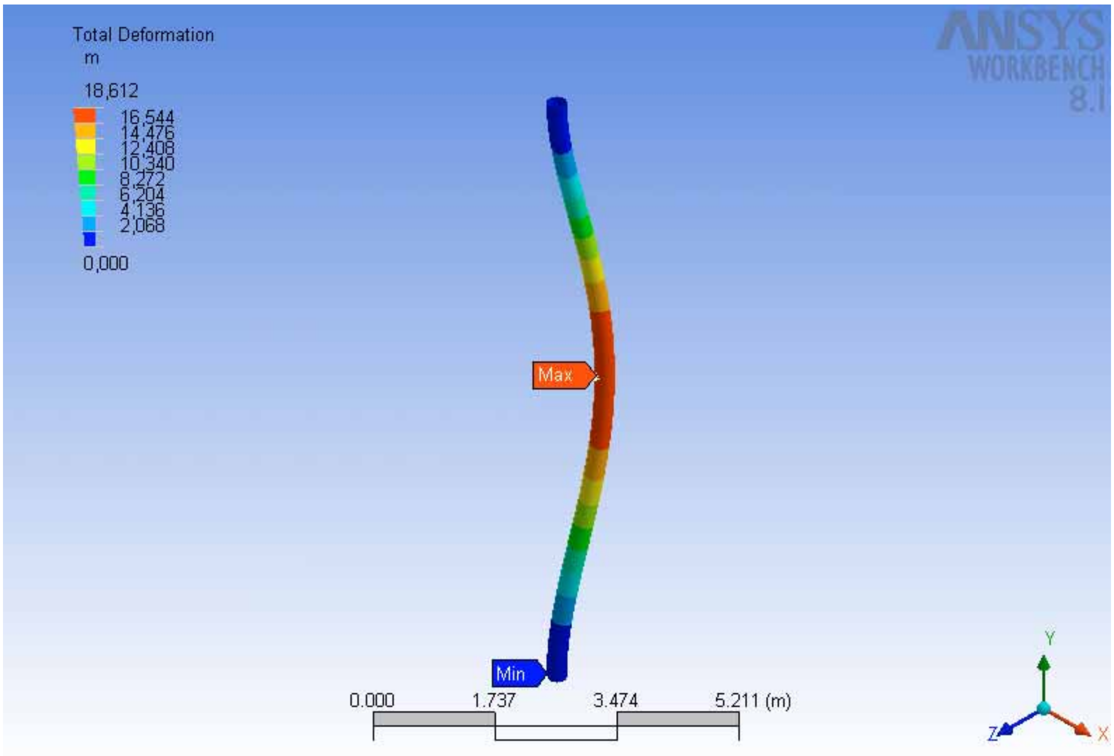

Figure 9. Deformed structure of the steel riser.

Applying a similar test to composite riser, the regions close to the top of the oil well and close to the top of the riser presenting, respectively, the following maximum resultant tensions: 1.478 x 10^5 MPa and 1.898 10^5 x MPa (Fig. 10).

Figure 11 presents the composite riser with a maximum deformation equal to 31.792 m.

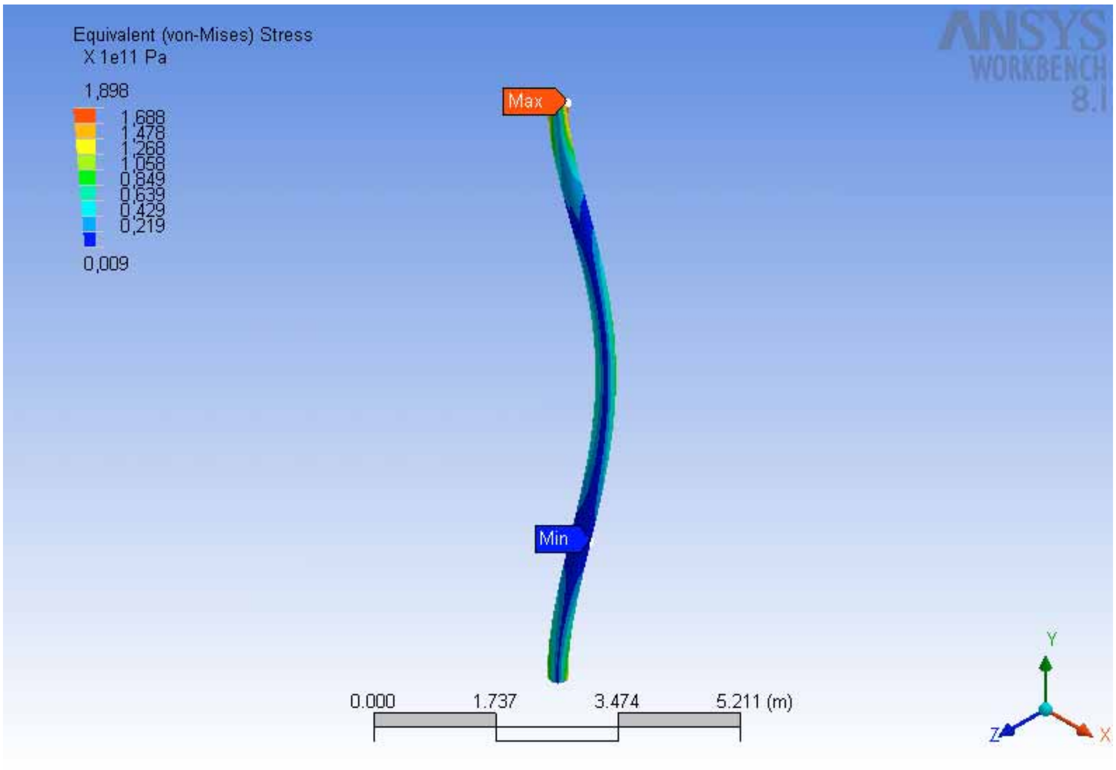

Figure 10. Composite riser with resultant tensions.

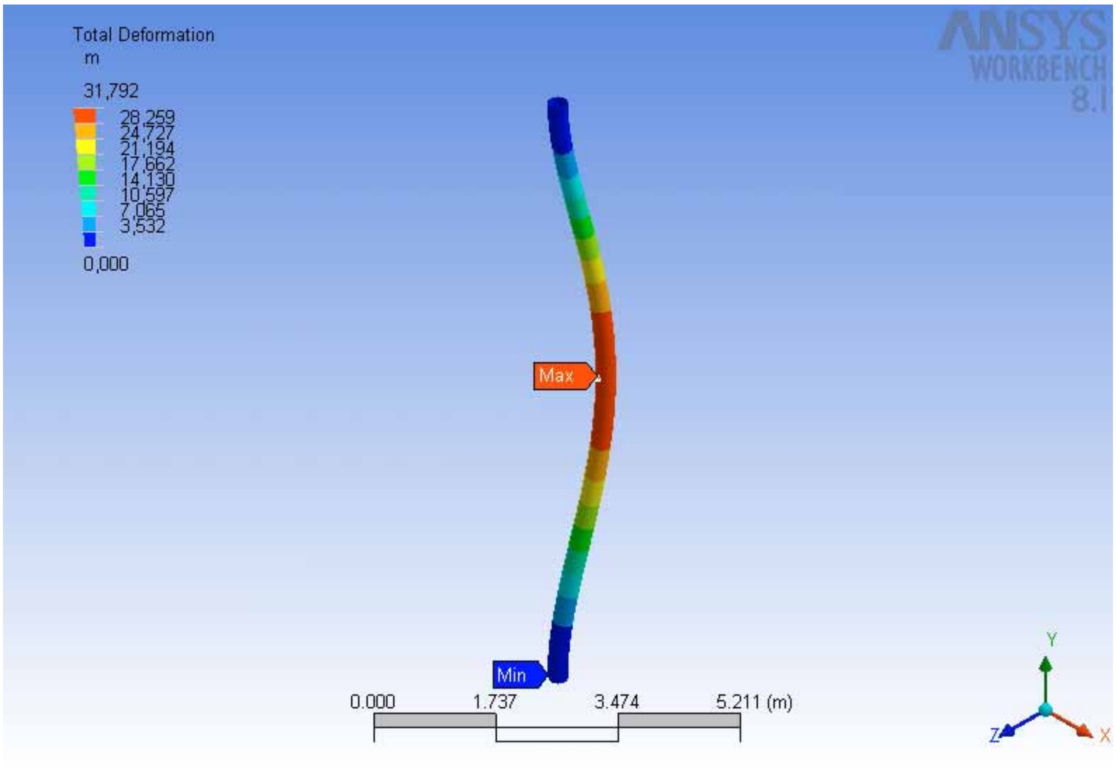

Figure 11. Deformed structure of the composite riser.

From results obtained by the analysis and shown in Figs. 9 and 11, we observe that the composite riser presents a greater deformation (31.792 m) when compared to the steel riser (18.612 m). This behavior is normal and already expected, since the longitudinal modulus of elasticity of the composite material is minor to the steel one. Thus, the composite riser presents a greater displacement when compared to the steel riser, taking into consideration the structure supported in both extremities. Also we can verify that the resultant tensions have near values (Figs. 8 and 10).

Comparing the results of the analysis presented here with the analysis performed by Gonzalez (1990), the steel riser presented a maximum deformation equal to 19 m, approximately. Then, the result is similar to the value of 18.612 m.

For the composite riser, taking into consideration that Gonzalez (1990) not performed the test, we stipulate the value for deformation from proportionally of the modulus of elasticity. Thus, the maximum deformation to the composite riser by analysis of Gonzalez (1990) will be 32.5 m. Then, the result is similar to the value of 31.792 m.

More details about this analysis presented here and other analyses related to the composite riser can be seen in Sousa (2007).

4. CONCLUSION

This work presented the development and tests of a riser in composite material. A study of the composite riser was presented, observing details in relation to the structural and functional characteristics. This study emphasizes the reduction of the costs from the use of composite riser in place of the steel riser. The composite material can be used not only in petroliferous industries, but also in naval, aeronautical, automobile, and aerospace industries.

By application of the finite element methods, from analysis using ANSYS, we concluded that the riser in composite material presented excellent results in the tests, when compared to the steel riser, representing a viable alternative to the current system.

5. REFERENCES

Baldwin, D.D., Newhouse, N., Lo, K.H., 1997, “Composite Production Riser development”, Proceedings of the Second International Conference on Composite Materials for Offshore Operations, CMOO-2, Houston, USA.

Fisher, F.J., 1995, “Composite Production Risers for Deepwater Offshore Structures”, Rev. Inst. Fr. Petrol 50.1, pp. 35-43.

Fisher, F.J., Lo, K.H., Wang, S.S., 1977, ”Material Requirements for Risers”, Proceedings of the Twenty-ninth Annual Offshore Technology Conference, Paper OTC 8431, Houston, USA, pp. 8-11.

Gonzalez, E.C., 1990, “Análise estrutural de risers para águas profundas”, M.Sc. Dissertation, COPPE/UFRJ, Brazil.

Johnson, B.D, Salama, M.M., Long, J.R., 1998, “Composite Production Riser - Manufacturing Development and Qualification Testing”, Offshore Technology Conference, OTC 8665, Houston, USA.

Sousa, S.R.M.de, 2007, “Estudo de uma Máquina de Enrolamento de Filamentos e Análise de seu Produto por Elementos Finitos”. M.Sc. Dissertation, Advisors: Dutra, M.S., Pina Filho, A.C.de, UFRJ, COPPE/PEM, Brazil.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.