FINITE ELEMENT ANALYSIS AND DESIGN OF SUPPORTING BRACKET OF A PIPE

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ABSTRACT

Design process of any product can consist of examining a design need and working on the problem by means of sketches, brain-storming, models, calculations as necessary, development of styling as appropriate and calculation of the costs. In this paper, the main aim is to design a supporting bracket of a pipe with a good style, a reliable factor of safety and low material cost. Four different materials were used to find out the minimum mass and cost of each model. NX8.5 Nastran was used for sketching and modeling. Moreover, a static simulation was done by the same software where a specific compressive load was applied as well as constraints to analyze stresses on the bracket. The load was estimated according to the pipe span. The result showed that the Steel alloy AISI4340 had the highest safety factor value of the design with Low material cost. Therefore, it was the best material of the design. Material cost of the model made of cast iron G60, Aluminum2014, and Steel AISI4340 were approximately the same despite the different required masses. The copper-c10100 was the most expensive with a low value of safety factor.
INTRODUCTION

It has become widely recognized that design and selection of pipe bracket is an important part of the engineering study of any modern steam generating or process installation. Supporting Bracket usually used to hold or support shafts and pipes in their position and prevent excessive deflection. Brackets can also be used to support and mount motors, generators and assemblies [1]. In general, pipes should be adequately supported because they are installed in the walls of buildings extending horizontally and vertically to carry oil, waters and other liquids. The bracket design depends on many variables. The material of the supporting bracket should be strength enough to withstand weight of the pipe, pressure and vibration. It should have a low mass as much as possible and a good resistance of corrosion. Steel alloys, aluminum alloys and ductile iron can be used as a material because their properties offer high strength with relatively low cost and weight. The alloys of steel and aluminum have a long life with corrosion resistance [4]. Installation of the bracket should be easy and taken into account. Sometimes, the supporting bracket fixes the pipe against the applied axial forces. These forces might result in buckling, thermal loads, water hammer and vibrating equipment [10]. Therefore, engineers should consider all that factors while designing and should make a structurally efficient and economical design. In this paper, the designed bracket is subjected to weight of the pipe and the liquid that runs inside it. It is represented as a compressive load. Value of the load is estimated to be 25000N.
Fig 1 Design of Supporting Bracket of pipe using NX8.5

The illustrated bracket in Fig1 is designed to be fixed on horizontal floor and not on walls. It consists of two components, base and cover. The base has two holes diameter 15mm to be fixed on the floor by bolts. The other part which is the cover is used to fix the pipe and prevent it from moving. Two bolts and nuts are used to join the cover with the base. Diameter of the pipe is designed to be 51mm. It is important to verify that actual bracketing requirements are in accordance with client specifications [8].

NX8.5 Software

In general, NX was formerly known as UG in 2000. Unigraphics purchased SDRC I-DEAS and began to integrate aspects of both software packages in order to make one single product called Unigraphics NX or just NX. Therefore, NX is advanced high-end CAM/CAD/CAE software since 2007 owned by Siemens PLM. It is for so many tasks such as design which includes direct solid,
parametric and surface modeling. It also used for engineering analysis comprises static, dynamic, electromagnetic, and thermal by using finite element method. Fluid analysis can be done by using finite volume method. NX software is considered a direct competitor to Catia, Creo, Autodesk Inventor and Solidworks software. NX8.5 is software produced by Siemens Company. It simplifies complexity during design stages, speeding up design processes to introduce the product to the market in a short time. It is a powerful tool which has a hybrid modeling capabilities because it is integrating explicit geometric modeling and constraint-based feature modeling [2]. Complex free-form shapes can be designed by this software such as manifolds and airfoils. Finally, NX software package is a 3D computer aided design suit which allows modeling solid components and assemblies to perform engineering analysis.

Simulation

The aim of simulation is to show the maximum deformation or displacement of the product and also explain stress concentration on the model where weak areas can be modified. The simulation process is static and linear which comprises, meshing, selecting material, making constraints and finally solving the problem.

1- Meshing:

It is a process to create finite element model which enable to create a mesh of 4 or 10 nodes on the solid body. Tetrahedral nodes were chosen as suitable for 3D model. 10 nodes mesh was very small and unable to be applied for the bracket geometry. Therefore, 4 nodes mesh was used. The process of meshing as shown in Fig2 enables computational solutions of partial differential equations. It partitions a solid space into elements or cells which the equations can be approximated [3,7].
Fi 2 Finite element model of the bracket

2- Selecting material:

Selection of a proper material is usually a difficult job for the designer. Generally, while selecting the material the following factors should be considered:

- Availability of the material
- Suitability of the materials for working conditions and service.
- The cost of materials

The four selected materials are available; however, suitability of the materials and their cost will be investigated and discussed in this research. The materials are: high strength Steel AISI4340, Aluminum 2014, Cast Iron G60 and Copper-C10100. The following, Fig 3 shows how to select one of the materials by using NX8.5 software.

Fig 3 Selection of material

The properties of each material are available in NX8.5 software such as, yield strength, ultimate tensile strength, fatigue coefficient and Young’s Modulus. The Aluminum 2014 is an alloy which contains about 93.5% of Aluminum with other elements such as copper, Silicon, Magnesium and Chromium. The alloy steel AISI4340 contains about 96% of Iron. Cast Iron G60 is a type of grey cast iron and has a good strength while Copper-C10100 has 99.9% of Copper [9].

3- Making Constraints:

The constraints represent the real working conditions of the design. Therefore, the base of bracket should be fixed as in the real condition which is shown in Fig4. Mass of the pipe and liquid is represented by a compressive load inside the hoop of the bracket as in the figure.
In Fig 5, the maximum deformation of the model made of steel AISI4340 is 1.109E-002mm while the maximum stress on the model is 105.78 Mpa. Mass of steel AISI4340 required for the model can be calculated by the software which is 1.4895kg.
Fig 6 The maximum stress and deformation of Aluminium2014

The maximum deformation of the model made of Aluminium2014 is 0.0289 mm as shown in Fig 6, while the maximum stress on the model is 102.36 Mpa. Mass of Aluminium 2014 required for the model can be calculated by the software which is 0.530162kg

Fig 7 the maximum stress and deformation of cast iron G60

In Fig 7, the maximum deformation of the model made of Cast Iron G60 is 0.0136 mm. The maximum stress on the model is 109.22 Mpa and the calculated mass is 1.3567kg
Fig 8 the maximum stress and deformation of copper- C10100

The maximum stress on the model made of Copper-C10100 is 103.83Mpa as shown in Fig 8 while the maximum deformation is 0.0186 mm. mass of the model is 1.6926kg

Factor of safety

In the design process, factor of safety is defined as the ratio of the maximum stress to the working stress.

\[
\text{Factor of safety} = \frac{\text{Maximum Stress}}{\text{Working Stress}}
\]  
………………….. (1)

When designing machine parts, it is desirable to keep the stress lower than the maximum stress at which failure of the material takes place. This stress is called as the working stress [5]. In ductile materials, the yield point is clearly defined and considered as the maximum stress.

\[
\text{Factor of safety} = \frac{\text{yield point Stress}}{\text{Working Stress}}
\]  
………………….. (2) The relation for static loads

In brittle materials such as cast iron, the yield point is not well defined. Therefore, factor of safety is based on ultimate stress.

\[
\text{Factor of safety} = \frac{\text{ultimate Stress}}{\text{Working Stress}}
\]  
………………….. (3) The relation for static loads

Because the main load which applied on the supporting bracket is a compressive force. Therefore:
Factor of safety = \frac{\text{Maximum compressive Stress}}{\text{Working Stress}} \quad \ldots \ldots \ (4)

Table (1) Factor of safety and Stresses

<table>
<thead>
<tr>
<th>Supporting Bracket Material</th>
<th>Working Stress (Mps)</th>
<th>Maximum compressive stress (Mpa)</th>
<th>Factor of Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel AISI4340</td>
<td>105.78</td>
<td>1178</td>
<td>11.13</td>
</tr>
<tr>
<td>Aluminium2014</td>
<td>102.36</td>
<td>422.28</td>
<td>4.12</td>
</tr>
<tr>
<td>Cast Iron G60</td>
<td>109.22</td>
<td>550</td>
<td>5</td>
</tr>
<tr>
<td>Copper-C10100</td>
<td>103.83</td>
<td>400</td>
<td>4.33</td>
</tr>
</tbody>
</table>

Table (1) shows the relation between the maximum compressive stress and working stress where the equation (4) is applied to find the safety factor.

Table (2) Base Metals Historical price Data in U.S Dollars

<table>
<thead>
<tr>
<th>Year</th>
<th>Aluminium</th>
<th>Aluminium Alloy</th>
<th>Alumina</th>
<th>Copper</th>
<th>Nickel</th>
<th>Lead</th>
<th>Zinc</th>
<th>Tin</th>
<th>Iron Ore</th>
<th>Steel (USA)</th>
<th>Steel (Europe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>2020.88</td>
<td>1845.86</td>
<td>1797.64</td>
<td>7964.23</td>
<td>17522.38</td>
<td>2062.45</td>
<td>1948.16</td>
<td>21095.76</td>
<td>131.63</td>
<td>656.57</td>
<td>659.47</td>
</tr>
<tr>
<td>2013</td>
<td>1845.86</td>
<td>1797.64</td>
<td>7964.23</td>
<td>7390.44</td>
<td>16022.63</td>
<td>2139.23</td>
<td>1910.09</td>
<td>22272.66</td>
<td>136.56</td>
<td>630.49</td>
<td>614.28</td>
</tr>
<tr>
<td>2014</td>
<td>1787.45</td>
<td>1795.43</td>
<td>6883.26</td>
<td>7380.13</td>
<td>16987.92</td>
<td>2095.05</td>
<td>2162.01</td>
<td>21878.75</td>
<td>97.34</td>
<td>657.79</td>
<td>568.37</td>
</tr>
<tr>
<td>2015</td>
<td>1720.53</td>
<td>1720.53</td>
<td>6608.75</td>
<td>397.42</td>
<td>18343.73</td>
<td>1787.3</td>
<td>1929.03</td>
<td>16053.44</td>
<td>55.64</td>
<td>462.25</td>
<td>420.18</td>
</tr>
<tr>
<td>2016</td>
<td>1553.26</td>
<td>1553.26</td>
<td>4871.3</td>
<td>320.71</td>
<td>9596.5</td>
<td>1866.99</td>
<td>2092.83</td>
<td>17960.96</td>
<td>59.61</td>
<td>517.96</td>
<td>439.86</td>
</tr>
</tbody>
</table>

Table (2) illustrates approximate metals prices in USD per metric ton. They were taken from Focus Economics website which working with reports used by the world’s Major financial institutions, multinational enterprises and government agencies [6]. The prices might changes widely according to the quantity demanding, however, they give good indication to the cost.
Table (3) Specifications of Each Supporting Bracket

<table>
<thead>
<tr>
<th>Supporting Bracket Material</th>
<th>Maximum Deformation (mm)</th>
<th>Material Mass (Kg)</th>
<th>Material Cost for 1kg (U.S.D)</th>
<th>Material Cost of the model</th>
<th>Factor of safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel AISI4340</td>
<td>0.011</td>
<td>1.4895</td>
<td>0.51796</td>
<td>0.771</td>
<td>11.13</td>
</tr>
<tr>
<td>Aluminium2014</td>
<td>0.0289</td>
<td>0.530162</td>
<td>1.55326</td>
<td>0.823</td>
<td>4.12</td>
</tr>
<tr>
<td>Cast Iron G60</td>
<td>0.0136</td>
<td>1.3567</td>
<td>0.51796</td>
<td>0.7027</td>
<td>5</td>
</tr>
<tr>
<td>Copper-C10100</td>
<td>0.0186</td>
<td>1.6926</td>
<td>4.8713</td>
<td>8.245</td>
<td>4.33</td>
</tr>
</tbody>
</table>

In table (3), the maximum deformation and the material mass in Kilogram are shown. In addition, cost of the required material of each supporting bracket is illustrated as well as the factor of safety.

Fig 9 Material cost of the supporting bracket and the safety factor

In Fig 9, it is obvious the relation between cost of materials and factor of safety changes significantly.
Conclusion

A supporting bracket was designed by using CAD/CAM software. NX8.5 was used for modeling and simulation. Four selected materials were used in the design. The aim of using different materials is to find out the required quantity of each material of the design and to discover the generated stress on the supporting bracket. By knowing the maximum stress, the safety factor for each material can be specified. A comparison was made between the material cost of the supporting bracket and the determined safety factor in order to find the cheaper material with a good safety factor. Furthermore, the maximum deformation by using different material was determined. Prices of the materials were taken from Focus Economic magazine. The figures showed no significant difference of the maximum deformation of the four materials. The maximum deformation was located of the Aluminum2014 material and was acceptable at the elastic range. Mass of the supporting bracket has a significant importance because it is related to its cost. The heaviest mass was for the copper-C10100 material while the lightest one was for Aluminium2014. There was no big difference of mass between cast iron G60 and the alloy steel AISI4340. The safety factor value was the highest for Steel AISI4340 and the lowest value was for the copper material. Therefore, Copper-C10100 was not good for the design because it was the most expensive with the lowest factor of safety. The material cost of the Aluminum 2014 was slightly higher than Cast Iron G60, however, the safety factor value of the Aluminum 2014 was slightly lower than Cast Iron G60. The best material is one which serves the desired objective at the minimum cost was the alloy steel AISI4340 with the highest safety factor.
References


