APPLYING FINITE ELEMENT METHODS IN THE STUDY OF A MECHANICAL SUPPORT FOR RIGID UNDERWATER PIPELINES

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Abstract. *When necessary, the establishment of piping on seabed is made through the installation of chucks or supports. The pavement of rigid underwater pipeline has as purpose the leveling of the piping so that not happen situations of critical free spans. The mechanical support is a device in the laybarge that is characterized by the leveling of the piping in these situations. In order that the mechanisms of the support are activated, a ROV (Remotely Operated Underwater Vehicle) is used. It actuates in the closing of the clamp around the pipe and is used in the extension of the support legs. ROV is electronically controlled by operators in the laybarge. Therefore, the reduction of installation time of a mechanical support is extremely important, being the main motivation of the referred study. The time spends in the operation requests high daily costs and, as smaller the time of use of the available resources in the laybarge, larger the reduction of the costs of installation of the support. Thus, the main objectives of this work are: a computational modeling of the mechanical support, by means of CAD techniques, evidencing the main parts of the structure; explanations of the active loads in the support, which can to compromise its operation mechanisms and structure; and the proposition of a new mechanical support with better cost/benefit, applied to rigid underwater pipelines, using finite element methods to analyze stresses, determining the viability of use of this new support.*

Keywords*: CAD, FEM, Mechanisms, offshore industry.*

1. INTRODUCTION

The offshore segment is a growing tendency in the world market, due to the high demand of petroleum and gas, and must be studied and managed in an effective way. The work presented here is related to the study of a mechanical support, which represents an element of fundamental importance for underwater pipelines. This device in the laybarge is characterized by the leveling of the piping in situations of critical free spans, that can cause fatigue in pipeline (Guo and Song, 2005; Braestrup et al., 2005).

Its structure and operation must be analyzed in a detailed way, so that it is possible to use it in appropriate support of the pipeline, avoiding any problem in the pipe what could cause not only problems in the distribution of the fluids, but also serious ecological problems. Usually, the operations of that support are made by a ROV (remotely operated underwater vehicle), which accomplishes a visual monitoring and it works the mechanism of clamping of the pipeline and of extension of the support legs. That use of the robot represents a high cost in the installation of the support. Thus, as smaller the time of use of the available resources in the laybarge, larger the reduction of the costs of installation of the support applied for rigid underwater pipelines.

Taking into consideration the presented motivation, in this work, a computational model of the support was developed, built by means CAD techniques, more specifically with the AutoCAD software, and a structure analysis by means of finite element methods, using ANSYS, will be performed. Brief explanations about the active loads for structural verifications, as well as the mechanisms of extension of the support legs and clamping of the pipeline were performed.

2. CHARACTERISTICS OF THE MECHANICAL SUPPORT

The mechanical support is a structure in steel built in way to accomplish the protection of the piping nets installed already in the marine soil. Constituted by four permanent parts (clamp, structures, fixed and retractable legs and shoes), the support is capable to promote the leveling of the piping for several height conditions, inclination and seabed. Figure 1 presents some examples of mechanical support.

The phenomena susceptible to occurrence in pipeline can compromise the integrity of the piping, as well as the distribution of the fluids and occurrence of serious ecological problems. Phenomena as accentuated bending of the pipeline, upheaval buckling and state of fatigue should be studied and taken into account in the design process and structural verifications of the mechanical support.

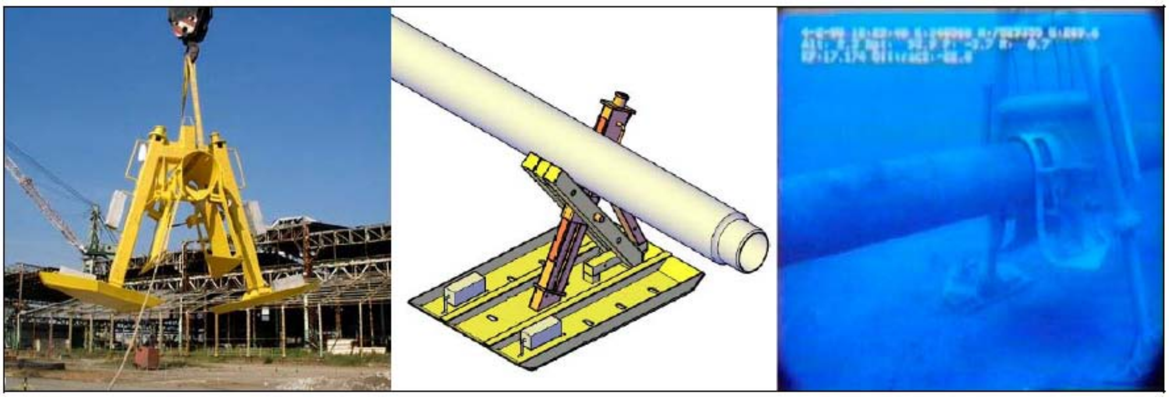

Figure 1. Examples of used supports.

The model presented in this work was based in supports used in a gas pipeline (Fig. 2), where, sometimes, several critical free spans exist. The performance of the support feels exactly in the clamping of the pipeline, when it is in situations of free span, and in the process of extension of the retractable legs that it promotes, in many cases, the first touch of the support in the soil and the sinking of the shoes as fixation warranty. Due to the complexity of the mechanical support, four groups that compose it will be studied: structure of support; fixed and retractable legs; shoes; and clamp.

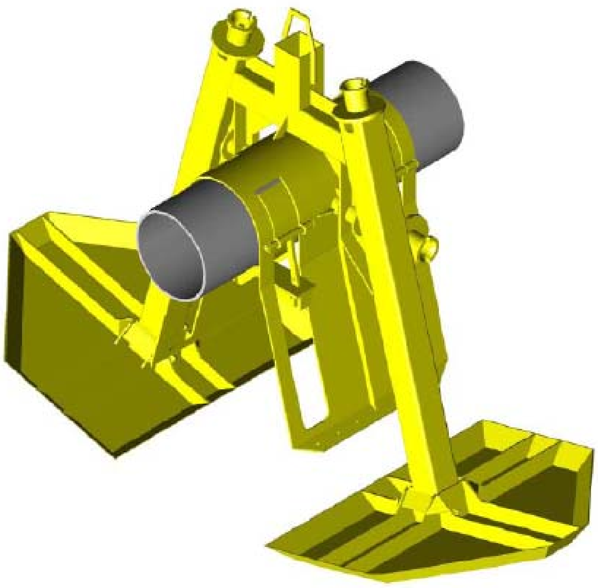

Figure 2. Computational modeling of a mechanical support.

The structure of support is responsible for the connection of the legs and the clamp of the support. This structure is of extreme importance in it inclusion of functions. Strategic locations and the need of correct measurements of certain structures that include several use conditions exist, such as: lift handle; connection tubes; and regulator of inclination of the handle.

The fixed leg is welded in the lateral area of the structure of the mechanical support. Inside the leg, a passer-by static screw exists coupled to a nut, being this welded to the retractable leg. The beginning of operation of the mechanism is similar to the necklace in a system of power screws (Shigley et al., 2005). In relation to the screw, as the compression load in the numberless is growing, proportional to the sinking (Bowles, 1995), it is of extreme importance to evaluate the resistance of the screw, as well as the bending stress, compression and torsion that appear in the engaged fillets of the thread.

The shoes are foundation elements used to transmit the load from the support to the soil, without the support suffers the collapse. Steel plates are used to build these shoes that are fixed to the mechanical support, guaranteeing stability for supporting the mechanism and the pipes.

Finally, the clamp is the responsible structure for the clamping of the pipe in the moment of first contact of the support with the piping, following by the use of ROV. In this work, new devices in mechanical support were modeled, in particular, the clamp was modified for no more need of ROV for pipeline clamping. The structure, legs and shoes are the same.

Farther the structural details, a important point of discussion is how the soil must be considered in the assessment. Irregularities of the marine soil, as well as the type of soil, are factors that directly influence the design of the mechanical support. The bathymetry of the ground defines the geometry of the support and allows to an evaluation of the sizes and possible configurations for support legs, making possible reductions in the manufacture costs. By means of geo-technique inquiries, the composition of the marine soil is verified and basic parameters are determined, such as: rigidity, coefficients of friction and degrees of cohesiveness (Bowles, 1995). Depending on the type of soil, such parameters allow an evaluation of the necessary power for tool of torque of the ROV, objecting a proper foundation.

3. PROPOSED MECHANICAL SUPPORT

The model of the new clamp for the proposed support uses structures of metal sheet and plates by weld strings, besides bars and springs, therefore, a simpler system and of better cost/benefit that the current. Figure 3 shows the clamp structure of the new proposed support.

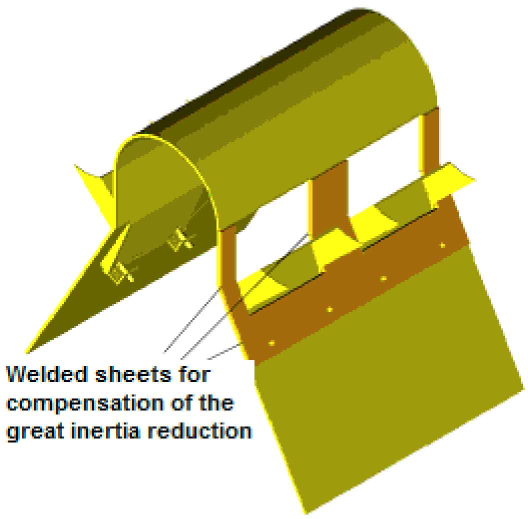

Figure 3. Clamp structure of the new support.

When going down to the seabed, the mechanical support touches the piping, and the clamps rotate until the accommodation of the support in the pipeline. The rotation angle of the clamps is limited by the deflection of the springs, which have pins as guides to guarantee the stability of the mechanical group (Fig. 4). When the piping makes comfortable, the clamp returns to original position, maintaining a contact area with the pipe, by means of three welded sheets, in the vertical position, in the main sheet. Thus, the clamp guarantees the fixing of the pipeline close to the support, without need of ROV.

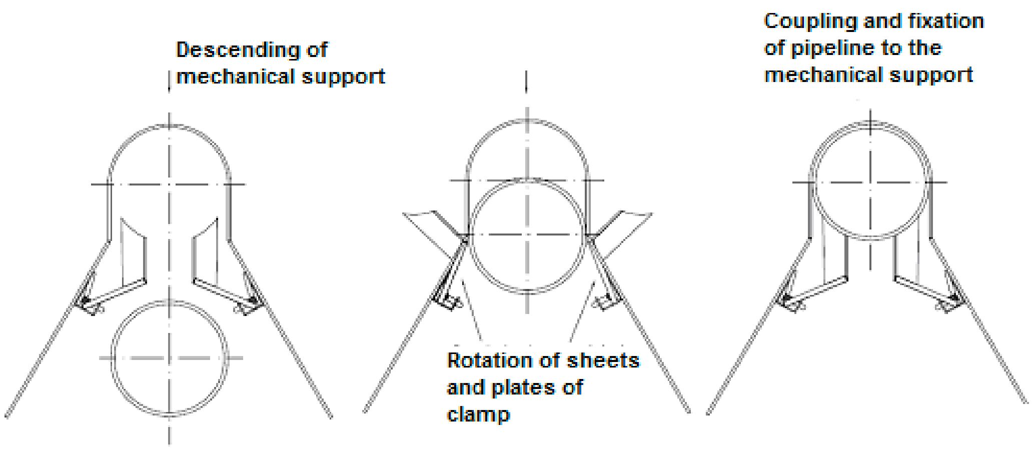

Figure 4. Performance of clamping when it interacts with pipe.

The movement of rotation of the clamps is made when the pipeline touches main plates that, later, it pushes the passer-by bar for the guide pins of the compression springs. That bar transmits the active load, leading off the deflection of the springs for the turn of plates and, consequently, for the passage of the piping.

For each clamp four shear areas are created in the bar, that should support the stresses originating from of the loading due to the contact with the piping. That constant loading has the magnitude of the own weight of the mechanical support in the air, subtracted of the created buoyancy, in other words: $Q = P_{SUPORTE} - E$, where Q is the transmitted loading, $P_{SUPORTE}$ is the weight of the mechanical support in the air, and E is the buoyancy. It is observed that, as they are four structures of clamps, the value of the loading should also be divided by 4, when of the measurement of the bars, you plate and springs.

The helical springs of compression should be measured to support the stresses originating from of the applied load so much in the passer-by bars for the guide pins guide, as well as allowing the necessary deflection for passage of the piping.

In the descending motion of the mechanical support, the structure of the clamp joins to the pipeline so that is warranty of fixation of the same. However, during the whole clamping stage, the turn of the clamps causes efforts in the structure, worsened by the great inertia reduction that is done necessary to guarantee the rotation motion.

As reliever measure for the problem, in this place, the thickness of the plate should be increased, for compensation of the material lack. For structural verification, an analysis in finite elements is necessary due to the high complexity of the efforts in the structure.

Therefore, it is of extreme importance a study for the measurements of the clamp structure, because a mistaken calculation can generate an unusable support and, in consequence, quite high costs. Other details about this study were presented by Bandeira et al. (2008).

4. ANALYSIS OF THE MECHANICAL SUPPORT

It will be verified the behavior of the clamp and its structure, when this is submitted to vertical load originating from pipe submarine weight added of operational fluid weight. As main output, it will be observed the regions and which points are stress concentration factors.

The structure will be analyzed by finite element methods, using ANSYS version 11, a powerful software that offers a full depth of analysis from concept simulation to advanced analysis.

The situation to be analyzed will be of an oil piping, in that the free span in subject will have length of 45 m. The pipeline has diameter in the value of 18 in, without concrete thickness, and isolation thickness, whose specific mass is of 841 kg/m³, in the value of 2 in (Tab. 1).

Table 1. Input data for analysis.

Input data	**Unit**	**Value**
External Diameter	in	18
Wall Thickness	in	0.5
Isolation thickness	in	2
Concrete thickness	in	0
Young’s Modulus	kN/m²	207e+6
Steel Density	kg/m³	7850
Fluid Density	kg/m³	841
Isolation Density	kg/m³	900
Acting pressure	MPa	3.26
Yield strength of clamp	MPa	345
Free span length	m	45

Considering the buoyancy, the total pipe submarine weight that will act at clamp structure is 75 kN. So, each clamp will receive ¼ of static loading, considering negligible the drag forces, due low current velocities, in this situation.

The analysis mediated only the clamp, considering as boundary conditions fixed basis and a pressure acting on the top of sheets, with magnitude of 3.26 MPa. The modeling considered just the half of clamp, due to symmetry. The mesh used was, in some regions, mapped, where there was not complexity in geometry. For other regions, it was used a mesh generated automatically (Fig. 5).

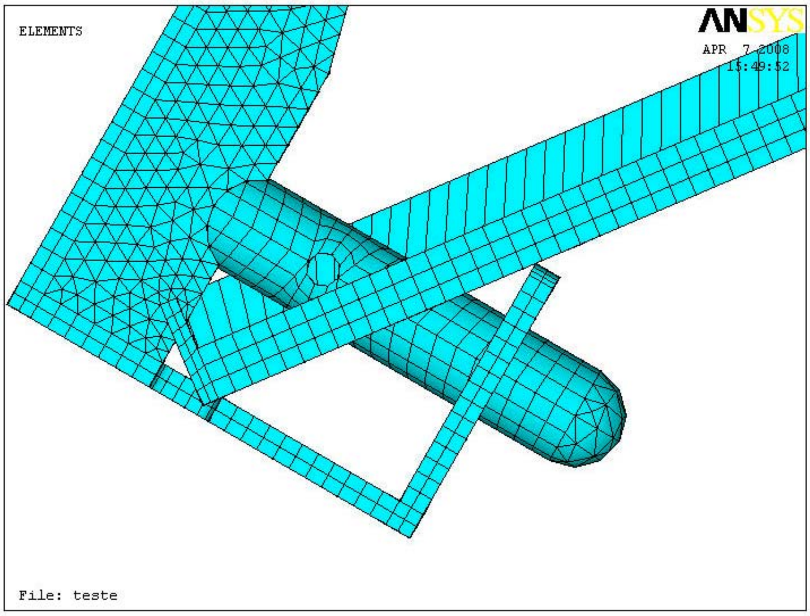

Figure 5. Clamp mesh detail.

The analysis, involving the static load (pipe submarine weight added of operational fluid weight), indicated the regions where stress concentration factors act. The von Mises stresses are shown in Fig. 6. The maximum Von Mises stress, of 1325 MPa, is located at normal contact regions, where is characterized by small displacements. The stresses are shown conform to color scale.

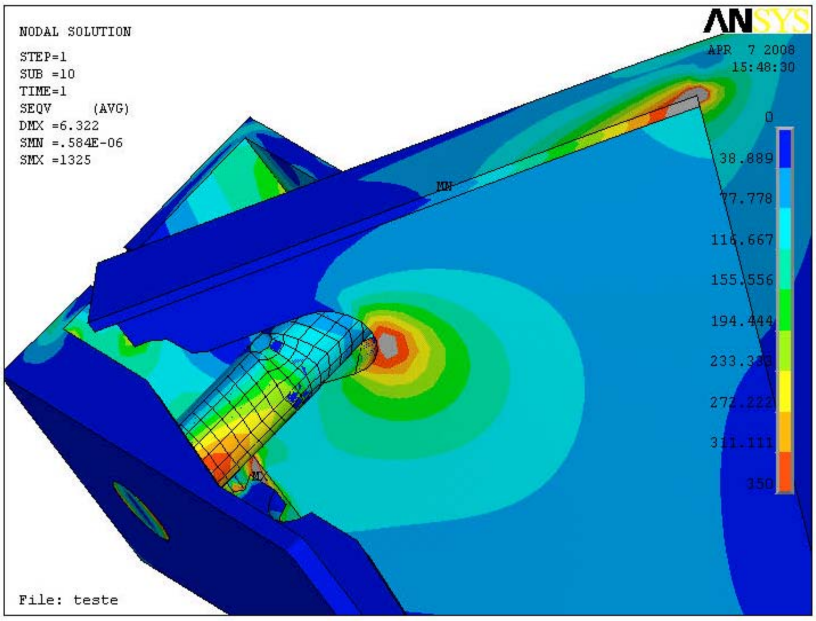

Figure 6. Von Mises stresses detail.

The maximum displacement occurred at extremity of vertical sheets, where the loading acts directly (Fig. 7). It reached the maximum value of 6.3 mm.

The combination of acting efforts resulted in a Von Mises stress larger than the yield strength. A solution for this problem is a tapper at the regions of encounter of sheets to reduce stress concentrations, and/or increase the thickness in the regions of direct or shears contact. A more expensive solution is improving the properties of clamp material, increasing the yield strength.

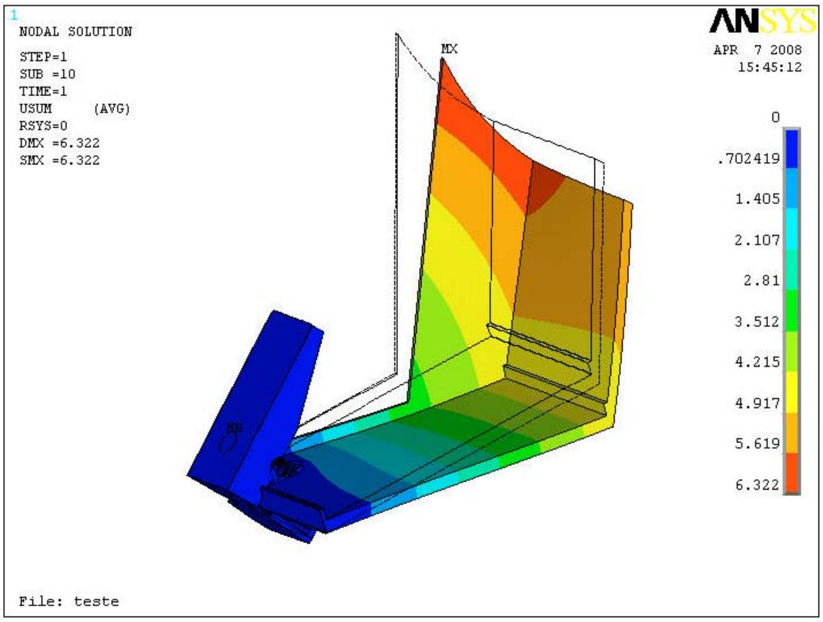

Figure 7. Deformed and undeformed shape of clamp.

The analysis in clamp structure was performed due to high inertia loss, created to allow the rotation of the clamps. All structure was modeled, and the applied loading and boundary conditions are the same that for previous analysis, including the encastre at the holes, where located the tubes for connection with structure of support. The contacts between the parts were modeled too, obeying the restriction and conditions of displacement of model. The clamps were not shown, since the previous analysis contemplated all the cases to be analyzed.

The mesh was generated automatically, due to high complexity of all structure. It is important to observe that, if the mesh was more refined, or mapped, the results would be closer of the real case. Due to mesh generated automatically, the elements could be distorted and they not have the same dimensions or formats, which justified the foregoing explanation.

For the analyzed situation, the most regions of clamp structure resisted quite to the active stress (Fig. 8). The maximum Von Mises stress reached the value of 696 MPa in stress concentration point (contact clamp-structure). In other regions, the stresses are distributed uniformly, reached a von Mises stress between 50 and 75 MPa.

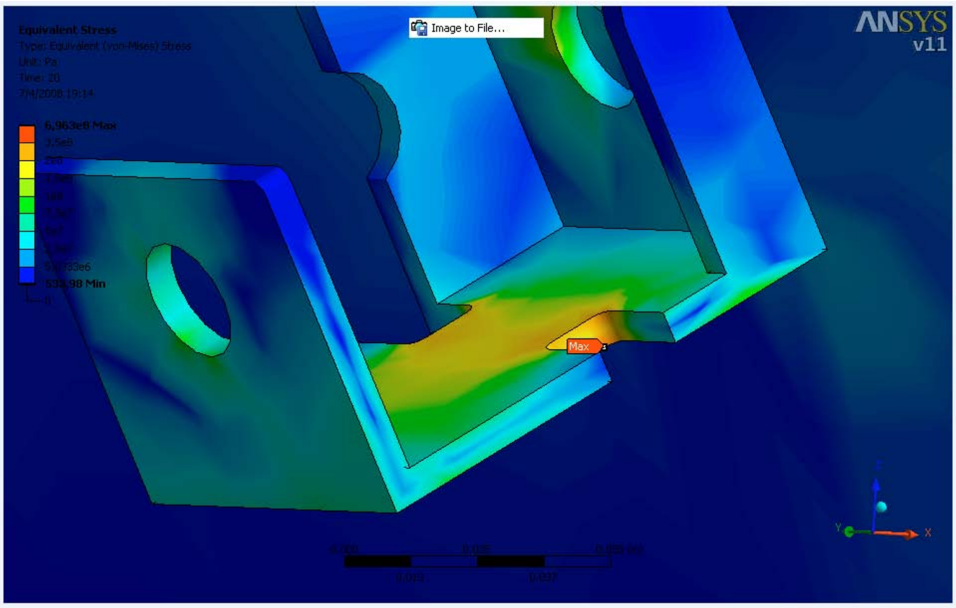

Figure 8. Detail of maximum Von Mises stresses in clamp structure.

The displacements are maximum at extremity of structure, with maximum value of 3.6 mm (Fig. 9).

As the maximum active stress passes the yield stress just in a point of clamp, and not in the structure, in general the structure resisted quite to the efforts. If the loading increase, a solution is the same for the clamp, i.e., increase the properties of material or increase the thickness of structure.

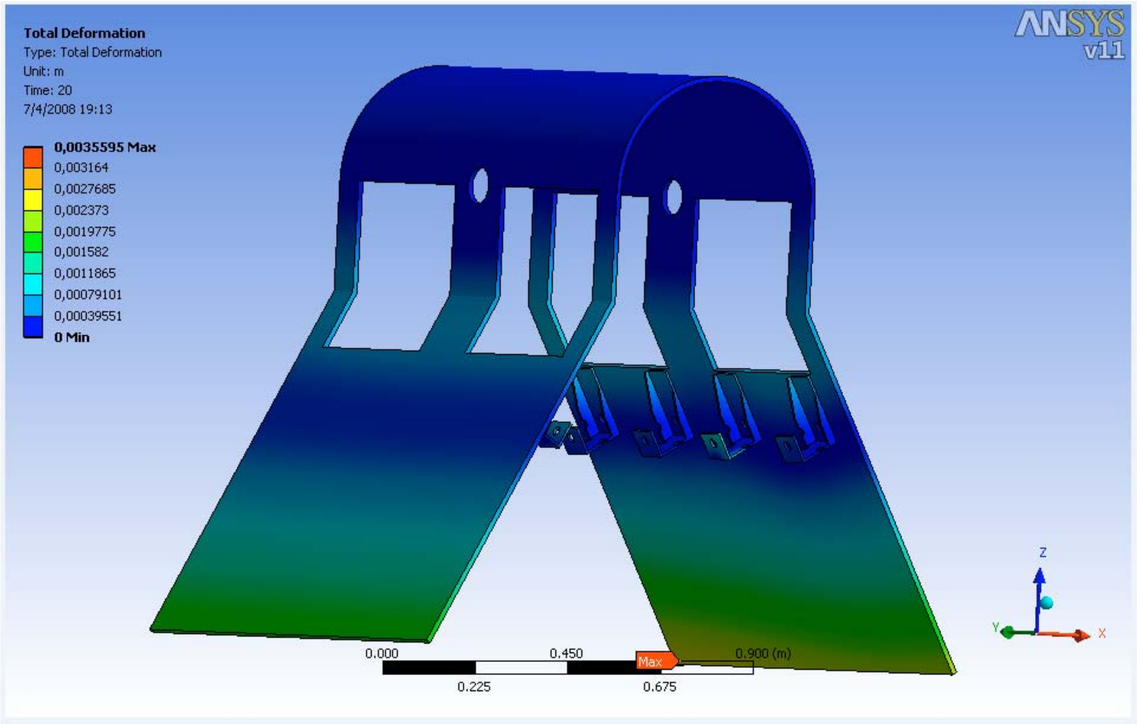

Figure 9. Distribution of displacements in clamp structure.

5. CONCLUSION

For better understanding of the active efforts, a study of the mechanical support used for rigid submerged pipelines in situations of free span was accomplished, presenting information on its structure and its operation mechanisms for leveling of the piping, as well as a computational modeling of the support using CAD techniques, more specifically with the AutoCAD software. The active efforts were characterized in the support, as well as the beginnings of clamping of the pipe and extension of the legs.

The operations of the mechanical support are made by a robot ROV, present accessory in the laybarge. The daily costs of the vessel are relatively high and, as the installation of the supports along a pipe net requests time, a new study of clamps, constituted just of sheets and mechanical elements as springs, it was proposed and accomplished by means of techniques of CAD. The new clamps would not need devices for the clamping of the pipe, reducing the costs of operation and project.

To verified how the new clamp responses to the free span simulation, it was modeled the new support in ANSYS version 11, submitted to the loading of magnitude of 75kN, corresponding to pipe submarine weight added operational fluid weight.

The yield stress was exceeded, and the maximum Von Mises stress reached was 1325 MPa, in a stress concentration region (direct contact). The maximum displacement encountered was 6.3 mm. The clamp structure resisted to the applied loading.

A solution, when the combination of stress surpasses yield strength, is a tapper at the regions of encounter of sheets to reduce stress concentrations, and/or increase the thickness in the regions of direct or shears contact. A more expensive solution is to improve the properties of clamp material, increasing the yield strength.

6. ACKNOWLEDGMENTS

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