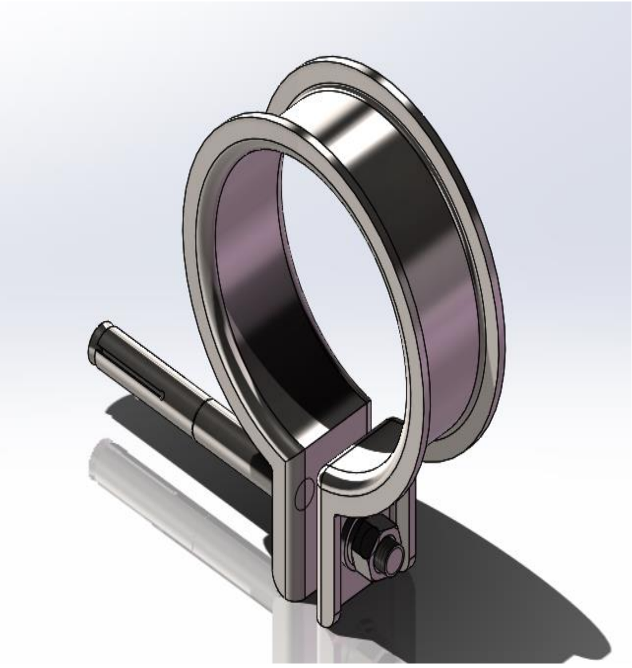
Centre for Engineering and Industrial Design
Engineering Development Project
MG7201B-1802

# Design pipe bracket for vessel with using Titanium metal in marine environment

Assessment 4: Project Report

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# Project Details

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# Abstract

The research investigates the design and utilization of the pipe bracket with titanium metal for the ocean going vessel to confront marine environment. The main aim of this report is to study the performance of titanium metal compared with other materials when they are being used in marine environment .Another aim of this report is to design pipe bracket for the ocean going vessel, then did the simulation and calculation of the loads which applied on the pipe bracket. The studying of my aims were targeted during all the phases of this project.

This report has gone through several stages so that be achieved. The first phase was referring the gathering information about the primary mechanical properties of titanium metal as light weight, flexible and strong resistance to corrosion. The different corrosion properties of pipe material and how they interact together with titanium metal or sea water. The second phase was concerning three different pipe types (rigid support, adjustable support, elastic support) and choose the type of adjustable due to it makes easily assemble due to nuts and bolts could be rearranged for adjusting the support when using on the vessel. Mention the Standard pipe size for using in different place and having a design drawing of my pipe bracket. The next phase was doing mechanical analysis of my bracket model on the Solidworks program and maximum loads which were applied on the bracket were calculated by using related formulas. The last phase was considering the manufacturing process for the pipe bracket and having the primary cost for making and selling it.

# Introduction

This project is to be offered to the Earthrace Conservation which is a public profit organization. There recently activity will make them to build an Earthrace-2 to achieve the global marine conservation. Earthrace conservation is considering that using Titanium metal to build brackets due to its mechanical performance so that improving the good looking and performance for the new Earthrace 2.  Titanium has been widely used in the aircraft and chemical industries due to good elevated temperature, however the marine industry has utilized titanium slowly. The main reasons for choosing Titanium metal is due to vast of the mechanical properties of superior strength to conventional metals, excellent corrosion resistance in aggressive marine environments and good elevated temperature. The Titanium metal pipe bracket could also oppose strong impacts and high temperature when the pipes are burn and roll. The corrosion properties of different pipe materials and how they interact together with sea water are related to the chosen of pipe materials. There are three common places used the bracket on the vessel (Galley, Engine room and Bunk house). Furthermore, the standard pipe sizes for different place need to be found in order to further design my pipe bracket.

The casting process of titanium is a great challenge due to the titanium reacts violently with oxygen, when it is heated.

The limitations of this report are not consider the variation in performance of titanium metal and other used metals before and after use in the marine environment and time factor impacts doing the real prototype and test it.

# Project Background

The Earthrace Conservation are going to construct the new ocean going vessel which is called Earthrace 2 that is the new version of the Earthrace 1 that was fabricated in 2006 (Alqahtani, 2017).The goal of building this new ocean going vessel is to amplify the job of Earthrace Conservation on marine conservation. There are some works need to be accomplished by ER- 2. For example preserving the life of ocean environment, cracking down on illegal fishing and shooting a marine protection documentary. It is planned to carry 14 staffs and 14 passengers. The length of vessel is 59.3m and the length of beam is 12 m (Conservation, n.d.).At the moment, Earthrace conservation is suggesting that using Titanium metal to build a number of components could improve the good looking and performance for the Earthrace vessel. The causes supported this development are quality improvement, good looking and good performance. They are related to the improvement of the durability of the component due to the life cycle of the vessel component is extended. Moreover, they signify advance corrosion resistance. It can reduce the repair and maintenance charges. Therefore, using Titanium metal looks like good material to produce components that can conduce to protect environment and develop sustainability.

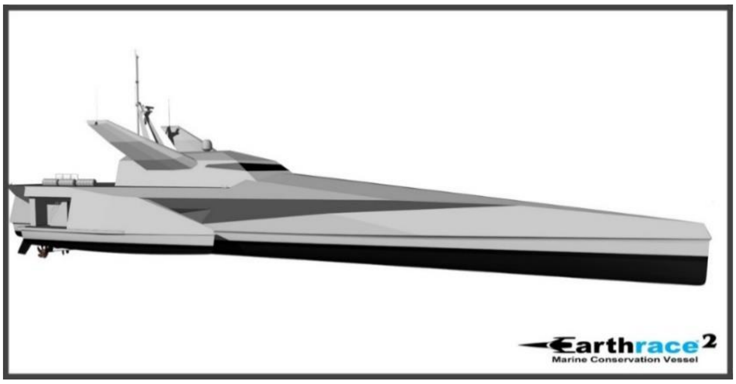


Figure 1: Earthrace2

## Case study

The idea of using titanium metal in the marine environment is not new conceive. The first all-titanium fishing boat was launched in Japan in1998.The weight of it is 4.6 tonnes and 12.5 meters long.The vessel can advance about 30 knots with improved fuel efficiency.Working cost can be saved due to no necessary for body painting and less demanding expulsion of biofouling (David Doran,Bob Cather, 2014). There were lots of people interested in developing titanium metal, so there was a seminar which has been supported by the office of Naval Research and facilitated by the University of New Orleans, where an ONR research program on titanium metal structure the ship.The Representatives of the shipbuilding industry, titanium suppliers, Navy, Coast Guard and Air Force labs, and academia discussed and examined materials, processes and applications. Nowadays, most of vessels are constructed from steel.Elective materials incorporate aluminum and composites.But the researcher thought titanium although more expensive than other materials, has many positive speciality that conduce to cheaper total ownership costs the whole life of the ocean going vessel.( Edward Lundquist, 2012).


Figure 2: All titanium boat

## Properties of Titanium

Titanium has been used as an excellent material for marine hardware because it has specifics of light weight, flexible and strong resistance to corrosion. Research have shown the pitting, crevice deterioration, and loss of strength are close to immeasurable even after titanium has been uncovered over a mile underneath the sea surface for long times .Titanium is a good solution for marine applications when engineer is seeking low repair charges and low fuel consumption, to approval with the outstanding metallurgical properties related to the metal.

Comparing with the steel, titanium has more strength for its weight.Ti (Marine Grade Metals, 2017) provides a 40% weight saving contrasted with steel —lightweight design can achieve that offer more payload limit. It could decrease fuel consumption and carbon emissions. Titanium metal is in fact corrosion- free in seawater. Atmospheric passivation makes titanium have excellent resistance to corrosion.The titanium metal is highly reactive at high temperature and need to shield of the molten metal when welding and cooling (Edward Lundquist, 2012).The density of titanium is 4.5x $10^3$ $kg/m^3$, the Young's modulus of titanium is 116 x $10^9$ pa and the Yield strength of titanium is 500 x $10^6$ $N/m^2$. The coefficient of thermal expansion is 8.9 x $10^{-6}$ $k^{-1}$ which means it has good temperature resistance.

Figure 12: titanium metal in nature

## Corrosion resistance of different material

Concrete and plastic are ideal and acceptable pipe materials in some applications. The non-steel piping material systems are usually use for the storm, water and air. However, this could not use for the mostly pressured piping systems on the vessel in marine environment. Steel or other metal materials pipe are necessary.It is very important to consider the corrosion properties and how they interact together with sea water due to metal materials pipes are using on the vessel in marine environment.In addition, to learn about what kind of metals are using in marine environment at the moment.

## Copper

All grades of copper have good resistance to atmospheric corrosion, thus they widely used for contacting with water. Copper metals react fast to surrounding and immediately form a film of surface oxidation. This patina only impacts the surface of the Copper metal and not break the interior of the metal. Consequently, the metal itself does not worsen. The surface oxidation is generally not dissolved in water and it sticks to the surface so that preventing exposure to further corrosion.

The corrosion resistance of copper and copper-base alloys depends on the performance of the protective corrosion product film in seawater. When Copper metal interacts with seawater, produce the film is known as cuprous oxide ($Cu_2O$) and sometimes present cuprous hydroxyl chloride [Cu2 (OH) 3CI] and cupric oxide (CuO) There are several copper-nickel alloys suitable for marine applications. Such as C70600 which contains nickel and manganese to help resist corrosion. C71500 is able to resist marine conditions as well. Its composition is as similar as alloy C70600 except that it has even more nickel in its chemical composition. (Marine Grade Metals, 2017)

**Applications**: water pipes, marine fittings, fasteners

## Steel

Steel is the most commonly used metals in engineering field. They are chosen not for their corrosion resistance but for its cost， ease of fabrication and strength. All steels and low-alloy steels rust in humid condition.we normally add 0.3% copper to carbon steel can cut down the rate of rusting by one quarter or by one half.

The main source of corrosion of steel is the process of dissolving oxygen when interact in seawater. Therefore, when steel corrodes, it generally produces large quantities of iron oxides corrosion of steel iron hydroxides and iron oxy-hydroxides as corrosion products lead to overall weight loss.

Most carbon steel is not suited for marine environment. But, there is several carbon steels can be used in marine environment. Such as AH36, DH36, and EH36 are generally used marine grade carbon steels that are approved by the American Bureau of Shipping. These steels have more alloying elements like manganese and chromium compared to their ASTM grade counterparts in order to achieve higher strength and more corrosion resistance.（Marine grade metal，2017）

## Stainless Steel

A thin surface film is formed in the presence of oxygen to resist corrosion so that protecting stainless steel. So stainless steels will have poor corrosion resistance in low oxygen condition like seawater. The chlorides from the salt will break the surface film faster than reform surface film in low oxygen area.

Corrosion resistance of stainless steel replies on the formation of chromium oxide film on the metal surface which has highly resistant to corrosion. Grades 304 and 316 contain 18% of chromium .Particularly， there is 2% molybdenum added in grade 316 to improve the corrosion resistance. Grade 304 is often appropriate for fittings which are cleaned with fresh water. Grade 316 is appropriate for the construction of deck fittings and critical rigging components. (Marine Grade Metals, 2017)

**Applications:** marine fittings

## Aluminium

A thin oxidation film will be formed quickly when aluminum surface is exposed to the atmosphere.  Oxidation film protects the metal from further corrosion. Aluminum has high resistance to corrosion due to self-protecting characteristic. Expect exposed to the condition that destroys this protective oxide coating, the metal can be fully protected by oxidation film against corrosion.

However, salt has strongly corrosive substance. When salt water contacts with aluminum, they can cause white coating of aluminum oxide， the chalky and unpleasant pitting.

The 5XXX and 6XXX grades aluminum are used as Marine grade aluminum. Grade 5052 is an excellent marine grade for marine applications .In addition, 6061-T6 is an all-around popular grade of aluminum used in marine application. They all have very good corrosion resistance and are precipitation hardened. These grades of Aluminum have additional chromium and manganese in order to help protect them from corrosive marine environment. （Marine grade metal,2017）

**Applications**: structural shipbuilding

## Brass

The most common brass which contains 70% copper and 30% zinc. The brass is easily suffered corrosion due to the zinc element of brass is easily lost when it contacts with seawater. It only leaves copper shell remaining after the zinc corrodes. If you want to improve the Corrosion resistance of Brass, it need to decrease zinc content. It is suggested that use those alloys containing less than 15% zinc.

Marine brass is normally used the Alloys C46200 and C46400 which contain zinc and tin .It can allow the brass alloy to resist corrosion in wet condition or underwater applications. Alloys C48200 and C48500 are similar to above brass alloy except that they have more lead element in their composition. (Marine Grade Metals, 2017)

**Applications**: pipes

## Titanium

The corrosion resistance is a very important factor of metal, because the corrosion has threat which harm the metal if it is being utilized in the marine environment. The corrosion resistance is a key element to protect the metal for the corrosion. For the project, we use the titanium metal in the marine environment, so it is very important to know the corrosion resistance of titanium metal. The titanium alloys has specificity on excellent corrosion resistance due to the metal surface forms steady, consistent, highly adherent, and defensive oxide films. Because of titanium metal is profoundly reactive and has a greatly high affinity for oxygen. When the metal are exposure to air or humid environment, the useful surface oxide film will be formed immediately.

Figure 4: The surface changed due to corrosion

## Galvanic Compatibility:

All different materials have the abilities to react with each other when they react within catalyst. The reaction is normally quite mild, but if the wrong materials are used together and exposed to an electrolyte like water, the effects can get serious. One of the metals have a faster than normal rate to corrode. Conversely, the other one have more slowly rate to corrode.

In an electrical couple, the cathode (-) represents the metal that has higher electrical potential and anode (+) means metal has the lower electrical potential. Current flows from the cathode to the anode, then anode through the electrolyte and return to the cathode. It will occur corrosion when the current leaves the anode to pass the electrolyte. In other word, while different metals contact, the anode corrodes and the cathode survives. (ASM, n.d.)

Table 4: Galvanic Series of Metals & Alloys

| | | | |
|---|---|---|---|
| Brass | Aluminum | 304 Stainless | Titanium |
| Copper | Steel | 316 Stainless | |

Table 1 shows that those within the same vertical group are reasonably compatible when used together; those from different groups cause a corrosion problem.

Table 5: Activeness of Materials

| |
|---|
| (Anodic)Most likely to corrode material |
| Aluminum |
| Steel |

| |
|---|
| Copper-nickel 715 |
| Brass |
| Stainless steel 304,316 |
| Titanium |

From the table 1, we can know if the steel material and aluminum material react together, it will not have ccorrosion occurrencebut. But, if titanium and aluminum contact, the activeness of aluminum is higher than Titanium, aluminum will be the anode, and will corrode.

**Precaution:**

1. It is better to use the metals which are as close together as possible in the table 2 above. Doing this will help to mitigate galvanic corrosion.

2. The area of the more active metal should be smaller than the area of the Titanium.

3. Add some insultions materials between the Titanium and other material.

Table 6: Costing of different materials

| Material | Titanium | Carbon Steel | Aluminum | Brass | Stainless Steel | Copper |
|---|---|---|---|---|---|---|
| Costing ($/kg) | 25 | 1 | 3.5 | 8 | 2 | 8 |

From the table1, when comparing with other materials, titanium is the most expensive metal which be used .However, when designing you can use less weight of titanium because its density is less than other materials, you can also use smaller sections thickness in design due to Yield stress. The corrosion resistance is greater should mean longer life.

# Design Background

The pipe bracket is a designed idea that exchange load from pipe to supporting structure. The total loads incorporate the weights of the pipe, the water or gas that are carried by the pipe, all fittings of pipe and the insulation material coving on the pipe .On the whole the design of a pipe bracket is rely on the size of load and application conditions. Generally main and minor supports are the two types of pipe bracket. Main support connects directly to the pipeline; inversely the minor support connects to the structure supporting the pipe.

Figure 13: Bracket

There are three types of pipe bracket based on different construction and function. The first type is rigid support that not allow move and fix one direction. It will keep on the structure that is supporting the pipe and can not be adjusted to the erection tolerance. The second type is adjustable support that belongs to rigid type, but it can be adjusted due to nuts and bolts could be rearranged for adjusting the support. The last type is elastic support that normally use in supporting hot piping. The elastic pipe bracket could support pipe even if it is constantly moving up or down because of the pressure and flow of substances inside the pipe .This project will present design of a pipe bracket like the second type which could have adjustable support. Because it makes easily assemble due to nuts and bolts could be rearranged for adjusting the support when using on the vessel. And will design the pipe brackets for the straight pipelines result in widely used on the vessel for different place like Galley, Engine room and Bunk house.

## Standard pipe size

It needs to know the standard pipe size used in different place in order to further design for my pipe bracket. The standard sizes for normal Pipe are issued by the North American used for temperature and high or low pressures. The American Standards Association created a system that designated wall thicknesses based on smaller steps between sizes after surveyed industry. The name of nominal pipe size replaced iron pipe size and the term schedule (SCH) was invented to specify the normal wall thickness of pipe. Nowadays, we know a range of wall thicknesses, namely: SCH 5, 5S, 10, 10S, 20, 30, 40, 40S, 60, 80, 80S, 100, 120, 140, 160, STD, XS AND XXS which are arranged from small to larger (Definition and Details of Nominal Pipe Size, 2006)

Nominal pipe size (NPS) is a dimensionless designator of pipe size. For example, NPS 2 indicates pipe outside diameter 60.3 mm.

For a given NPS, the outside diameter stays constant and the wall thickness increases with schedule number increase. The inside diameter will reply upon the pipe wall thickness specified by the schedule number. (Definition and Details of Nominal Pipe Size, n.d.)

In marine field, we generally use schedule 40 for light duty and schedule 80 for heavy duty as their thicknesses. (Sanguri, 2018)

There are three common places using the bracket on vessel (Galley, Engine room and Bunk house). The pipe bracket could use for the kitchen sink drain in the galley and use for the handrail in the Bunkhouse.

There are a lot of pipelines used in Engine room and are labeled with color code for recognition. These pipelines in Engine room are widely used for below application.

- Fuel oil system
- Sea water system for cooling the fresh water (which cools the diesel engine)
- Steam supply system for heating fuel oils, accommodation
- Hot water for accommodation and cooking purposes
- Compressed air piping for starting the engines
- The costing is a very important factor to be considered in the design process. I am going to compare the costing between titanium and other materials in the same weight.

## The Standard Pipe Sizes in different place

**Using for the Handrail**

NPS 1.25, Outside Diameter 42.2mm

| | |
|---|---|
| Schedule | Sch.40 |
| Wall Thickness (mm) | 3.6 |
| Internal Diameter (mm) | 35 |

**Using for the kitchen sink drain**

NPS 1.5, Outside Diameter 48.3 mm

| | |
|---|---|
| Schedule | Sch.40 |
| Wall Thickness (mm) | 3.7 |
| Internal Diameter (mm) | 40.9 |

**Using for the Engine room**

NPS 2 , Outside Diameter 60.3 mm

| | |
|---|---|
| Schedule | Sch.80 |
| Wall Thickness (mm) | 7.6 |
| Internal Diameter (mm) | 45.1 |

# Methodology

The project divided into four main stages so that designing and building the pipe bracket with utilizing titanium metal for the ocean going vessel to confront marine environment .The first stage was learning about the project and realizing the possible risk during the project. The second stage was gathering the data and reading any relevant book about titanium metal and the application of bracket. In addition, finding any previous examples of utilizing Titanium metal to make bracket. The third stage was about design processes which are relied on the research of primary pipe bracket and the standard pipe size. After that Drew the model on the solidworks.Then, did the mechanical analyses which about stress, strain, displacement and factor of safety of my bracket and also did the basic calculation of them so that comparing results between theoretical calculation and simulation. The fourth stage was talking about the manufacturing process and the cost for making and selling.

## Issues identification

At the beginning of project, it was very important to consider that why used titanium metal nor other materials and where can be used of these bracket on the vessel. Learning about the mechanical properties of titanium metal and other materials and the type or application of pipe bracket are necessary. Main purpose of this step was to further study. Also made sure any potential risk that may arise when Titanium material reacts with other materials.

## Data collection

Investigating the issues which were presented on the first stage and further studied material strength of Titanium metal like Yield Strength (YS), Tensile stress (UTS) and Modulus of Elasticity (E) from the relevant online resource such as the Engineering Toolbox web-site and the Machinery's Handbook, This information would be used in the calculation so that getting the maximum force that can be loaded on each bracket. Learnt about the case study of titanium material's applications in the marine environment from the book called "Construction material Reference". In addition, read the relevant book about the properties of titanium metal and other materials.

## Design processes

**3.1 Using the minimum titanium material** to design it for protecting environment. It will use my knowledge from material strength and mathematics.

3.2 **Design**

Identified the types of pipe bracket and possible type used on the vessel.Researched the standard pipe size which using in the different place vessel like Galley, Engine room and Bunk house on the vessel in order to fit with my further designed bracket. Have a sketch of my initial design, then discuss the benefits and drawbacks of those designs with my supervisors to have the final design. Drawing the final design in the SolidWorks, after that ask for the supervisors what need to be developed. Finally, used the SolidWorks simulation to show the model with stress, strain and displacement when applied the required load on it.

3.3 **Mathematical process**

The total load applied on the pipe bracket may basically include the weights of the pipe, the water or gas that are carried by the pipe. The below formulas are used for calculating the pipe load which applied on the Bracket:

$$F_p = \rho_p \times L \times A \times g$$

$F_p$ is load of pipe (N)

L is length (m)

A is section area (m^2)

g is gravity (m/s^2)

$\rho_p$ is Density of pipe material (kg/m^3)

$$A = T \times (D - T) \times \pi$$

A is section area (m^2)

T is thickness (m)

D is outside diameter (m)

$\pi$ is 3.14

If carried the water, the load of water is calculated by formula

$$F_w = \rho_w \times (D - 2T) \times \pi \times L \times g$$

$F_w$ is load of Water (N)

L is length (m)

A is section area (m^2)

g is gravity (m/s^2)

$\rho_w$ is Density of water (kg/m^3)

The formula of total load applied on the bracket could be summarized like:

$$F_t = \rho(\mathrm{p}) \times \mathrm{L} \times T \times (D - T) \times \pi \times \mathrm{g} + \rho(w) \times \left(D - 2T\right) \times \pi \times L \times \mathrm{g}$$

$$= \mathrm{L} \times \pi \times \mathrm{g} \times [\rho_p \times T \times (D - T) + \rho_w \times (D - 2T)]$$

The formula of calculating the Factor of Safety is

$$\mathrm{FOS} = \frac{\gamma}{\sigma_n}$$

FOS is Factor of Safety

$\gamma$ *is yelid strength of titanium* $(N/m\char`^2)$

$\sigma_n$ *is normal stress* $(N/m\char`^2)$

The required value of factor of safety is normally issued by law, standard, specification, contract or custom, to which a structure must conform or exceed. This can be referred to as a *design factor*, *design factor of safety* or *required factor of safety*. This project the factor of safety should around 2 so that avoiding occurring the yielding.

The formulas of calculating the normal stress and strain could be

$$\sigma_n = \frac{F_t}{A}$$

$\sigma_n$ *is normall stress* $(N/m\char`^2)$

$F_t$ *is* total load includs pipe and water(N)

*A is the section area of pipe bracket* $(m^2)$

$$\varepsilon = \frac{\sigma_n}{E}$$

$\varepsilon$ *is Strain*

$\sigma_n$ *is normall stress* $(N/m\char`^2)$

*E is Young's modulus of titanium*

The values of Yield strength of titanium is 500 x $10^6$ $N/m^2$ and the Young's modulus of titanium is $116\times 10^9 N/m$^2 .Finally, comparing the results of stress, strain, factor of safety of my bracket between the theoretical calculation and simulation.

## Manufacturing the prototype and testing

Have meeting with the industry supervisors to ask for the manufacturing process .Plan the working time to go to workplace so that using titanium metal to build up the component and check their qualities. It is necessary to do a lot of testing and calculation so that increasing the efficiency，reliability and validity. If the components are not satisfying with the standards, rebuild the component until conform to standards. After complete each component, assemble the component and check qualities again. If the components are not satisfying with the standards, re-assemble the component until conform to standards.

# Design Drawing

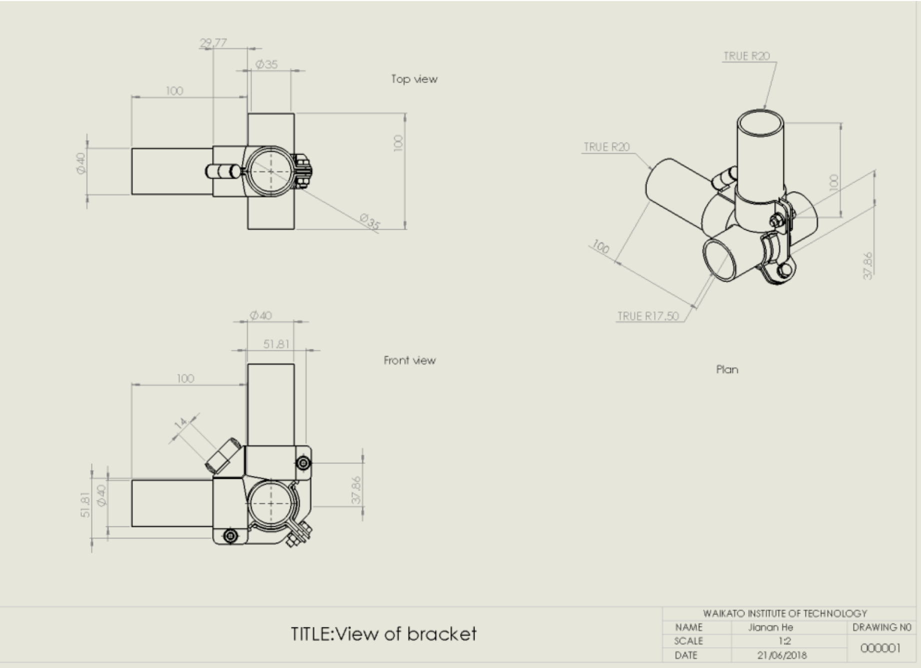


Figure 6: Template of bracket

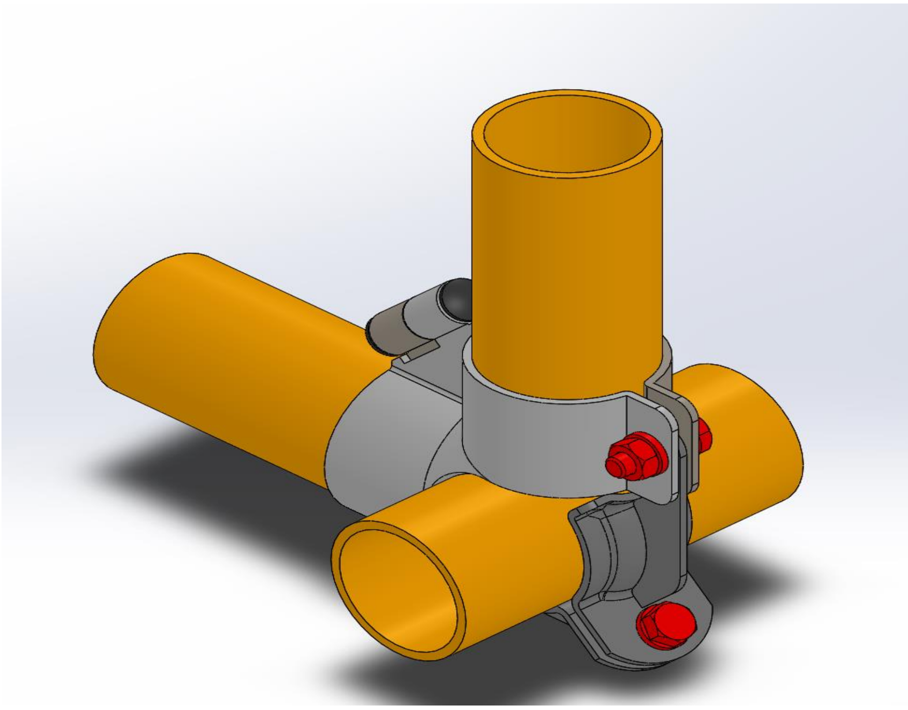

Figure 7: Isometric plan of bracket

The figure 6 and 7 shows the initial plans of pipe bracket. The main dimensions of the bracket and diameters of pipes have been labeled. We can see that there are three different direction pipes can be fixed in the bracket, and the each intersection angle of the pipes are similar to 90 degrees. However it could not fix on the wall and could not be used for straight pipe. So it needs to design a new one which suit for using the pipe in the Engine room or other place on the vessel.

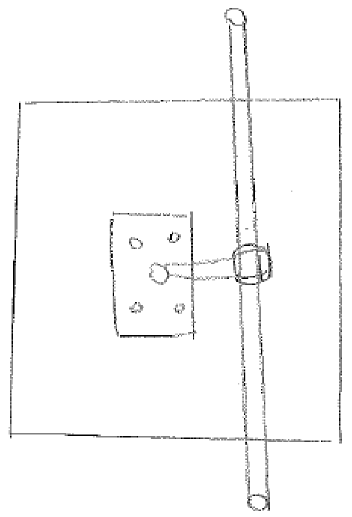

Figure 8: The sketch of bracket

The figure 8 is my initial drawing of pipe bracket which improve my old design .As mentioned before, this project was about designing a pipe bracket like the type which have adjustable support. Because it makes easily assemble due to nuts and bolts could be rearranged for adjusting the support when using on the vessel. And it could be used for the straight pipelines so that widely used on the vessel for different place like Galley, Engine room and Bunk house.

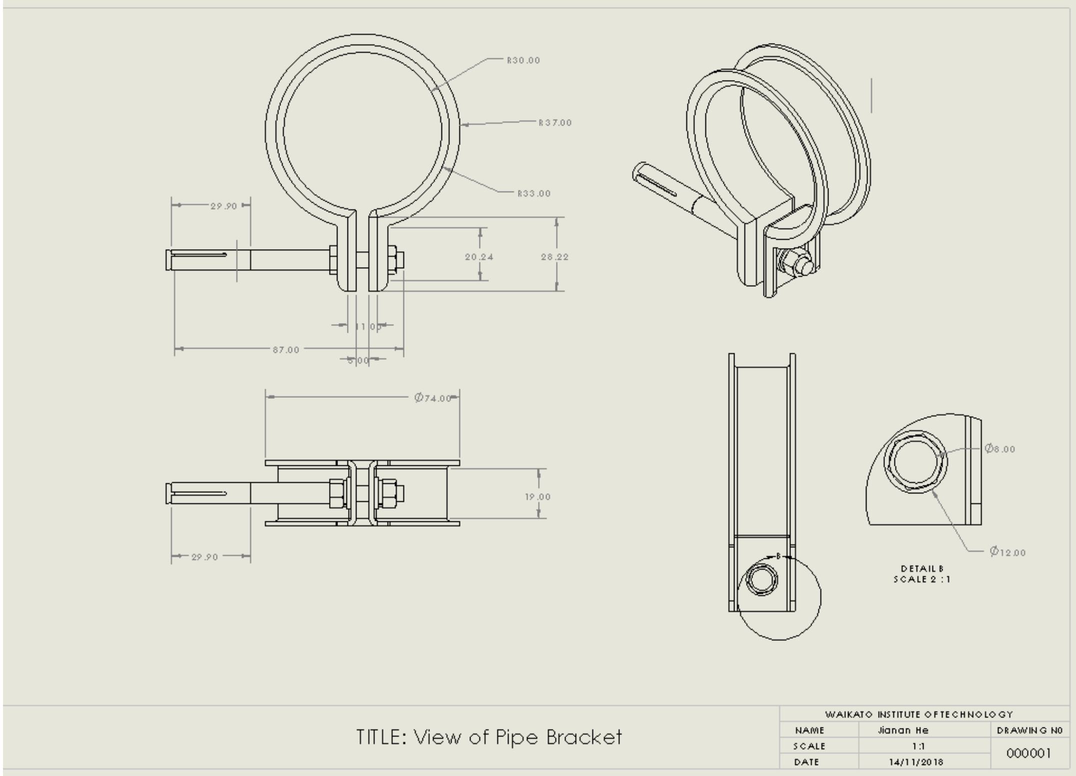


Figure 9: Template of final pipe bracket

Figure 10: Final Plan of pipe bracket

The figure 9 and 10 are my final design of my pipe bracket.The inside diameter of the bracket is 60mm which is similar to the outside diameter of standard pipe size using in Engine room :

**Using for the Engine room**

NPS 2 , Outside Diameter 60.3 mm

| | |
|---|---|
| Schedule | Sch.80 |
| Wall Thickness (mm) | 7.6 |
| Internal Diameter (mm) | 45.1 |

There are two nuts fixed on each side of the bracket in order to adjust to the erection tolerance. The bolt could be fixed on the wall and used for the straight pipelines. It is better to use in the Engine room to support the pipe and the water or gas that are carried by the pipe.

## Mathematical calculation

Using the formula $\mathrm{FOS} = \frac{\gamma}{\sigma_n}$ to work out the $\sigma_n$ ,where Yield strength of titanium is 500 x $10^6$ N/$m^2$ and Factor of Safety is 2 in marine environment

$$\sigma_n = 500 \text{ x } 10^6 \mathrm{N/m^2} \div 2 = 250 \times 10^6 \mathrm{N/m^2}$$

Then, it can work out the strain where Young's modulus of titanium is given as 116$\times 10^9 N/\mathrm{m}^2$

$$\varepsilon = \frac{\sigma_n}{E}$$

$$\varepsilon = 250 \times 10^6 \div (116 \times 10^9) = 0.002$$

The section area of the pipe bracket which fixed on the wall could be gotten from the Sloidwork which is $23.7 \times 10^{-6}$.It will used for the formula $F_t = A \times \sigma_n$ to calculate the total load

$$F_t = 23.7 \times 10^{-6} \times 250 \times 10^6 = 5925N$$

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Material | Copper | | | | |
| 2 | | | Galley | Engine ro | Bunk house | |
| 3 | Thickness (m) | | 0.0037 | 0.0076 | 0.0036 | |
| 4 | Length (m) | | 4.5 | 3.7 | 5.3 | |
| 5 | Diameter(m) | | 0.048 | 0.063 | 0.042 | |
| 6 | Density(kg/m^3) | | 9000 | 9000 | 9000 | |
| 7 | Sectional area (m^2) | | 0.000515 | 0.001323 | 0.000434 | |
| 8 | Mass for pipe(kg) | | 20.85501 | 44.04711 | 20.71581 | |
| 9 | Force of pipe (N) | | 204.3791 | 431.6617 | 203.015 | |
| 10 | Density of Water (kg/m^3) | | 1000 | 1000 | 1000 | |
| 11 | Force of Water (N) | | 5624.896 | 5445.096 | 5678.466 | |
| 12 | Total load (N) | | 5829.275 | 5876.758 | 5881.481 | |
| 13 | | | | | | |
| 14 | | | | | | |

Figure 11: The Excel for showing each load

Accorded to the formula which calculated the total load which applied on the bracket, made an Excel show to show the total load in different place when the other information is given.

Applied the external load of 5925N to the simulation and the fixture should fix into the wall. The below figures shows the results of simulation.

# Simulation:

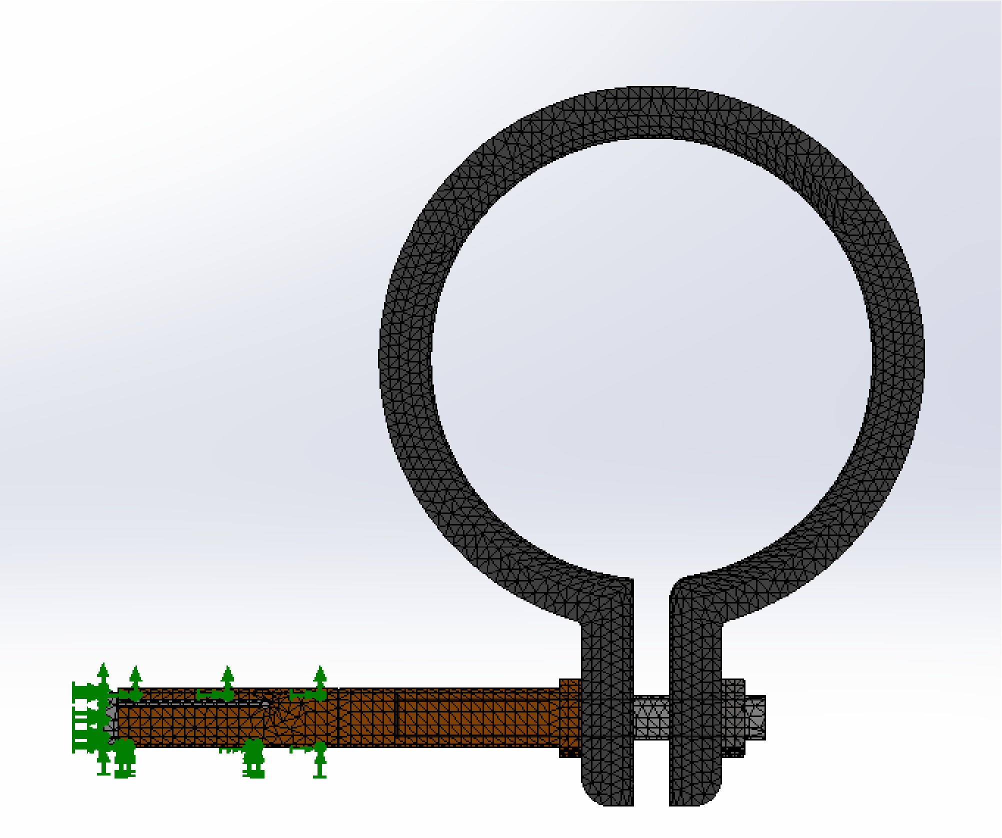

Figure 12: the Mesh of bracket

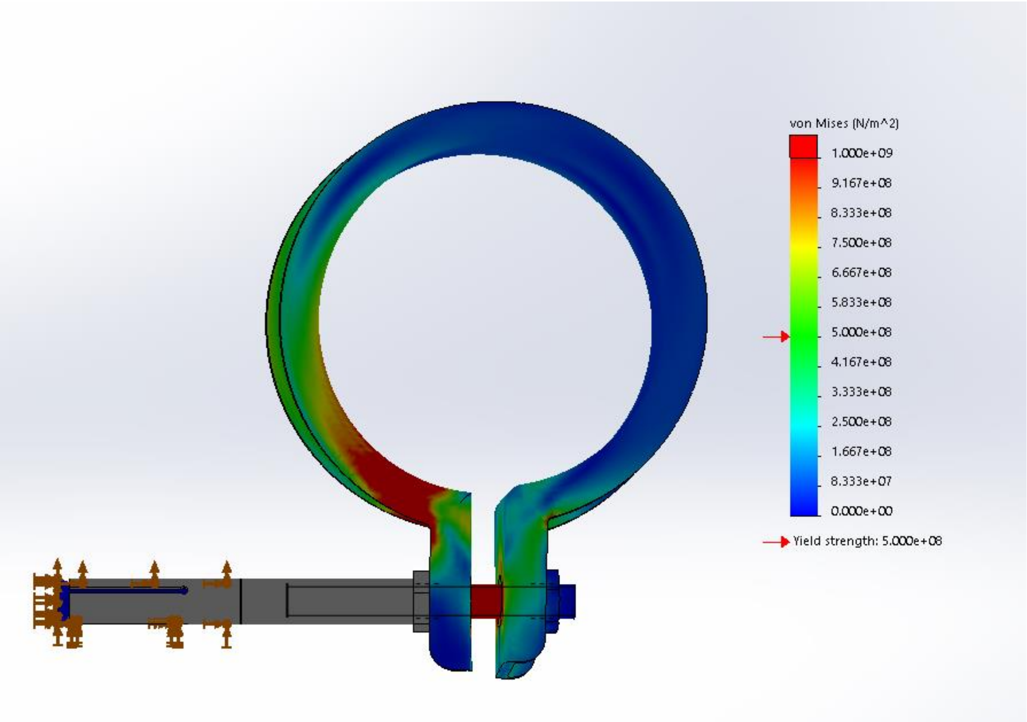


Figure 13: the stress of bracket

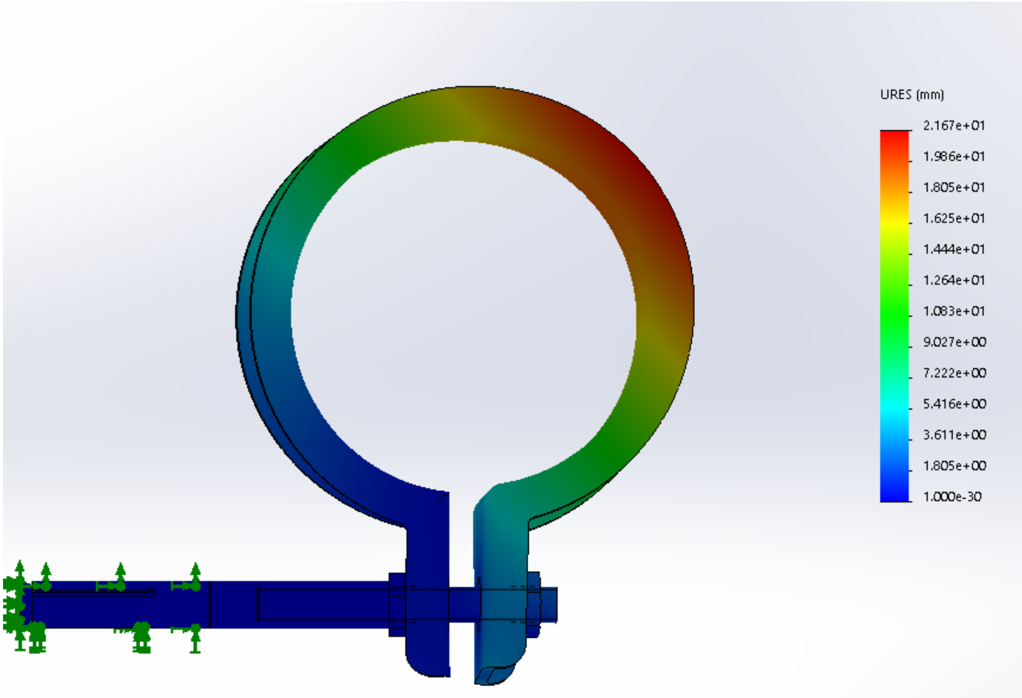


Figure 14: The displacement of bracket

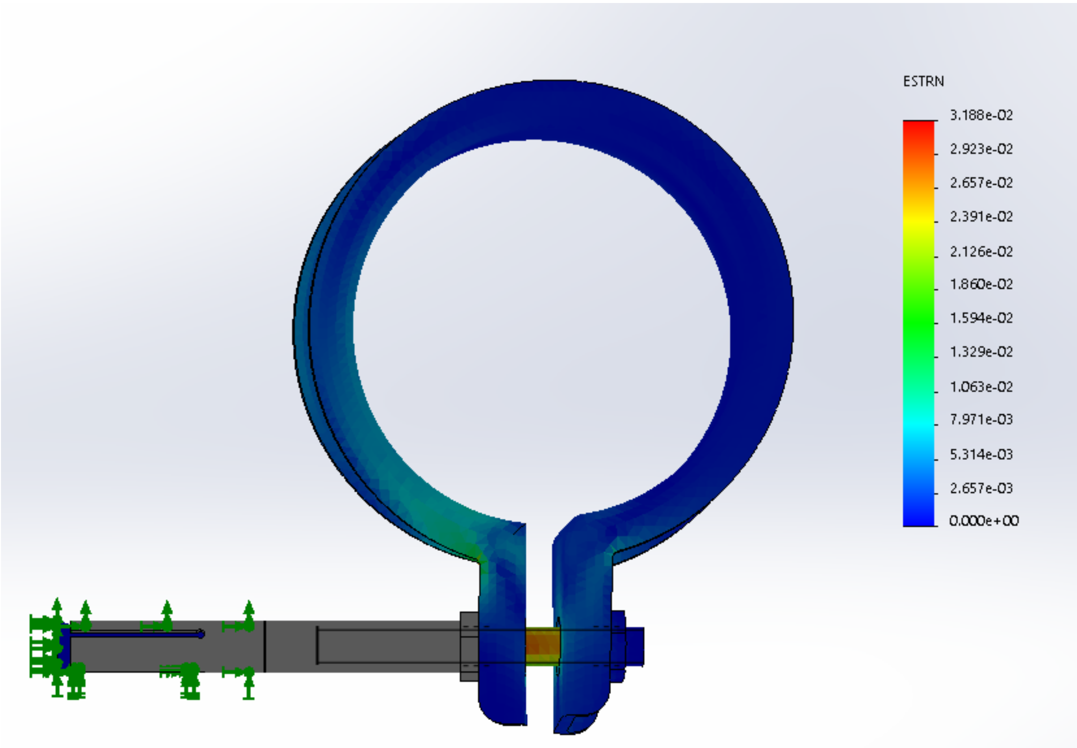


Figure 15: The strain of bracket

## Discussion:

In the design drawing, firstly there had initial design drawings were shown in figure 6 and 7.Although it could be used for three pipes at the same time, it could not fix on the wall. So it needs to design a new one which suit for using the pipe in the Engine room or other place on the vessel. The figure 9 and 10 showed my final design drawing. The inside diameter of bracket is based on the standard pipe size which issued by the North American used for temperature and high or low pressures. The other essential requirement had been also solved. The maximum stress was calculated as $250 \times 10^6 \mathrm{N/m^2}$ . The strain was calculated as 0.002, then worked out the total load which is 5925N.The figure 12 shows what the maximum length of the Copper pipe used for each bracket in different places. When the bracket is applied the calculated total load which is closed to the 5925N.Applied the calculated external load of 5925N to the simulation, we can see that from figure 13, the stresses in left side area and bolts are shown higher than the yield stress, it means the bracket will make deflection. Also the figure 14 shows there had deflection occur. This result expresses the applied load on the pipe bracket is too much lead to the bracket make deflection. The errors could be caused by the experiment instrument or people operation. The Solidworks could not totally show same appearance of section area, it will make the mistake for calculating the total load. Also the section area is very complex due to use the expansion bolt fixed on the wall.

## Manufacturing Process:

The titanium reacts violently with oxygen, when it is heated. Thus casting process is a great challenge to Titanium. Molten titanium reacts with the smallest amount of trace oxygen present in most refractory compounds during this process. Refractory is usually used to produce investment casting mold. At the moment, there are three common techniques for producing cast titanium components in industry: rammed graphite, metal injection molding and investment casting. I will discuss them and choose the best one which are able to be used for constructing my bracket.

**Rammed Graphite for Cast Titanium**

One of the methods to control titanium's reactive property is to produce casting mold with graphite which is a chemically inert material. This method is called rammed graphite casting. Firstly, Graphite is mixed with pitch syrup and water, then rammed it, against a pattern to create a mold. After that, the graphite mold is dried and baked to burn down the sticking materials and remain the pure graphite shell. The graphite mold shell is placed into a vacuum environment and put molten titanium into it. Concrete and cool it. Finally break it and get final cast titanium product.

This method prefer to produce rougher surface of titanium castings, because it is made of the rough graphite sand.

**Metal Injection Molding for Cast Titanium**

The second method is Metal Injection Molding.Blend tiny ground titanium powder with suited alloying powders and mingled with the thermoplastic binder at the high temperature. The binder can improve the plasticity of the mixture so that making it come into the precision-machined mold.

The Metal Injection Moulding ca n show the product detailed features. However, there should spend a lot of money on the multi-step and required initial cost on the injection moulds of my bracket.

**Titanium Investment Casting**

Investment casting is the last method we use for casting Titanium. This is an ideal balance between accuracy and cost. The investment casting process begins with the production of an exact wax model of product. This pattern is normally produced with injection molding or 3D printing. Coat the pattern in a ceramic material to make a shell. Place the mold into furnace to make the wax melt and drain from the shell, leaving the empty cavity.

Place the shell into a vacuum environment.  Pour the Molten titanium into the ceramic mold. Then, the titanium needs to solidify and cool. Finally, the ceramic mold is broken and removed from the component casting, appear the final cast titanium part.

In my project, investment casting looks like the best way to produce the bracket .Because it is a less costly process relative to Metal Injection Molding and can manufacture high precision product. The manufacturing process may be used casting machine and molding machine and related materials wax and the titanium will be used.

Table 4: Manufacturing process cost

| Items | Cost ($) |
|---|---|
| Titanium | 1.2 |
| Wax | 1.5 |
| Expansion Bolts | 0.5 |

| | |
|---|---|
| Manufacturing process | 2 |
| Total | 5.2 |

The Making cost is constructed with the necessary materials and working process. If you make hundreds of brackets, the total cost will be cheaoer.However, due to the time management, I could not to go to workshop to do a real prototype and test it. The Manufacturing processes can affect the design outcomes because you will find two approaches. One you design to suit a manufacture method or two to design then find manufacture process to suit the design.

# Conclusion and Recommendations

Overall, this report has been investigated the utilizing and design pipe bracket with using titanium metal for the ocean going vessel to confront marine environment .The designed titanium metal bracket can be widely used for the different kinds of pipes on the vessel. It is very easy to assemble and have adjusted support. It can be used for the straight pipe as well. The pipe bracket can be used longer life due to the excellent corrosion resistance of titanium .In addition, it can used less weight due to the density of titanium is less than other materials. It can improve the performance and good looking for the Earthrace 2 to achieve their global marine conservation. The weaknesses of my design is not consider the variation in performance of titanium metal and other used metals before and after use in the marine environment. And it need to be fixed on the supporting structure like wood or metal board. It is better the increase the thickness of the bracket and increase the length of the bolts or use stronger strength material bolts so that making the bracket safer. There are some advices shown below:

- Regularly doing every work on time
- Making the prototype, because the manufacturing processes can affect my design outcomes in a practical condition.
- Calculating the load applied on the bracket used in different conditions
- Be careful when melt the titanium due to it is molten in very high temperature.

The further work should consider about the earthquake or unsteady factor when pipe bracket is being used on the vessel. And need to disuse my design with expert that are there anything going wrong so that avoiding causing personal injury and financial loss during making and using.

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# Glossary

**1. Corrosion resistance**: Corrosion resistance refers to the resistance a material offers against a reaction with adverse elements that can corrode the material. (Corrosion Resistance, n.d.)

**2. Office of Naval Research:** The Office of Naval Research (ONR) coordinates, executes, and promotes the science and technology programs of the United States Navy and Marine Corps. (The Office of Naval Research Science& Technology, n.d.)

**3. Thermal expansion:** It is the tendency of matter to change in shape, area, and volume in response to a change in temperature. Temperature is a monotonic function of the average molecular kinetic energy of a substance. (James, n.d.)

**4. Marine environment:** The oceans, seas bays estuaries and other major water bodies. (Definitions.net., 2017)

**5. Galvanic Corrosion:** Galvanic corrosion refers to corrosion damage that occurs when two different metals are in electrical contact in an electrolyte, where the more noble metal is protected and the more active metal tends to corrode. (Galvanic Corrosion , n.d.)

# Abbreviations

**ER-2**: A developed version of Earthrace 1 vessel which is going to be built by Earthrace Conservation Company.

**Cp-Ti**: Commercially pure titanium.

**UTS**: Ultimate tensile strength or ultimate tensile stress.

**YS**: Yield stress.

**NPS**: Nominal pipe size

**Cu2O**: Cuprous oxide

**CuO:** Cupric oxide

**Cu2 (OH) 3Cl**: Cuprous hydroxyl chloride

**SCH**: Schedule

**E**: Modulus of Elasticity

**ONR:** Office of Naval Research

# Appendices:

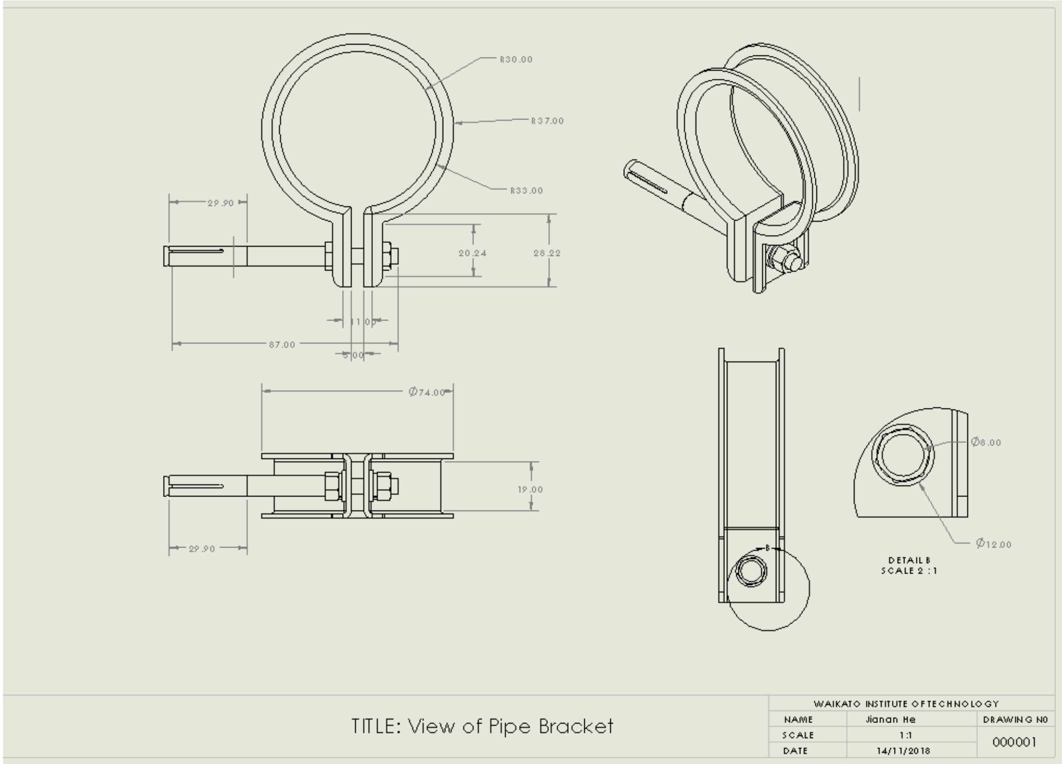


Figure 16: The Dimensions for bracket

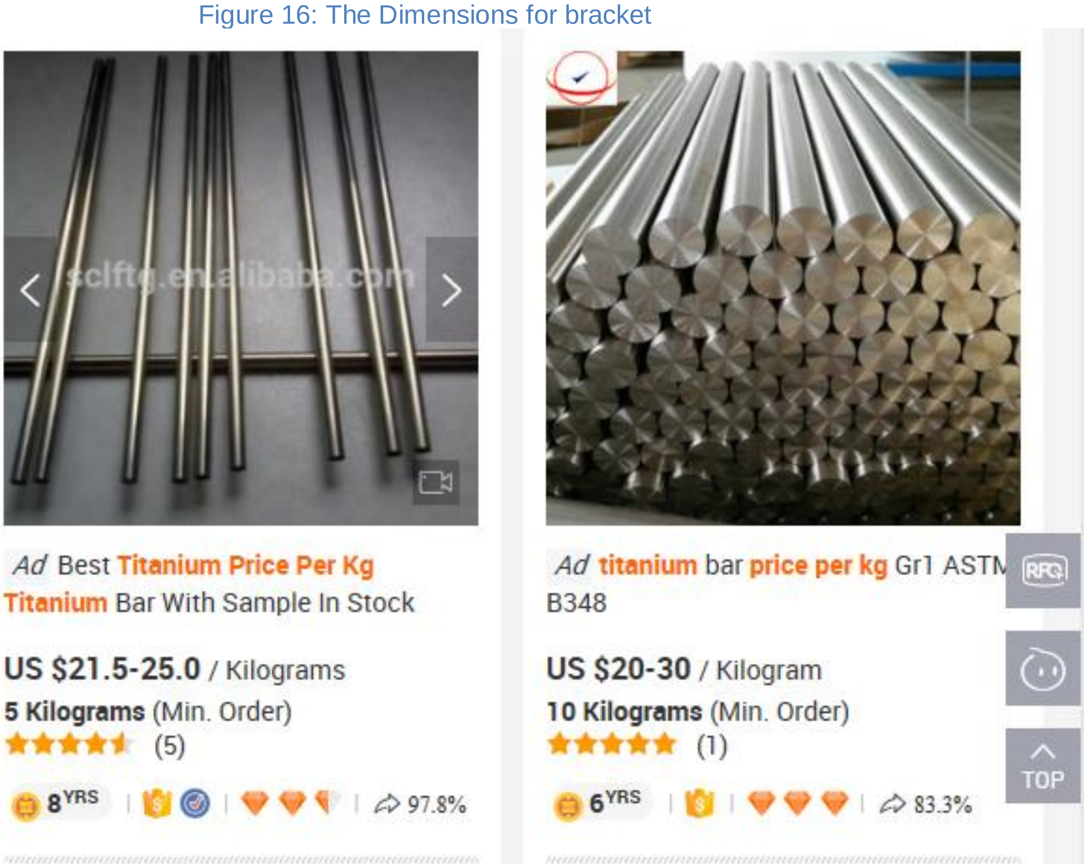


Figure 17: The price for Titanium

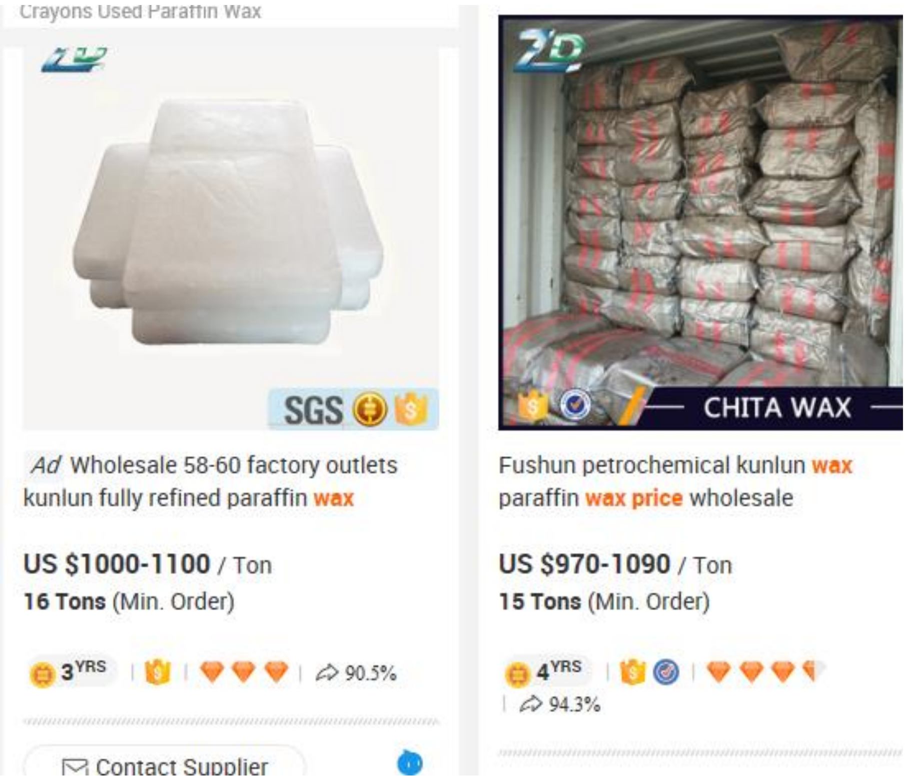


Figure 18: The price for Wax

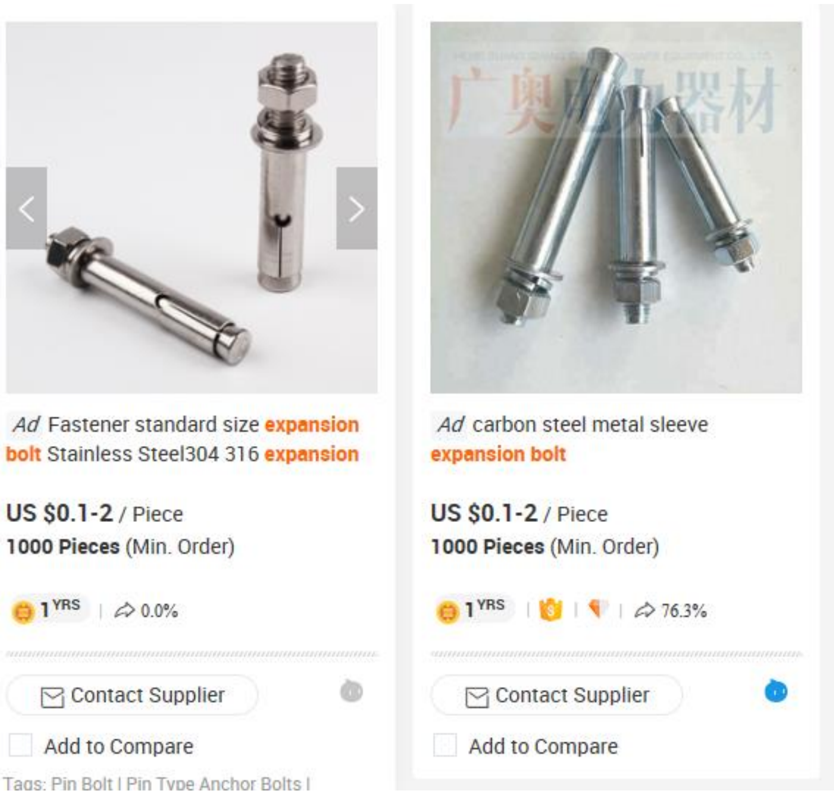


Figure 19: The price for expansion bolt

# STUDENT DECLARATION

I have not copied any part of this report from any other person's work, except as correctly referenced. Collaboration: No other person has written any part of this report for me.

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Completion Date ___16___/_11__/__2018_