Design and Analysis of AC14 Ship Anchor

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Abstract. A Ship’s anchor makes a ship to be at a fixed location against currents and winds when ship is in rest position. Purpose of anchor is to restrict the drifting of ship, which is occurs due to the currents. Even though there are many different types of anchor, present paper intended to do design and analysis on stockless anchor AC14 type. Project aims to determine the equivalent von-mises stress and maximum deformation in anchor when subjected to proof test. Proof test load is decided based on the mass of the anchor. (Reference is taken for the relationship of proof test load and mass of the anchor. Solid modeling of Stockless ship anchor model is carried out on NX 11.0 and modal analysis of ship anchor is carried out using ANSYS 16.0)

Keywords: Ship Anchor, Stockless Anchor, AC14 Anchor, proof test load, von-mises stresses

1. Introduction
Ship anchor’s purpose is to secure the vessel to the bed of a water body to prevent the craft from drifting due to water currents and heavy winds. Anchors can either be temporary or permanent. The current paper is targeted to do the design and analysis for stockless AC14 ship Anchor. Project aimed to determine the equivalent von-mises stress and maximum deformation in anchor when subjected to proof test. The corresponding proof test load is chosen based on the mass of the anchor. Mass of the anchor is considered as 2800kgs and corresponding proof test load is selected is 450kN as per the standards. This paper intended to determine the induced von-mises stresses and maximum deformations in the anchor, by conducting both Transient and modal analysis on the designed AC14 ship anchor. If the induced stresses are within limits then the design of ship anchor is considered to be Safe. To conduct this analysis, 3D model is ship anchor is to be prepared. So for solid modeling is NX 11.0 platform is used and for transient and modal analysis ANSYS 16.0 is used. By the resultant maximum von-mises stresses and maximum deformations in the AC14 ship anchor, safe proof test loading is identified.

2. Materials and methods
Grey cast iron is most widely used material for making ship anchors because it is tough and resist shock loading. The following material properties are used with the ANSYS software.
Table 1. Material Properties of grey cast iron.

| Property                        | Value                  |
|---------------------------------|------------------------|
| Density                         | 7200 kg m$^{-3}$       |
| Coefficient of Thermal Expansion| 1.1e-005 C$^{-1}$      |
| Specific Heat                   | 447 J kg$^{-1}$ C$^{-1}$|
| Thermal Conductivity            | 52 W m$^{-1}$ C$^{-1}$ |
| Resistivity                     | 9.6e-008-ohm m         |
| Young's Modulus MPa             | 86874                  |
| Poisson's Ratio                 | 0.26                   |
| Tensile Ultimate Strength       | 2.4e+008               |
| Compressive Ultimate Strength   | 8.2e+008               |
| Bulk Modulus MPa                | 60329                  |
| Shear Modulus MPa               | 34474                  |

2.1. Design of ship anchor

A model of anchor parts is designed in Siemens NX 11.0 software. The dimensions of the shank and design are mentioned in Fig 1. The dimensions of the main anchor or base and design are mentioned in Fig. 2. After modeling the individual parts, the parts are assembled in the assembly drop down as shown in Fig 3.

Fig 1. Shank of an Anchor  
Fig 2. Main anchor or base

Fig 3. Front view and isometric view of ship anchor

2.2. Analysis on ship anchor

Here, the anchor is subjected to proof test loads. The analysis is performed to find maximum deformation and von-misses stresses for grey cast iron material. Anchor analysis is performed in ANSYS WORKBENCH 16.0. For the ship anchor analysis, different types of proof test loads are applied according to weight of the ship anchor. The material properties of Grey Cast Iron are represented in Table 1.

In this analysis, mass of the anchor considered is 2800kg. So the corresponding proof test load applied is 450 kN as per the standards. When the proof test load applied, there will be certain deformations
and von-Mises stresses are developed in the anchor. If the induced stresses and deformations are within the limits, the design will be safe. During the analysis, the base is provided with fixed boundary condition as shown in the Fig 5 and the proof test load is applied periodically as shown in the Fig 6 to determine the deformation and stresses. The maximum load of magnitude 450 kN is applied in 5 sec.

![Fig 4 Meshed body of ship anchor](image)

![Fig 5: Fixed support](image)

![Fig 6: Force on anchor](image)

3. Results and discussions

By performing transient analysis on the anchor for grey cast iron, the maximum stress induced is 48.285 MPa for an applied load of 450 kN is shown in Fig 7. The total deformation of the ship anchor is observed to be 0.24523 mm near the tip of the shank and minimum value is 0 m near the bottom of crown as shown in Fig 8.

![Fig 7 Equivalent stresses induced over the ship anchor](image)

![Fig 8 Total deformation observed in the ship anchor](image)

| S.No | Time (sec) | Force (kN) | Total Deformation (m) | Von-Mises Stresses (Pa) |
|------|------------|------------|-----------------------|------------------------|
| 1.   | 1          | 90         | 4.9397e-005           | 9.6603e+006            |
| 2.   | 2          | 180        | 9.8624e-005           | 1.9331e+007            |
| 3.   | 3          | 270        | 1.4766e-004           | 2.8983e+007            |
| 4.   | 4          | 360        | 1.9654e-004           | 3.8635e+007            |
| 5.   | 5          | 450        | 2.4523e-004           | 4.8285e+007            |
With the periodical increment of load on the anchor, the corresponding deformations and von mises stresses induced in the anchor are shown in the table 2 and are represented graphically in the Fig 9 and 10 respectively.

Fig 9. Time vs Deformation  
Fig 10. Time vs von-Mises stresses

4. Modal analysis of anchor
Modal analysis is the process of determining the inherent dynamic characteristics of a system in forms of natural frequencies, damping factors and mode shapes, and using them to formulate a mathematical model for its dynamic behavior. In this analysis, a total of 48 modes with are calculated for the anchor. The obtained natural frequencies at the corresponding nodes are shown in Fig 11.

By performing the modal analysis for the anchor, the maximum and minimum deformations induced in the material at different natural frequencies are obtained and tabulated below.

| Frequency (Hz) | 183.46  | 322.89  | 467.77  | 548.42  | 656.36  | 790.36  | 896.64  |
|---------------|---------|---------|---------|---------|---------|---------|---------|
| Minimum Deformation (mm) | 4.4151e-009 | 3.0806e-008 | 9.7283e-009 | 8.7377e-010 | 1.2568e-011 | 2.7373e-014 | 2.4221e-017 |
| Maximum Deformation (mm) | 118.68  | 95.175  | 101.88  | 73.852  | 103.46  | 128.66  | 176.03  |
It is observed that, the maximum total deformation of 176.03 mm is induced in the anchor at the natural frequency of 896.64 Hz and the mode shape is shown in the Fig 13.

5. Conclusion

Three Dimensional models of Shank and Anchor were created in NX 11.0 separately and then assembled in the same software. Transient analysis & modal analysis carried out on the assemble part using ANSYS WORKBENCH 16.0. From Transient Analysis on ship anchor, it was found that the maximum deformation obtained due to proof test load on ship anchor is 0.00024523 m and the maximum Equivalent (von-Mises) stress is $4.8285 \times 10^7$ Pa. By conducting the Modal Analysis on the anchor results the maximum deformation due to Natural Frequency of 896.64 Hz created as 176.03 mm. If the anchor does not exceed the above-mentioned values the anchor need not to be replaced and if the values are exceeded when subjected to proof loads they need to be replaced.

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