



Heavy Lifting Winch Deck Interface Assembly Analysis

Control Number: 3350-00009

Version: 1-00

Date: 2011-09-09

Author: Kaitlyn McCartney

Coastal and Global Scale Nodes
Ocean Observatories Initiative
Woods Hole Oceanographic Institution
Oregon State University
Scripps Institution of Oceanography



Revision History

Version	Description	Originator	ECR No.	Release Date
1-00	Initial Release	K. McCartney	1303-00465	9/9/2011

Table of Contents

List of Figures	ii
1.0 Introduction	1
1.1. Scope	1
1.2. Purpose	1
2.0 Reference Documents	1
3.0 Definitions & Acronyms	1
4.0 Lantec Heavy Lifting Winch for At Sea Test 2	1
4.1. Overview	1
4.2. Assumptions.....	2
4.3. Calculations.....	2
4.4. Discussion.....	6

List of Figures

Figure 4-1 <i>Three-dimensional rendition of the winch-deck interface assembly</i>	2
--	---

1.0 Introduction

1.1. Scope

This document describes and analyzes the mechanical interface between the Lantec heavy lifting winch and the R/V *Oceanus* 475. It will be an integral part of the Woods Hole Oceanographic Institution's At Sea Test 2.

1.2. Purpose

This document details the calculated analysis of the capabilities and specifications of the custom deck-plates designed to secure the Lantec heavy lifting winch to the deck of the R/V *Oceanus* 475. The winch will be used during deployment of the Coastal and Global Scale Nodes (CGSN) involved in the OOI's At Sea Test 2 (AST2), conducted by the Woods Hole Oceanographic Institution (WHOI). The Version 1-00 of this document was submitted for design approval September 9, 2011 prior to the departure of the AST2 cruise.

2.0 Reference Documents

Table 2-1 Reference Documents

Document Identification	Document Title
3207-00014	R/V <i>Oceanus</i> 475 Cruise Plan

3.0 Definitions & Acronyms

AST2 – At Sea Test 2

BARF – Benthic Anchor Recovery Frame

MFN – Multi-Function Nodes

CGSN – Coastal and Global Scale Nodes

WHOI – Woods Hole Oceanographic Institution

4.0 Lantec Heavy Lifting Winch for At Sea Test 2

4.1. Overview

The Lantec heavy lifting winch, hereafter referred to as “the winch”, will be used during AST2 for the deployment of the Multi-Function Nodes (MFNs), as well as the recovery of the Benthic Anchor Recovery Frame (BARF) should it be necessary. The total air weight of the MFN assembly is 10,000 pounds, and the anchor recovery air weight is 7,000 pounds. The winch will be fastened to the 01 deck of the R/V *Oceanus* 475, where the line pull will be primarily horizontal. Should recovery of the BARF become necessary, however, the line may be raised through the block on the vessel's A-frame, resulting in an approximate 30° upward angle.

The winch will be secured to the 01 deck of the R/V *Oceanus* 475 via a custom-built welded steel deck assembly. The deck of the *Oceanus* specifies a maximum loading of 1,700 pounds per bolt in vertical force and 5,000 pounds per bolt in shear. The winch will be equipped with 5/8" Amsteel Blue spectra line, which has a tabulated Samson breaking strength of 47,000 pounds at a minimum and average breaking strength of 52,800 pounds. The primary objective of the assembly is to ensure that the weak link in the system is the deployment line, not the connection between the winch and the deck. This will require that the steel assembly created as the deck-winch interface is stronger than the breaking strength of the line used, specifically 52,800 pounds.

Figure 1 is a 3D model of the welded deck plate assembly, viewed from the starboard of the high tension end of the winch. This configuration utilizes two welded plate-tube assemblies that interface with the deck, two welded tube-angle assemblies that interface with the winch,

and a single angle that spans the separate plates. The two tube-angle weldments will be bolted to the plate-tube weldments via the angle brackets and hole cutouts through the tubing on the plates. The winch will be bolted to the rectangular tubes spanning the center, and the single long angle piece will tie the assembly together.

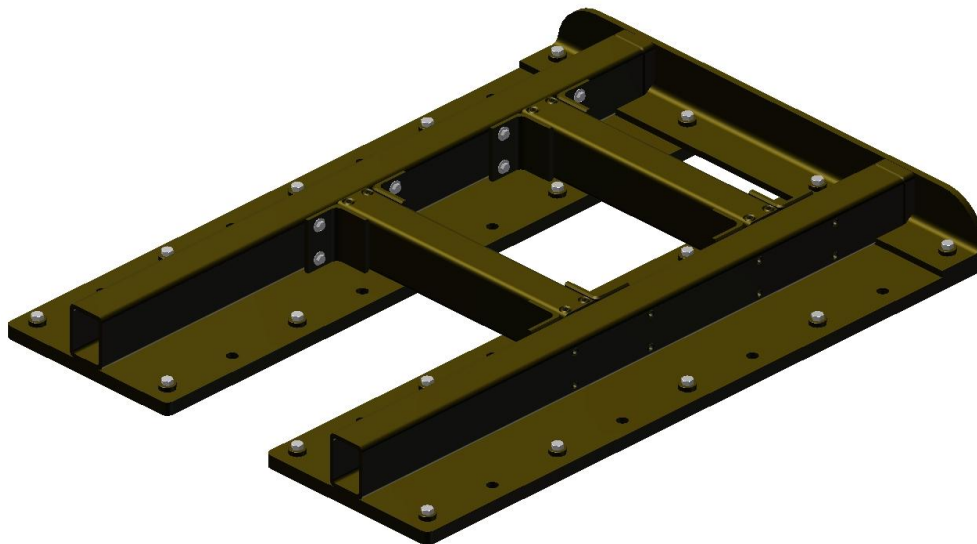


Figure 4-1 Three-dimensional rendition of the winch-deck interface assembly

4.2. Assumptions

Several assumptions were made in order to numerically evaluate the mechanical interface between the winch and the deck. A safety factor of 1.5 was included in the deck bolt loading parameters, and also in the load cases for maximum bending stress on the assembly.

The two welded plates were treated as solid members and area moment of inertias were calculated for the plate and rectangular tube as one body. Additionally, it was assumed that all bolts would be acting equally to resist the forces applied by the winch during deployment and recovery. This is an inaccurately generalized assumption, however efforts were made to increase the ability of the assembly to properly transfer loads from an overloaded member to the surrounding supports.

4.3. Calculations

Moment and Stress Calculations for the Lantec Winch-Oceanus Deck Interface

General Parameters

$$\text{Weight} := 5480\text{lb}$$

$$\text{SF} := 1.5 \quad \text{Safety Factor of 1.5 required}$$

Winch weighs 5,480 lbs

$$\text{Load}_1 := 1700\text{lb}$$

$$\text{Load}_2 := 5000\text{lb}$$

Maximum loading of 1,700 lbs per bolt in vertical, 5,000 lbs per bolt in shear

$$\text{Force}_1 := 52800\text{lb}$$

$$\text{Force}_2 := \text{Force}_1 \cdot \text{SF}$$

$$\text{Force}_2 = 7.92 \times 10^4 \text{lb}$$

Force₁ is breaking strength of line. Safety factor of 1.5 (Force₂) used in calculations

$$\text{Mass}_1 := 2172.83\text{b} \quad \text{Inertia}_1 := 429\text{in}^4$$

Mass of single deck plate with rectangular tube attached
Moment taken about front edge of winch (43.25" from front edge of deck plate)

$$\sigma_1 := 53.89\text{in}^3$$

Section modulus for single plate

Pertinent Physical Properties of a Complete Deck Assembly

$$\text{Mass}_2 := 5141.15\text{t} \quad \text{CG}_1 := 56.314\text{n} \quad \text{Length}_1 := 103\text{in}$$

Mass of entire deck assembly
Center of gravity with respect to front edge of deck assembly

Shear Stress Calculations

Use Force₁ because maximum loading force of bolts includes safety factor = 1.5

$$\text{Bolts} := \frac{\text{Force}_1}{\text{Load}_2} \quad \text{Bolts} = 10.56$$

The assembly will require a minimum of 11 bolts to compensate for a maximum shear loading case

Bending Stress Calculations

Bending Stress at Front of Winch

$$\text{Arm}_1 := 7.75\text{n}$$

Bending moment arm to location of center of plate - to subtract weight of plate

$$\text{Arm}_2 := 43.25\text{r}$$

Bending moment arm to front of deck plate - location of pivot point

$$\text{Arm}_3 := 21.25\text{r}$$

Bending moment arm to center of winch - to subtract winch weight

$$\text{Arm}_4 := 7.75\text{n} + 31.75\text{n} + 55.75\text{r}$$

Bending moment arms to deck tiedowns

$$\text{NAxis}_1 := 7.96\text{n} \quad \text{Distance to extreme fiber (neutral axis)}$$

$$\text{Bending}_1 := \frac{\left(\text{Force}_2 \cdot \text{Arm}_2 - \frac{\text{Weight}}{2} \cdot \text{Arm}_3 - \text{Mass}_1 \cdot \text{Arm}_1 - \text{Load}_1 \cdot 2 \cdot \text{Arm}_4 \right) \cdot \text{NAxis}_1}{\text{Inertia}_1}$$

$$\text{Bending}_1 = 5.616 \times 10^4 \frac{\text{lb}}{\text{in}^2}$$

Bending Stress at the front of the winch is ~56,000 lbs per in² - this value is divided between the two deck plates = 28,000 lbs/in² per plate, which is less than 32,000 lb/in² (the yield strength for plates of A36 hot-rolled steel less than 8 inches thick)

Lifting Moment Calculations

Use Force₁ because maximum loading force of bolts includes safety factor = 1.5

Lifting Moment due to Horizontal Pull

$$\text{Height}_1 := 38.25\text{n} + 10\text{n} \quad \text{Height}_1 = 48.25\text{n}$$

Height of the line pull off winch = height of winch + height of base assembly

$$\text{Arm}_5 := \text{Arm}_2 + \text{Arm}_3$$

Moment arm to center of winch from front of deck assembly

$$\text{Arm}_6 := 83.25\text{n} \quad \text{Arm}_5 = 64.5\text{n}$$

Moment arm to back of winch from front of deck assembly

$$\text{Bolts}_1 := \frac{(\text{Force}_1 \cdot \text{Height}_1 - \text{Weight} \cdot \text{Arm}_5 - \text{Mass}_2 \cdot \text{CG}_1)}{\text{Length}_1 \cdot \text{Load}_1} \quad \text{Bolts}_1 = 10.877$$

Moments due to horizontal loading require 11 bolts to fasten assembly to deck

Lifting Moment due to 30 Degree Upward Pull

$$\text{Height}_2 := 74.036\text{n}$$

Height of the line-pull off winch given a 30 degree angle upward

$$\text{Bolts}_2 := \frac{(\text{Force}_1 \cdot \text{Height}_2 - \text{Weight} \cdot \text{Arm}_5 - \text{Mass}_2 \cdot \text{CG}_1)}{\text{Length}_1 \cdot \text{Load}_1} \quad \text{Bolts}_2 = 18.653$$

Moments due to 30 degree vertical loading require 19 bolts to fasten assembly to deck

Bolt Strength and Thread Engagement Calculations

$$\text{Pitch}_1 := 0.9188\text{n} \quad \text{Pitch}_2 := 0.6850\text{n} \quad \text{Diam}_1 := 1\text{in} \quad \text{Diam}_2 := \frac{3}{4}\text{in}$$

Basic pitch diameter and maximum diameter for 1"-8 and 3/4"-10 thread bolts

$$\text{Yield}_1 := 32000 \frac{\text{lb}}{\text{in}^2} \quad \text{Tensile}_1 := 58000 \frac{\text{lb}}{\text{in}^2}$$

Yield and tensile strengths for A36 hot-rolled steel

$$\text{Yield}_2 := 130000 \frac{\text{lb}}{\text{in}^2} \quad \text{Tensile}_2 := 150000 \frac{\text{lb}}{\text{in}^2} \quad \text{Proof} := 120000 \frac{\text{lb}}{\text{in}^2}$$

Yield and tensile strengths for Grade 8 bolts

$$\text{Bolts}_4 := 4$$

Four bolts acting to withstand shear as well as tensile forces on assembly due to uplift

Shear Strength for 3/4"-10 bolts in angle flanges

$$\text{Shear}_2 := \frac{\text{Force}_1}{\left[\frac{\pi \cdot (\text{Diam}_2)^2}{4} \right]} = 1.195 \times 10^5 \frac{\text{lb}}{\text{in}^2}$$

119,500 lbs/in² is less than 130,000 lbs/in² (the yield strength for grade 8 bolts)

$$\text{Force}_4 := 0.577\pi \cdot (\text{Diam}_2)^2 \cdot \frac{\text{Proof}}{1.5} = 8.157 \times 10^4 \text{lb}$$

Maximum allowable force for active bolts is greater than maximum load condition

Tensile Strength for 1"-8 bolts holding down winch

$$\text{Length}_1 := 4\text{in}$$

$$\text{Thread}_1 := 2 \cdot \text{Diam}_1 + \frac{1}{4}\text{in} = 2.25\text{in} \quad \textit{Threaded portion of the bolt}$$

$$\text{NoThread}_1 := \text{Length}_1 - \text{Thread}_1 = 1.75\text{in}$$

$$\text{Grip}_1 := 1.25\text{n} \quad \text{Thread}_2 := \text{Grip}_1 - \text{NoThread}_1 = -0.5\text{in}$$

$$\text{Area}_1 := 0.606\text{n}^2 \quad \textit{Tensile Area of a 1"-8 bolt}$$

$$\text{Area}_2 := \pi \cdot \frac{(\text{Diam}_1)^2}{4} = 0.785\text{n}^2 \quad \textit{Major diameter area of a 1"-8 bolt}$$

$$E_1 := 30000000 \frac{\text{lb}}{\text{in}^2} \quad \text{Young's Modulus for Grade 8 bolt} \quad E_2 := 29000000 \frac{\text{lb}}{\text{in}^2} \quad \text{Young's Modulus for A36 Hot-Rolled Steel}$$

$$\text{Stiff}_1 := \frac{\text{Area}_2 \cdot \text{Area}_1 \cdot E_1}{\text{Area}_2 \cdot \text{Thread}_2 + \text{Area}_1 \cdot \text{NoThread}_1} = 2.138 \times 10^7 \frac{\text{lb}}{\text{in}} \quad \text{Effective bolt stiffness}$$

$$\text{Stiff}_2 := \frac{0.5774 \cdot E_2 \cdot \text{Diam}_1}{2 \cdot \ln \left[5 \cdot \frac{(0.5774 \text{Grip}_1 + 0.5 \text{Diam}_1)}{0.5774 \text{Grip}_1 + 2.5 \text{Diam}_1} \right]} = 4.111 \times 10^7 \frac{\text{lb}}{\text{in}} \quad \text{Member Spring Rate}$$

$$\text{Stiff_Const} := \frac{\text{Stiff}_1}{\text{Stiff}_1 + \text{Stiff}_2} = 0.342 \quad \text{Stiffness Constant for Bolt & Steel Plate Assembly}$$

$$\text{Preload} := 0.75 \text{Area}_1 \cdot \text{Proof} = 5.454 \times 10^4 \text{ lb} \quad \text{Recommended preload of } \sim 55,000 \text{ lbs}$$

$$\text{Bolts}_5 := \frac{\text{Stiff_Const} \cdot \text{SF} \cdot \text{Force}_2}{\text{Proof} \cdot \text{Area}_1 - \text{Preload}} = 2.236 \quad \text{Three bolts per side are required to hold down the winch - designed assembly utilizes four bolts per side}$$

4.4. Discussion

Under the assumptions previously mentioned, the winch and base are designed to withstand the given loads, including a 1 ½ times safety factor. In all cases, more than the required bolts and strengths have been used, as shown through the preceding calculations. Under the maximum loading condition, where tension is at 30° above horizontal and causes the largest vertical lifting force, the forces do not exceed the loading potential of the design and will not cause significant deflection in the beam-plate weldment. The calculated maximum bending moment caused by this lifting force requires at least 19 bolting points and the proposed design uses 20 deck tie-downs. Under all other considered loading conditions, fewer than 20 bolts would be required. Utilizing Grade 8 bolts to fasten the angled sections of the beams to the stiffening members on the plates, as well as to bolt the winch to the base itself ensures that in both shear and tension, the winch will remain in position.