MODELLING AND DESIGN OF MOUNTING SYSTEM FOR AN ELECTRIC PERSONAL WATERCRAFT

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Abstract

With rises in petrol prices, increases in demand and issues with pollution, the Renewable Energy Vehicle Project (REV project) at the University of Western Australia have made strides towards a better, cleaner future. The aim for the REVSki project is to showcase the potential of electric powered transports outside of typical vehicles. We hope to expand concept of electric power and promote research into renewable energy inside the University and wider community.

Since 2012, the REVSki project has aspired to create a recreational water vehicle that has similar performance to its petrol powered counterpart, whilst producing zero emission. These vehicles could provide a significant reduction in pollution and emission as they are more efficient to run and significantly quieter. The base vehicle of the REVSki is a 2008 Sea Doo GTI130, with the internal combustion engine being replaced with 50kW continuous rated three-phase AC induction motor and the fuel system replaced with Lithium iron Phosphate batteries arranged to provide a nominal voltage of 96V DC. At the end of 2015, the prototype of the REVSki was functioning, with the majority of the important components installed in order to have a working demo. The vehicle was publically launched, with support being shown from the general public. Since then, the REVSki has been disassembled in order to fix some of the major problems with the demo and apply improvements.

A major problem with the balance and stability of the REVSki from the initial demo had to be addressed, as it was observed that the demo was far too front heavy when undergoing water trials. This effected the driver's ability to brake and accelerate, as well the overall balance of the REVSki. To solve the stability problem, a large scale redesign of the interior components was necessary in order to shift the weight distribution towards the rear of the Jet Ski. This resulted in a major change in the location of the batteries, motor controller and fuse box, rendering the current method of mounting obsolete.

This paper addresses the design, modelling, manufacture and installation of a new mounting system for these interior components. As a result the work from the 2017 REV team, the REVSki has been completely rebuilt and installed from the ground up, including a completely revised mounting system. The vehicle concept has been successfully proven, and the REV team hope to improve its performance in order to make it commercially feasible.

Acknowledgements

I would like to first thank my girlfriend, family and friends for their unwavering support throughout my final year project.

I would like to thank Professor Thomas Bräunl for all of his help in guiding me through my final year project. My REV team, Rain and Jayden for enduring our final year projects together. Marcus Pham, my student supervisor for all of his guidance and Mark Henderson from the mechanical workshop for all of his input on the design of the battery mounts.

The REVSki team would also like to give a big thank you to all of our sponsors, Altronics, tmt, AMA and SME, for without you this project would not have been possible.

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Table of Acronyms

ACRONYM	DESCRIPTION
PWC	Personal Watercraft
REV	Renewable energy vehicle project
FYP	Final Year Project
UWA	University of Western Australia
MC	Motor Control
BMS	Battery Management System
AS	Australian Standards
ISO	International Standards Organization
COM	Centre of Mass

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1. Introduction (background)

Since the original Jet Ski was introduced in 1972 by Kawasaki motors, personal watercrafts (PWC) have widely been used as a popular leisure activity. With the majority of PWCs employing a high-powered engine, tailpipe emission and excessive noise pollution are major issues that need to be addressed. Large restrictions in the areas that PWCs can be operated have been implemented in America and Europe due the excessive volume.

The REVSki project is a part of the Renewable Energy Vehicle (REV) project at the University of Western Australia. Since 2012, the REVSki project has aspired to create a recreational water vehicle that has similar performance to its petrol powered counterpart, whilst producing zero emission and still being safe and reliable. These vehicles could provide a significant reduction in pollution and emission as they are more efficient to run and significantly quieter. A PWC has been under development at UWA since the second half of 2012, with improvements and changes being applied by FYP students. The base vehicle, a 2008 Sea Doo GT1130, was originally purchased, with the internal combustion engine being replaced with 50kW (67Hp) continuous rated three-phase AC induction motor and the fuel system replaced with Lithium iron Phosphate batteries arranged to provide a nominal voltage of 96V DC.

At the beginning of 2017, the prototype of the REVSki was functioning, with the majority of the important components installed in order to have a working demo. The vehicle was publically launched, with support being shown from the general public. Since then, the PWC has been disassembled in order to fix some of the major problems with the demo and apply improvements.

2. Problem identification

By the end of 2015, a working demo was produced by the former REVSki team, but with a multitude of problems. A major problem with the balance and stability of the REVSki from the initial demo had to be addressed as it was observed that the demo was far too front heavy when undergoing water trials. This effected the driver's ability to brake and accelerate, as well the overall balance of the REVSki. Although there were several other problems with the REVSki that were addressed this year, the balance and stability is the main problem addressed in this Final year project.

In order to ensure the safety of the driver, all electrical systems must be fastened securely to the hull of the Jet Ski in order to prevent water ingress, short circuiting and risk of injury. A complete redesign of the major interior components including the batteries, motor controller and fuse box was necessary in order to address the stability issued that arose from the initial demo of the REVSki. This directly resulted in the need for a new mounting system to be manufactured as the redesign rendered the old battery, motor controller and fuse box mounting obsolete.

There were several major restricting factors on the design of the mounting for each component. These were:

- No modification can be made to the hull. This restriction is mainly in place in order to maintain the integrity of the hull and prevent water ingress. It also removes the need for recertification in accordance with Western Australia boating laws.
- All major components must be easily be accessible from the front or back hatch in order to make adjustments if necessary.
- The electric motor must remain in the current location as it is directly connected to the drive shaft and impeller.
- Easy installation, maintenance and removal off all components must be possible

The redesign of the REVSki components was complete by fellow REVSki team member Rain Yu Liu, and each major internal component had a set location in which they needed to be mounted in order to adjust the stability of the REVSki. This left very little room for error as the amount of space in the hull of the REVSki was severely limited.

2.1. General design requirements:

The structure should be capable of sustaining the most adverse combination of static and dynamic forces that may be reasonably expected from all expected loads. For a single lateral constraint (support), it should be designed to:

- to resist a force of 0.025P, in addition to any other forces to which it may be subjected, where P is the maximum axial force in the critical flange or cord
- to not exceed 0.0025L, where L is the span of the restrained member, to prevent deflection
- to operate for an appropriate number of cycles (based on fatigue)
- to protect against corrosion if exposed to a corrosive environment

For fully rigid designs, adequate elastic analysis to show that permissible stresses specified in the standard are not exceeded. Any weld or places subjected to tensile stress should also be examined for brittle failure.

3. Literature review/Previous work

3.1. Motor controller and fuse box mounting

Previous work on the mounting system was conducted by C. Jensen (Jensen, 2015). However, the nature of the FYP was completely focused on mounting for the motor controller and fuse box, with no mention of any battery mounts. Concepts on design strength and testing from the Jensen can be used as a basis for the design of new mounts.

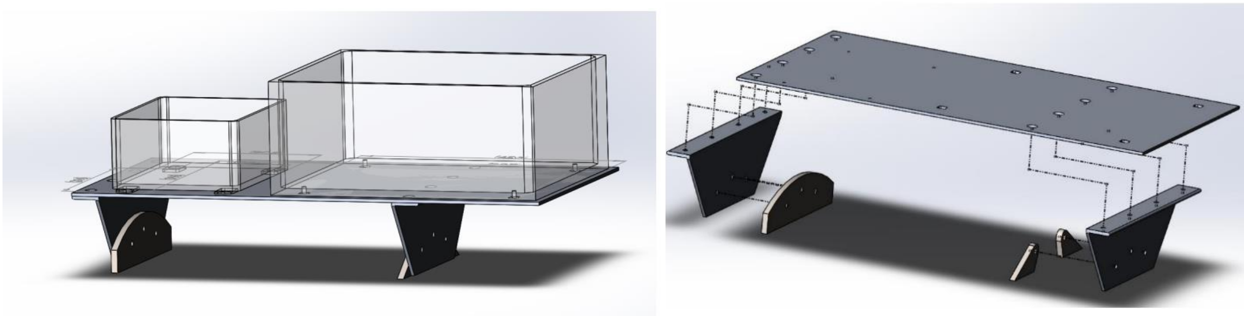

Figure 1: Existing motor controller and fuse box design (Jensen, 2015)

The key components of the motor controller were mounted into an enclosure manufactured by Integra (Jensen, 2015). The components are mounted to an internal mounting plate which is fasten securely to the enclosure. The lid is also clear to allow for easy inspection of major cables and major components. The fuse box was constructed from a waterproof container purchased from Altronics.

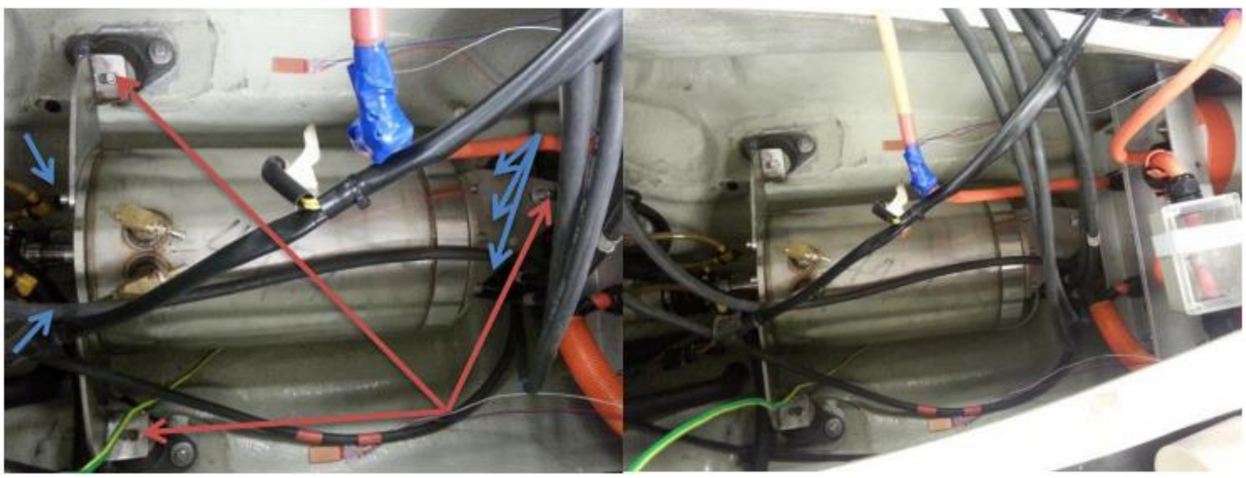

Figure 2: Available mounting points and interior of hull.

The electric motor is mounted directly to the hull using the existing motor mounts (from the petrol motor), with the motor controller and fuse box mounted directly above.

3.2. Battery Mounting

At the start of 2017, the REVSki consisted of four battery tubes in series, two longer tubes housing eight cells in series and two smaller tubes housing seven cells in series. The batteries were sealed in PVC piping to ensure that each tube was watertight.

Figure 3: Battery cells before installation in PVC pipe

The initial battery restraint system was designed and manufactured by previous REVSki team member Alexander R. Hildebrand in 2014. The system incorporated four support systems that held each pipe securely in place. Each support comprised of three wooden cradles that were cut from laminated wood purchased from Smart frame and were secured using M10 316 SS threaded rod. The front two supports were secured to the hull using an adhesive, with the other two supports secured to I-beams that were also secured to the hull using an adhesive.

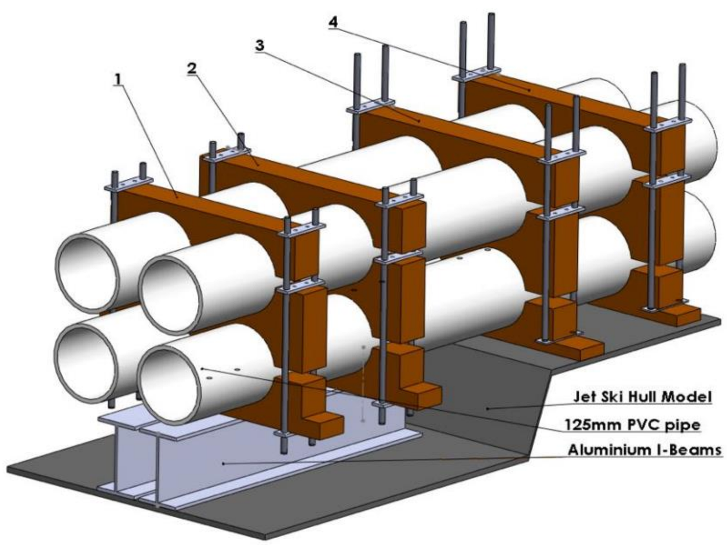

Figure 4: Battery mounting system post 2015 (Hildebrand, 2014).

To ensure that the pipes were secure, a clamping system was used consisting of two clamps on either side using threaded rods bolted against an aluminium bracket (Hildebrand, 2014). Steel pins were used to prevent the bracket from falling off and loctite nuts were used to ensure that the bracket would stay tight during operation.

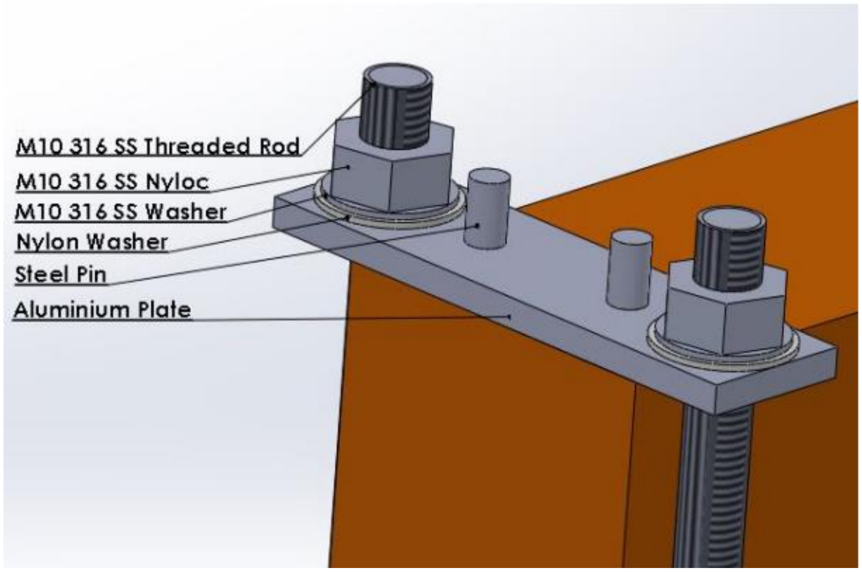

Figure 5: Battery clamping system (Hildebrand, 2014).

3.3. Force Analysis

Test data from FYP student R. Jayamanna (Jayamanna, 2013)on the estimated g-load of a PWC can also be used as a basis for estimations of g-load on PWCs today. Using an accelerometer attached to a petrol powered PWC, the maximum acceleration experienced were recorded and are shown below.

DIRECTION OF ACCELERATION	G-FORCE
VERTICALLY DOWNWARDS	1.44g
VERTICALLY UPWARDS	4.18g
AFT (FORCE APPLIED TOWARDS REAR OF SKI)	2g
BOW (TOWARDS FRONT OF SKI)	1.83g
PORT SIDE	2.63g
STARBOARD SIDE	2.21g

Table 2: Acceleration results from Jayamanna, 2013

Any estimations made with this data must be conservative as the data collected may be outdated, and is not directly correlated with an electric PWC.

3.4. Standards

For the purpose of this FYP, the first two Australian standard reviewed were AS 1799.1, general requirements for power boats, and AS 4132.1 – 1993, boat and ship design and construction. It is stated that the general design of the boat should take into account all aspects of construction, power, accommodation, access and egress. Any boat hardware or fittings must comply with the following requirements:

- Be of sufficient strength to withstand the maximum loads likely to be applied in normal and emergency service

- Be of a size and design to permit easy use, particularly with regard to the attachment of lines
- Be resistant to deterioration by corrosion or weather
- Be free of sharp edges or dangerous features that could cause injury

All load bearing fittings should be welded or through-fastened with bolts and secured so they cannot become damaged or work loose in service. In relation to the mounts being designed, this is the extent of the restrictions for PWCs, with no mention of any restraining features being mentioned in AS 4132.1 - 1993, boat and ship design and construction. For a more in-depth study, standards based on mechanical equipment and steel work were analysed in relation to supports.

3.5. Corrosion

Due to the nature of personal watercrafts (PWC), all materials used in any mounting system must be highly corrosion resistant. Metals like stainless steel and aluminium are ideal as they produce a protect oxide layer that protect the material from corrosion. Non-reactive materials such as polycarbonates and plastics are also considered as they are immune to expose to salt water and atmospheric conditions. In the case of laminated wood, the wood must be sealed in order to elongate lifespan and prevent rot from occurring.

Corrosion of alloys also occurs in aluminium when in contact with dissimilar metal due to its high galvanic potential. The use of stainless steel in contact with aluminium is permitted per Australian Standards, provided there is some form of electrical insulation between the two surfaces (Standards, boat and ship design and construction, AS 4132.1 – 1993, 2017). To prevent any galvanic corrosion, contact between the two metals should be avoided.

4. Disassembly

Working in conjunction with Rain and Jayden, the first semester of work was dedicated to redesigning the interior arrangement of the REVSki. This involved the removal and weighing of all individual components, as well as locating the centre of mass of the REVSki hull and motor. The aim of the redesign was to shift the centre of mass from the front of the REVSki to direct underneath the driver to prevent nose diving.

All interior wiring was also removed with careful notes, pictures and records taken for reassembly. Interior components were then unfastened and removed for weighing. Special lifting clamps were also made for the REVSki that allowed for the centre of mass of the hull to be located. Once all necessary information was recorded, a large scale redesign of the interior components was produced by Rain that altered the position of a majority of the internal components to significantly shift the centre of mass of the REVSki.

Figure 6: Disassembly of the REVSki

5. Design criteria

5.1. Redesign of REVSki

A complete redesign of the major interior components including the batteries, motor controller and fuse box was necessary in order to address the stability issued that arose from the initial demo of the REVSki. This involved the removal and weighing of all individual components, as well as locating the centre of mass of the REVSki hull and motor. All interior wiring was also removed with careful notes, pictures and records taken for reassembly.

Once all necessary information was recorded, a large scale redesign of the interior components was produced by fellow REVSki team member Rain Yu Liu that altered the position of a majority of the internal components. The main components that were shifted were the battery packs, motor controller and fuse box.

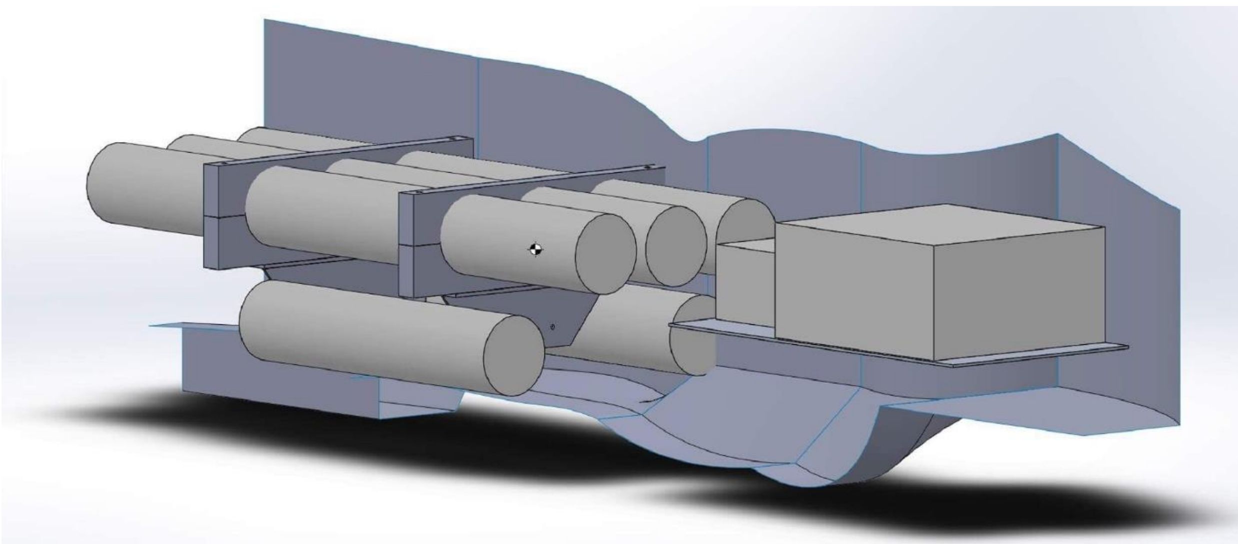

Figure 7: Interior component redesign by Rain Yu Liu

The initial battery tubes were altered in order to accommodate the different space available at the rear of the hull, converting from four tubes housing eight and seven cells respectively to a five tube system. The five tube system consist of three tubes housing eight cells in series and two smaller tubes with three cells each.

The motor controller and fuse box were shifted towards the front of the REVSki as the battery tubes occupied a majority of the space in the rear of the hull. Being significantly light then the batteries, this adjustment did not have a major impact on the stability of the Jet Ski.

5.2. Design Process

When approaching the design of the new mounting system for each of the three components (Batteries, motor controller and fuse box) several design factors were taken into account. In order of importance, these were:

5.2.1. Space restriction

Space restriction was the foremost design factor in the design of the mounting system. As the already limited space was further reduced by the redesign of the interior components, many of the components had very low tolerance and had to be designed and manufactured to exact dimensions. Due to the odd shape of the hull, measuring and modelling of designs proved difficult, resulting in many redesigns. Each design was carefully tested to ensure it fit in the designated area using cardboard models. These models were also used to ensure that all bolts and fasteners were in positions that could be easily accessed for easy installation.

5.2.2. Strength

Any new structure should be capable of sustaining the most adverse combination of static and dynamic forces that may be reasonably expected from all expected loads. Data from Jayamanna was used in order to carry out finite element analysis (FEA) on all design parts to ensure that any new part would not mechanically fail during normal operation.

A fatigue analysis was also conducted to ensure that the final product would operate for an appropriate number of cycles (10000 hours).

5.2.3. Cost

The second major restriction on the design of the mounting was the limited budget of the REVSki team. With a restricted budget for the REV team, many of the funds were devoted to acquiring new batteries as many of the existing batteries had failed due to incautious use. This left a smaller portion of the budget for new components to be made and heavily restricted design freedom. Many of the components were secured in new positions using materials and resources already available, with minimal changes done in areas that were not required. Wherever possible, existing structure was used in order to reduce cost.

5.2.4. Suitability

No modification could be made to the hull. This restriction was mainly in place in order to maintain the integrity of the hull and prevent water ingress and removes the need for recertification in accordance with Western Australia boating laws. This heavily restricted the amount of innovation that could be put into the design of mounts created. All components were forced to be attached to the existing structure, leaving limited options for mounting and restricted the mounting of the batteries to the three existing motor mounts.

Suitability also covers the suitability of certain materials in in water environments. Although no large amount of water should be present in the hull of the REVSki, any material implemented must have high corrosion resistance to extend the expected life cycle.

5.2.5. Installation/maintenance/removal

A major issue with existing mounting system was the difficulty installing and removing components. As many of the fasteners were in difficult to reach locations, the existing battery mounting system proved almost impossible to disassemble, making maintenance difficult. When designing any new mounting components several extra restrictions were put into place to ensure that installation and maintenance could be completed smoothly.

All bolts were designed to be accessible from both sides from the front or rear hatch if necessary, and accessible from one is in the case of blind holes (tapped). No bolt was put in locations there were difficult to reach, and no Loctite nuts were used in situations that were unnecessary.

5.2.6. Accessibility

All major components must be easily be accessible in order to make adjustments if necessary. This includes replacement of batteries and fuses as well as access to components for future improvement. Any new mounting must be unobtrusive so that all components can be accessed from the front or back hatch.

5.2.7. Time

At the start of 2017, the REVSki team envisioned launching a finished product by November 2017. This meant that the manufacture of new components was on a strict deadline to be complete by the time reassembly was possibly in order to prevent delays in the project.

5.2.8. Availability

Working with Mark Henderson, Senior technical services technician at the mechanical workshop at UWA, several design choices were made based on the available material at the workshop as well as the availability of certain staff with expertise in handling those materials. As many new designs needed to be significantly stronger and smaller than the existing mounting, different materials were required to satisfy strength constraints. These meant that professional workshop skills were required in order to manufacture the exact specifications required.

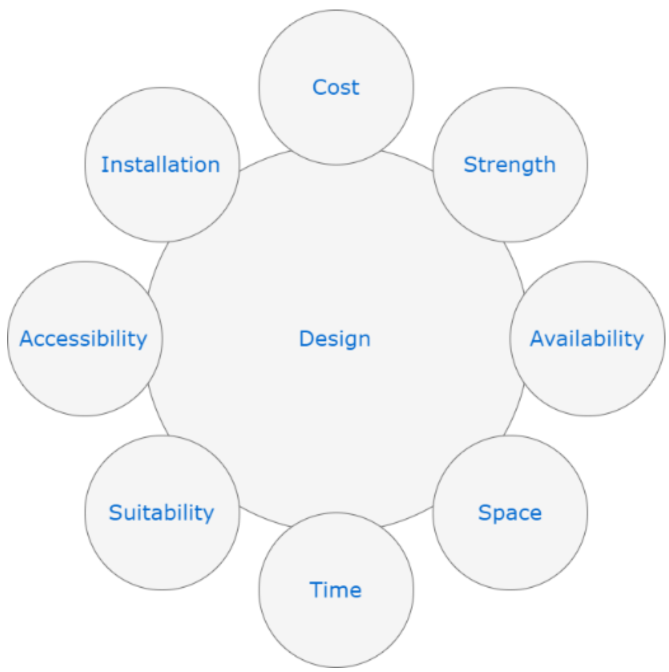

Figure 8: Design criteria of mounting system

6. Motor controller and fuse box mounting

With the redesign of the interior components, the motor controller and fuse box, as well as several other small box were shifted towards the front of the REVSki. As the batteries were removed from this section of the hull there was an abundance of space available to fit all of the components. It was decided as a team that no alterations were to be done on the motor control box or fuse box in order to use the existing steel plate as the basis for mounting, reducing the cost of the process.

As no alterations could be done on the hull of the REVSki, the new mounting was forced to be mounted onto existing superstructure, in this case the obsolete front battery clamps attached to the hull with adhesive and the existing L-brackets that were used to mount the rear battery clamps. The wood from the existing battery mounts were also repurposed for support beams, further reducing the cost of the process.

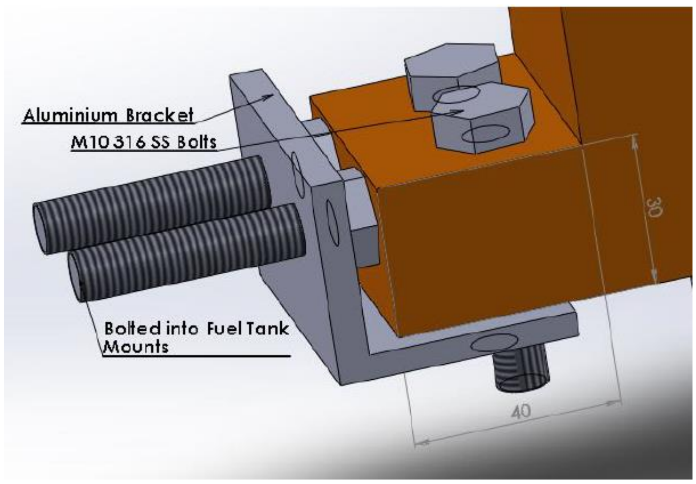

Figure 9: Existing L-brackets used for fuse box mounting

In order to fit the motor control box into the front of the REVSki, the metal plate initially used for the mounting had to be cut into two pieces in order to allow for easy fitting from the front access hatch. The fuse box plate was mounted directly onto the second (from the front) battery clamp and first set of L-brackets (third clamp from the front). Wood screws were used to fasten directly to the second clamp and M10 316 SS bolts were used to fasten the back of the plate to a wooden support spanning across the first set of L-brackets. Two extra supporting steel plates were also manufactured using spare plate to support the steel plate.

The motor controller and sever other boxes including the throttle and blade fuse box were mounting to the first and second existing wooden clamps (from the front) using wood screws. As the existing structure and system for mounting the components created by Jenson in 2015 was not altered, the REVSki team were confident that the mounting would be able to withstand expect operational loads.

Figure 10: Fuse box mounting plate (left), Motor controller mounted (right)

7. Battery mounting

Unlike the motor controller and fuse box, no existing mounting could be used from the initial demo. This was due to the fact that the battery tubing system was altered from four tubes to a five tube system, three tubes of eight cells and two tubes with three cells each. The initial design was also too bulky for the reduced amount of space at the rear of the hull. As many of the components required shifting towards the rear of the Jet Ski, and the motor being in a fixed position, the amount of space in the rear of the hull quickly became an issue.

Each iteration of design was compared against the design criteria in order to assure that all design factors were met. If a design was unable to fulfil all eight design criteria it was reviewed and improved until all criteria were met.

By request, all manufacturing was also to be done in-house by the mechanical workshop of UWA. This reduced the cost of manufacturing as there was a significant reduction in labour from the workshop when working on university projects. It also gave the REV team access to the insights of several experienced engineers and labourers when working on designs.

7.1. Material selection

Four main materials were taken into consideration during the design process of the battery mounting system. These where:

- Aluminium 6061
- Stainless steel
- Laminated wood
- Poly carbonates

7.1.1. Aluminium 6061

Aluminium 6061 offered medium-to-relatively high strength, good corrosion resistance, and is generally so tough that fracture toughness is rarely a design consideration (Bucci, 2017). The material also has good weldability, good corrosion resistance to salt water and is excellent in atmospheric conditions (Interlloy, 2017). These properties made and material good for the requirements of the REVSki.

Aluminium 6061 was also readily available at the UWA workshop for manufacture and this was a large design factor as it eliminated the cost of procurement and any wait times.

7.1.2. Stainless steel

316 Austenitic stainless steel has good strength and excellent corrosion resistance (Interlloy, 2017). Although the material fit the requirement of the design, it was ruled out as an option due to its high cost and unavailability. As the UWA mechanical workshop had no stocks of the material, new resources would have been ordered increasing the cost of the project.

7.1.3. Laminated wood

The wood used in the previous iteration of batteries mounts was LVL15 Smartframe (Hildebrand, 2014). This was used as a cheap alternative in order to reduce the cost of the REVSki project. The material was found to be too bulky and occupied too much space in the hull of the REVSki. With the new design of the battery mounts, it was also not structurally sound due to the fact that the number of clamps on the batteries were reduced from four to two. This eliminated laminated wood as an option, but the remnants of the battery mount were used in other parts of the project.

7.1.4. Polycarbonates

Polycarbonates and/or plastics was put into consideration due to its good corrosion resistance, but due to the properties of the material, it was deemed too structurally unsound to place the weight of over 100 kg of batteries, cables and other components on it. The price of poly carbonates was also out of the price range of the final year project.

7.1.5. Comparison

MATERIAL	ULTIMATE TENSILE STRENGTH (MPA)	YIELD STRENGTH (MPA)	ELASTIC MODULUS (GPA)
ALUMINIUM 6061	240	310	68.9
316 STAINLESS STEEL	305	215	71
LAMINATED WOOD	N/A	35	15.5
POLYCARBONATE	62	N/A	2.35

Table 3: Comparison of materials for battery mount

The final material decided was aluminium 6061. Aluminium proved able to withstand the necessary loads when undergoing finite element analysis, occupied significantly less volume then the previous laminated wood mounting and was significantly cheaper to manufacture then stainless steel and polycarbonates. The reduced manufacturing time and expertise of certain staff in handling aluminium also played a key role in the selection of the material.

7.2. Initial designs

The clamping system used in the initial demo of the REVSki proved an effect way of ensuring that the battery were safely secured during operation. For the new design, the battery clamping system was revamped to account for extra battery tubes as well as occupying a reduced amount of space. The number of mounts was also reduced from four to two due to the need to mount to existing superstructure. This meant that the material used for the mount was required to be far stronger than its predecessor.

Testing using cardboard cut outs were used to ensure that the all components fit and that all bolts and fasteners were accessible during assembly. Each design was reviewed against the design criteria (section 4) to ensure that all aspects of the design were met before proceeding.

7.2.1. Design 1.0

One of the main issue with the redesign of the batteries was the difficulty securing the two smaller battery tubes. The position of the smaller battery tubes places the tubes directly to the left and right of the electric motor. The amount of space available was heavily restricted and access to certain areas of the hull were unavailable due to odd shape of the cavity. Blind holes (tapped) were used in several places to remove the need to access both sides of the bolt, which was almost impossible when the batteries were installed.

The initial design consisted of the small battery circular clamps secured by a long bolt attached directly to a flat bar housing the three longer tubes. The design was reviewed due to the difficulty installing the bolts for the smaller tubes as the thickness of the clamps exceed the allowance of space on the right side of the hull, making it impossible to install. The bolts on the smaller battery tubes were also very difficult to install as the bottom of the clamp was completely blocked off from access by the battery tube itself.

Design specifications are available in Appendix A.

7.2.2. Design 1.1

The second iteration of the design replaced smaller replaced the smaller battery clamping system with a thinner muffler clamp inspired component. This reduced the need to access both sides of the clamp and could be installed with access only to the top of the clamps. This design was reviewed due to the difficulty access the bolts closest to the side of the hull. The front of the REVSki hull was also smaller than anticipated and changes had to be made as access to the side bolts clamping the larger battery tubes down was unavailable.

Design specifications are available in Appendix B.

7.3. Final Design

The final design of the REVSki replaced the smaller battery clamp bolts with a system inspired by hose clamps. The design allowed for the smaller tubes to be secured easier access to only one bolt was required and also removed the issue with space by replacing the machined aluminium with sheet metal. The front of the battery mounts was also altered by changing the position of the securing bolts from the side to the middle of the flat bar. This allowed for the bolts to be easily accessed from the back hatch and made installation and removal much easier.

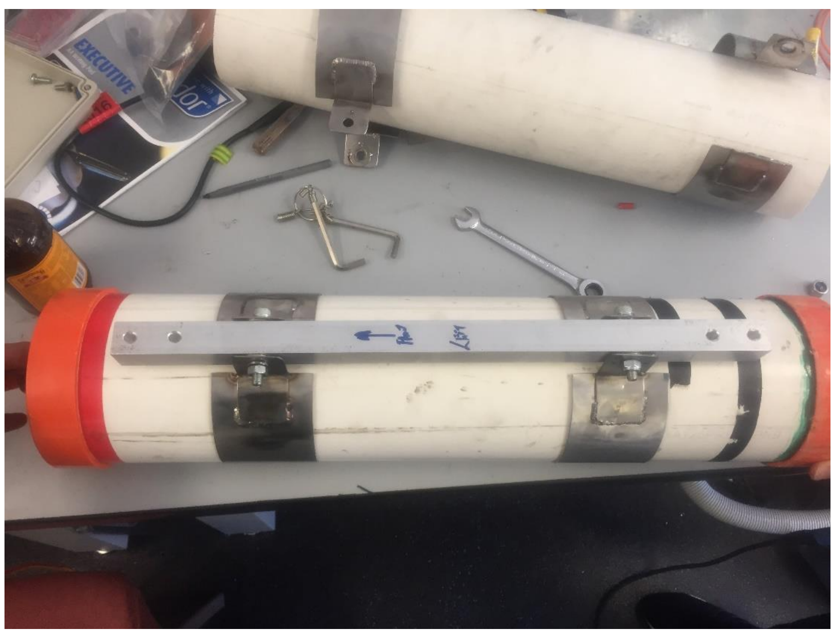

Figure 11: Final small battery tube mounting system

The top clamping component was also altered to ensure extra security for the battery tubes. The change also solved a problem with the bracket hitting the curved sides of the hull when trying to install the component.

Design specifications are available in Appendix C and D.

7.4. Finite Element Analysis (FEA)

Before the final design was approved, a finite element analysis (FEA) was conducted to ensure that the structure would be able to withstand expected loads during normal operation. This FEA analysis was conducted using the Inventor 2018 inbuilt analysing system. All values used in the testing are from testing done from R. Jayamanna. Larger tubes are set to be 25 kg in mass and smaller tubes 10 kg.

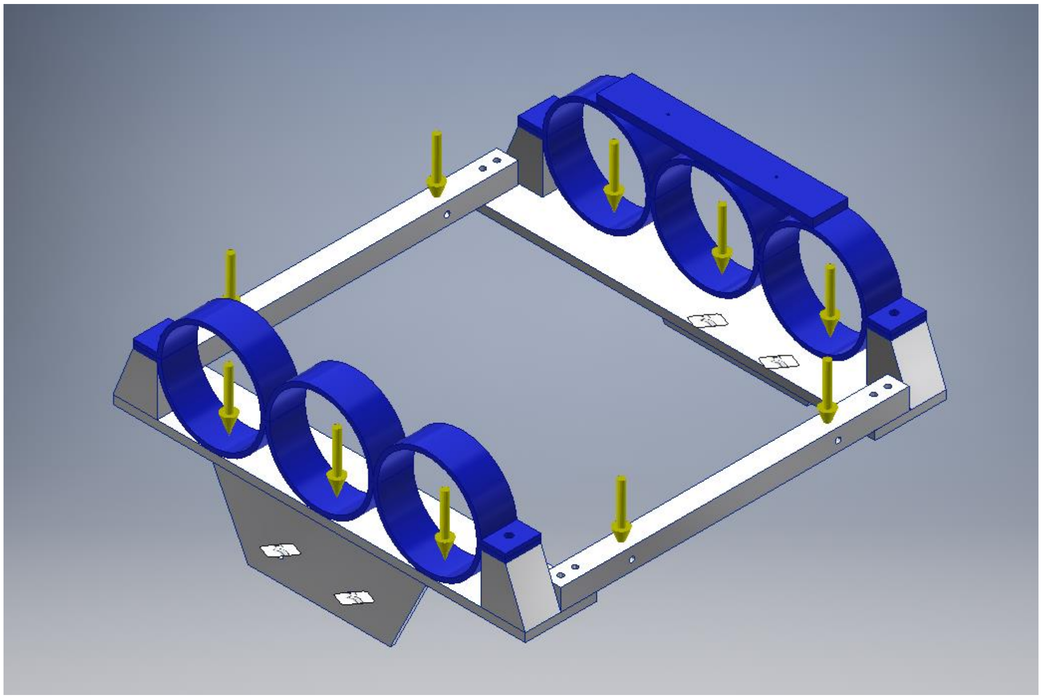

Figure 12: Force locations on battery clamping system

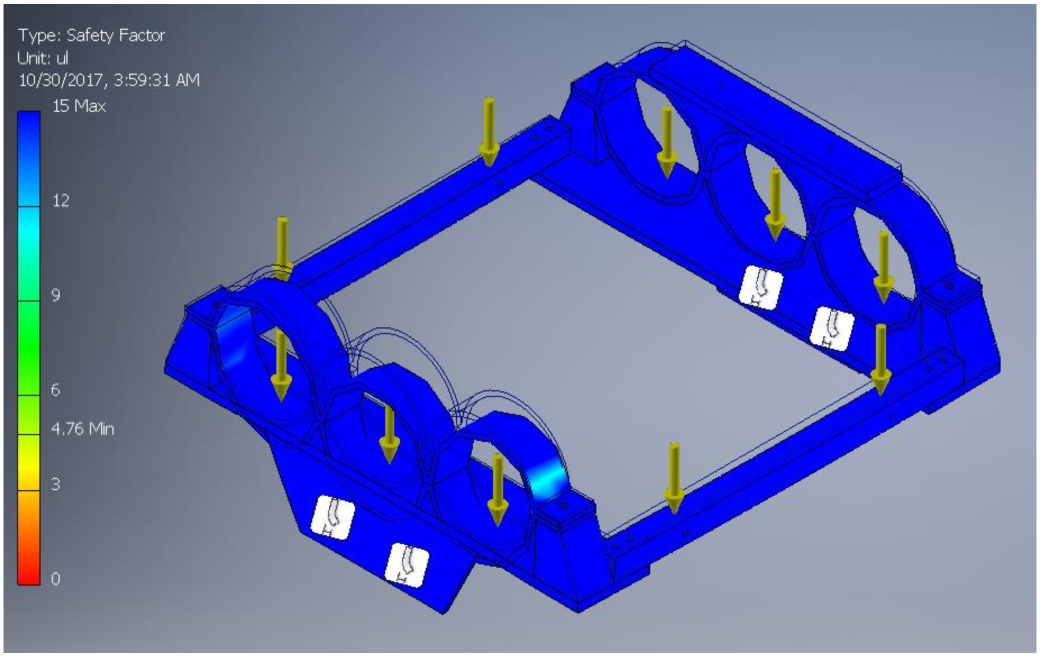

Figure 13: Safety Factor FEA analysis

When undergoing FEA analysis for normal operation, a minimum safety factor of 4.76 was found when applying expected loads from Jayamanna's data (using a maximum acceleration of 4.18), confirming that the battery clamping system as a viable option from a strength perspective.

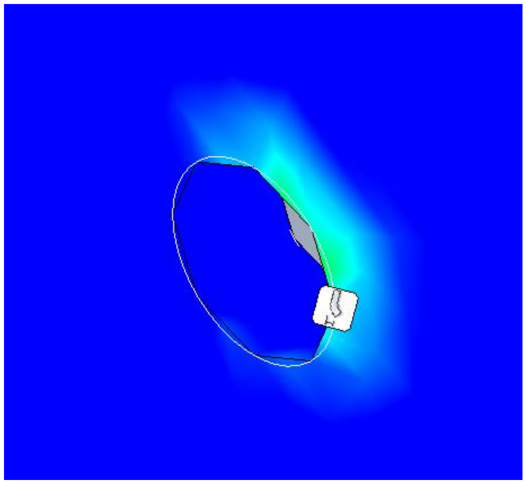

Figure 14: Stress concentration at bolt holes

As expected, the bolt holes and openings were the weakest points in the structure, but due to the fact that the new battery clamping components were forced to be attached to existing structure (project restriction), this was an inevitability.

7.5. Construction and assembly

Once a final design was complete, models drawn using Inventor 2018 were sent to the mechanical workshop for fabrication. This process took three weeks longer than anticipated as there was a delay in starting the project due to lack of staff and a backlog of orders from other projects that the mechanical office had to address. This delayed the reassembly of the REVSki by one week.

A thin (3 mm) layer of rubber was also implemented on the inside of any battery clamp to ensure that the restricting force of the clamp was applied consistently without any slipping. The rubber also serves as a soft layer of extra protection for the battery tubes against the metal structure.

Once all internal wiring was complete, the battery mounts were installed. This process went smoothly due to the design considerations and there were no major issues with the installation. Once the batteries were in place, the structure was checked for integrity and no signs of deformation have appeared over a three week period.

Figure 15: Final battery mount design installed

8. Conclusion and Future Work

To date, a completed battery restraint system, motor control and fuse box mount have been successfully implemented in the REVSki. All new mounting components were made in accordance of Australian Standards and is safe for use in normal operation with a significant safety factor.

All interior components of the REVSki are functional and final minor issues are being trouble shoot before the first test launch. Unfortunately due to the time constraint, test work on the new components has yet to be carried out. Field testing of the components using strain gages and other instruments to measure the stress on each component must be carried out in order to verify the model.

As the REVSki is at the forefront of innovation for electric personal watercrafts, many of the components have yet to be optimised, the current mounting system included. The majority of the components were produced as a proof of concept in order to verify the feasibility of an electric water vehicle. The current model the REVSki is yet to have competitive performance to its petrol counterpart. With improvements and optimisations the REVSki can potentially fill a gap in the existing market without comprising in performance.

The mounting system for the REVSki can also be revamped to accommodate for more batteries and components. In the current state of the REVSki, a total of 240 batteries are accommodated in the batteries tubes. These produce a total of 30 minutes range on a 3.5 hour charge and the REV team of 2017 envisions the possibility of doubling this number to improve the range and power of the current model. Finding the space and innovating ways to accommodate for the extra volume of batteries whilst keeping weight, balance and stability in check is a new challenge that could possibly bring the REVSki into the competitive market.

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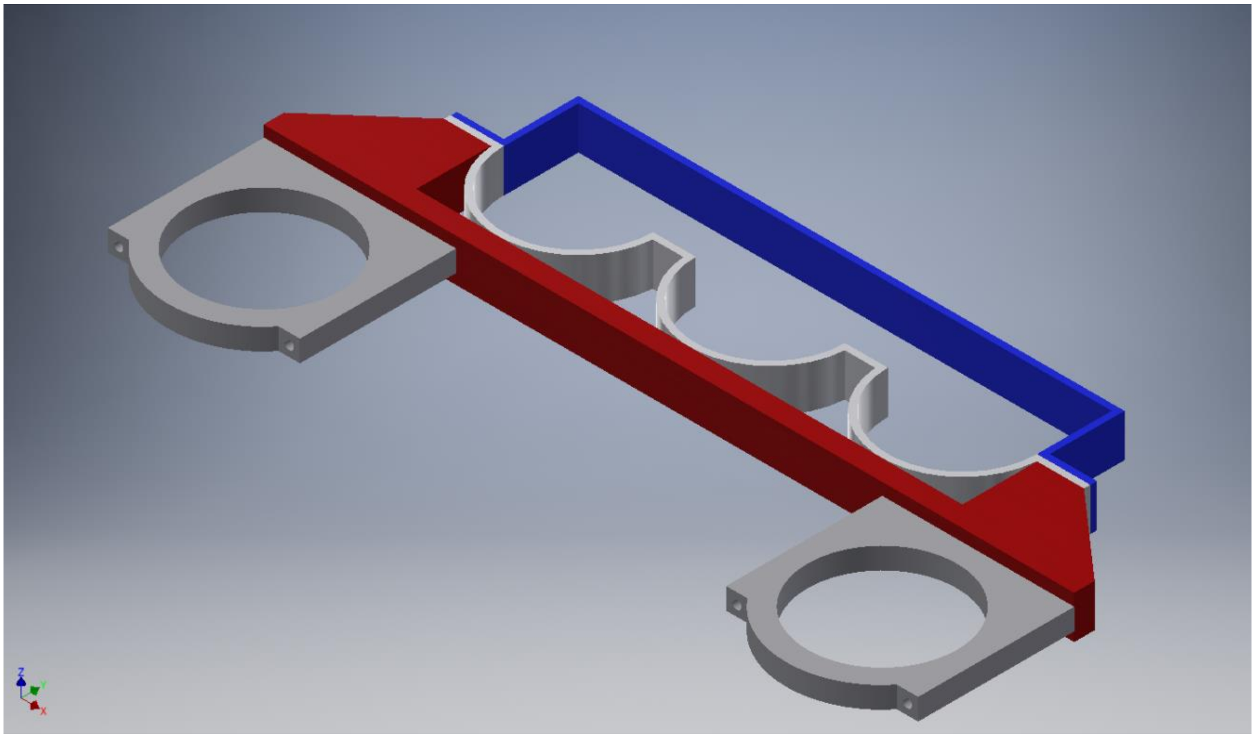
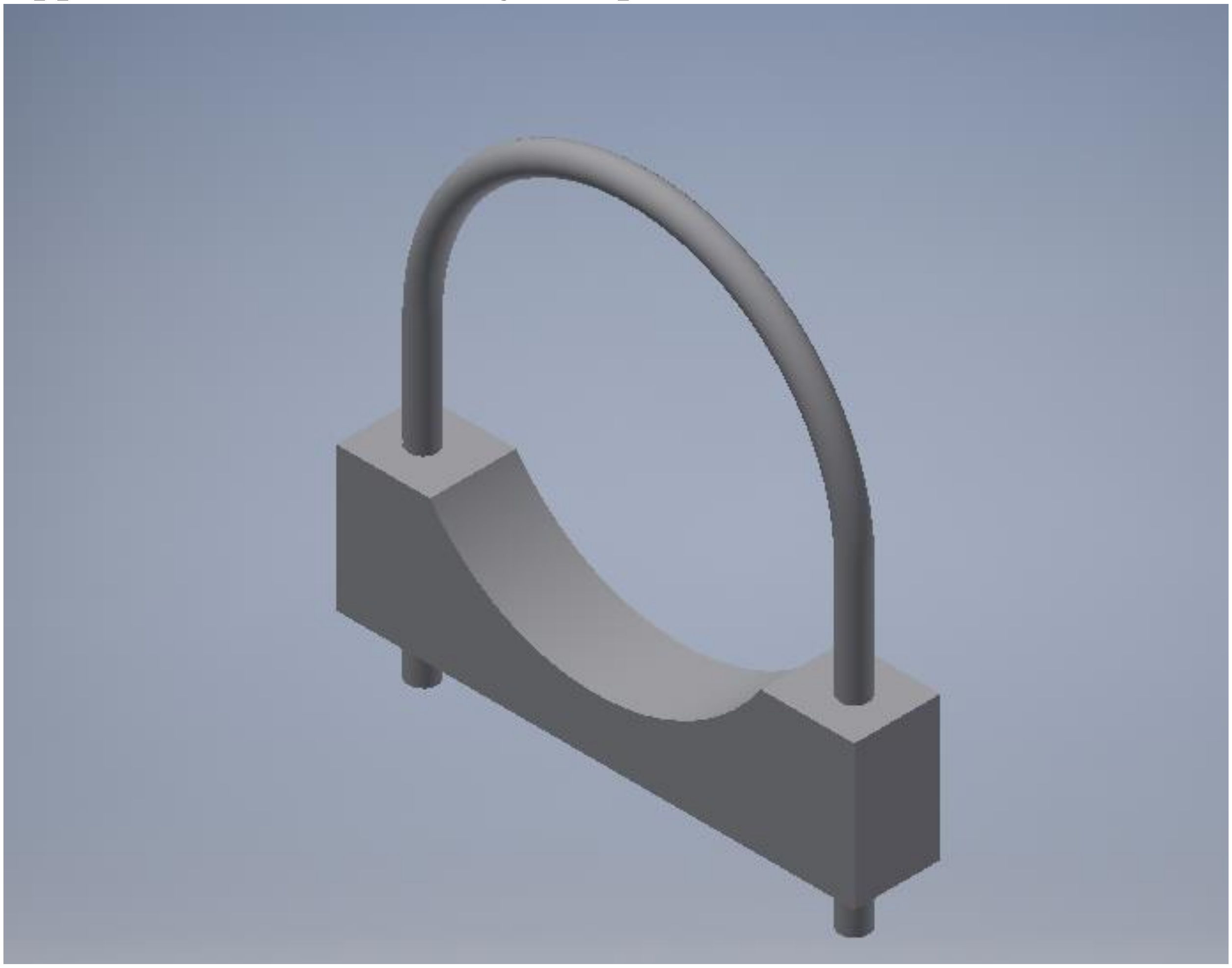
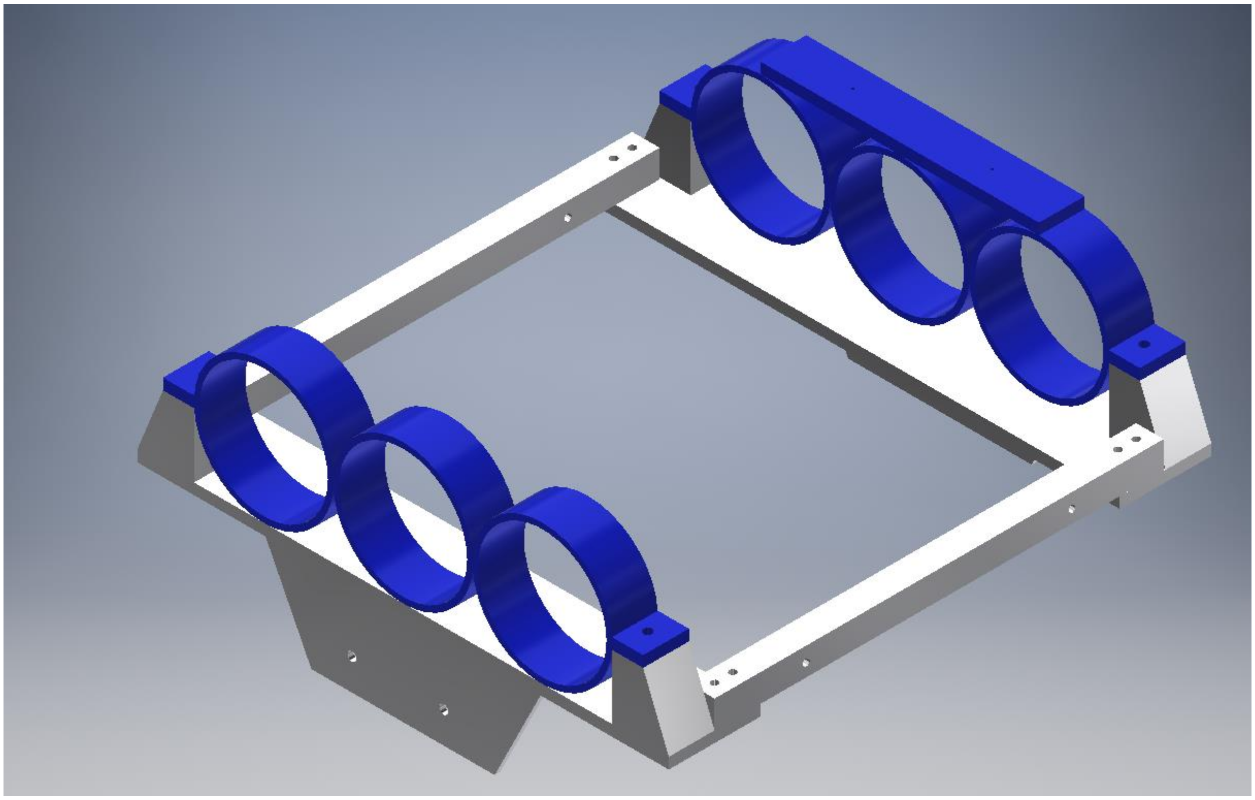
Appendix A: Design 1.0



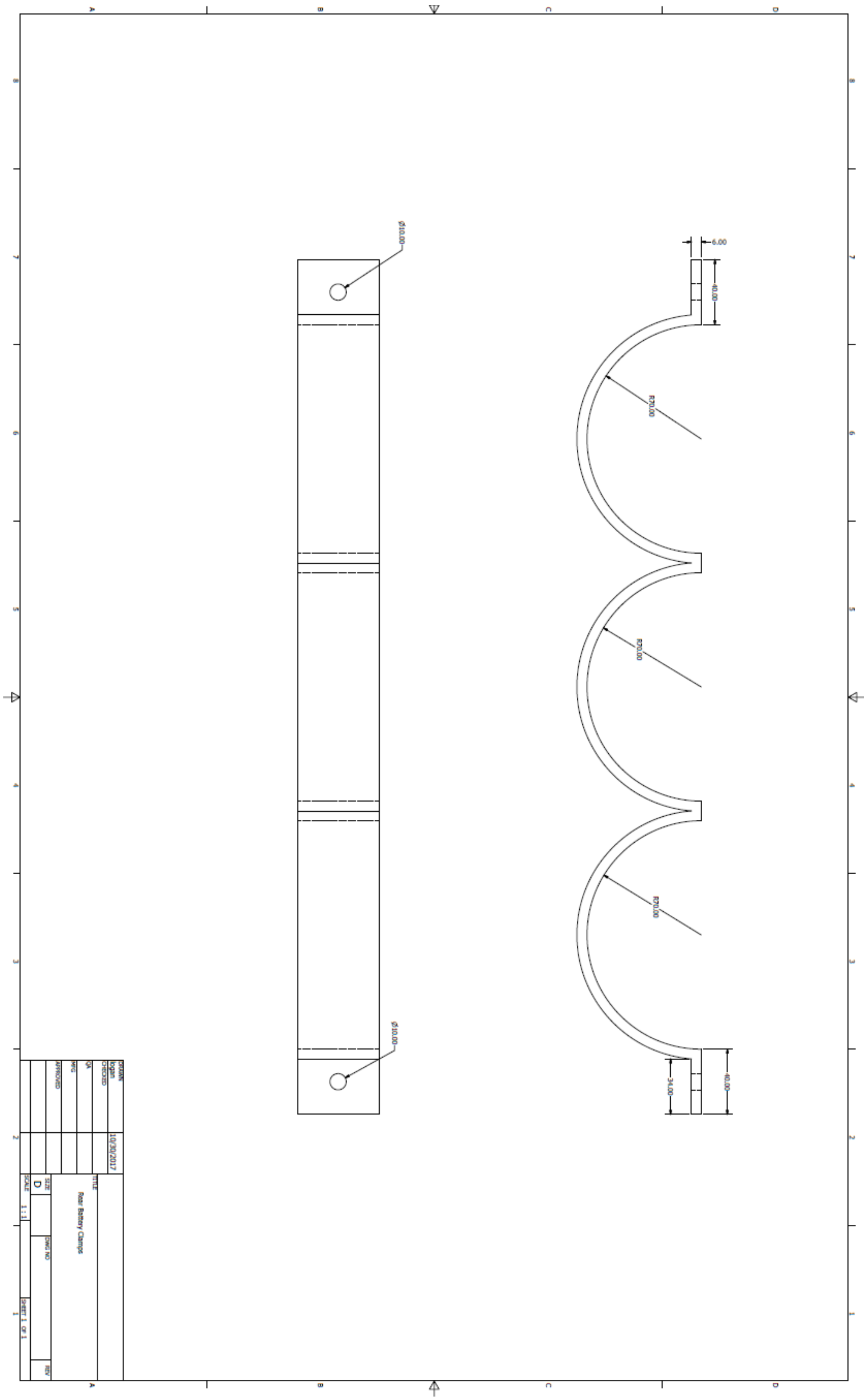
Appendix B: Revised battery clamp

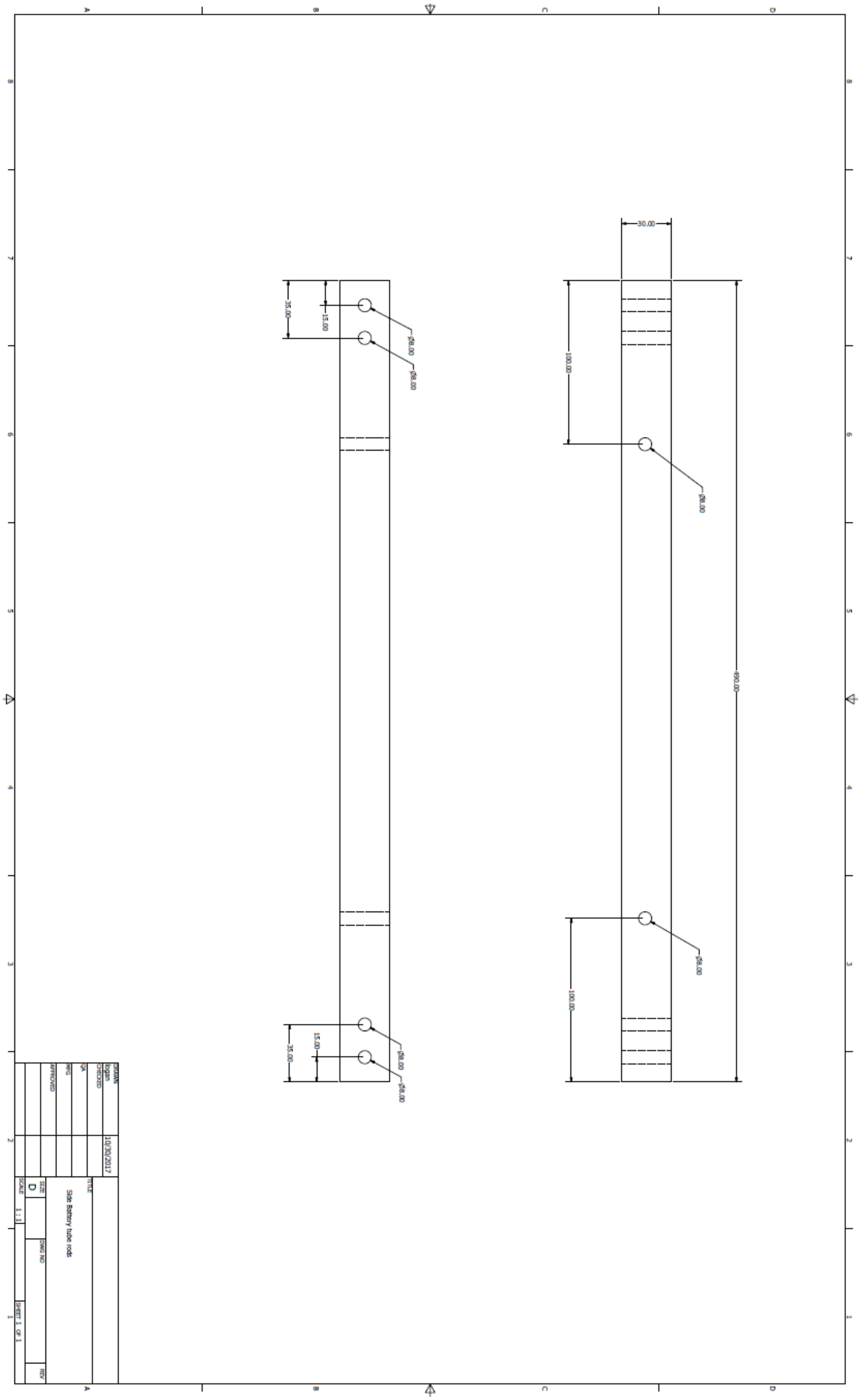


Appendix C: Final Design



Appendix D: Engineering diagrams for final design

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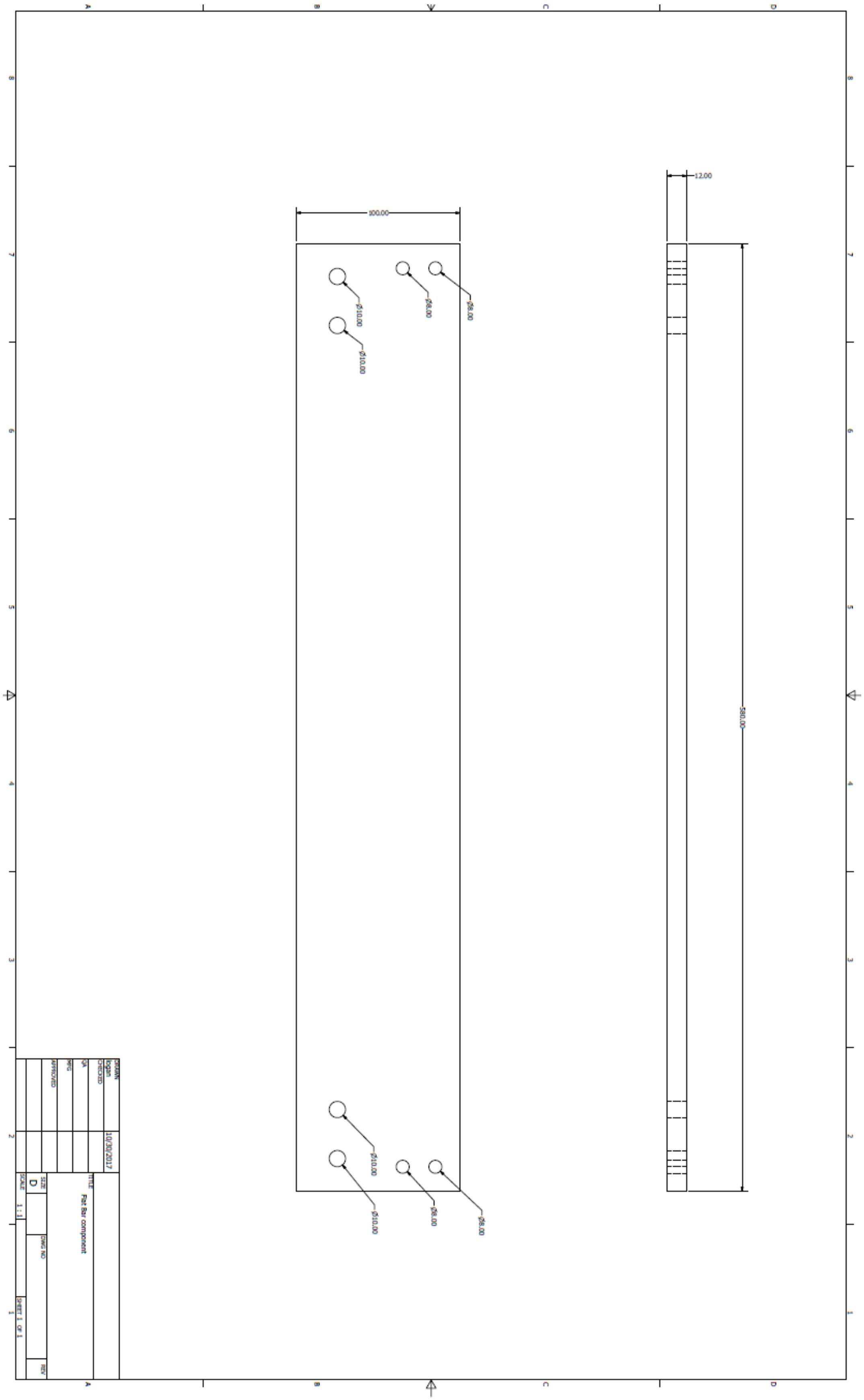
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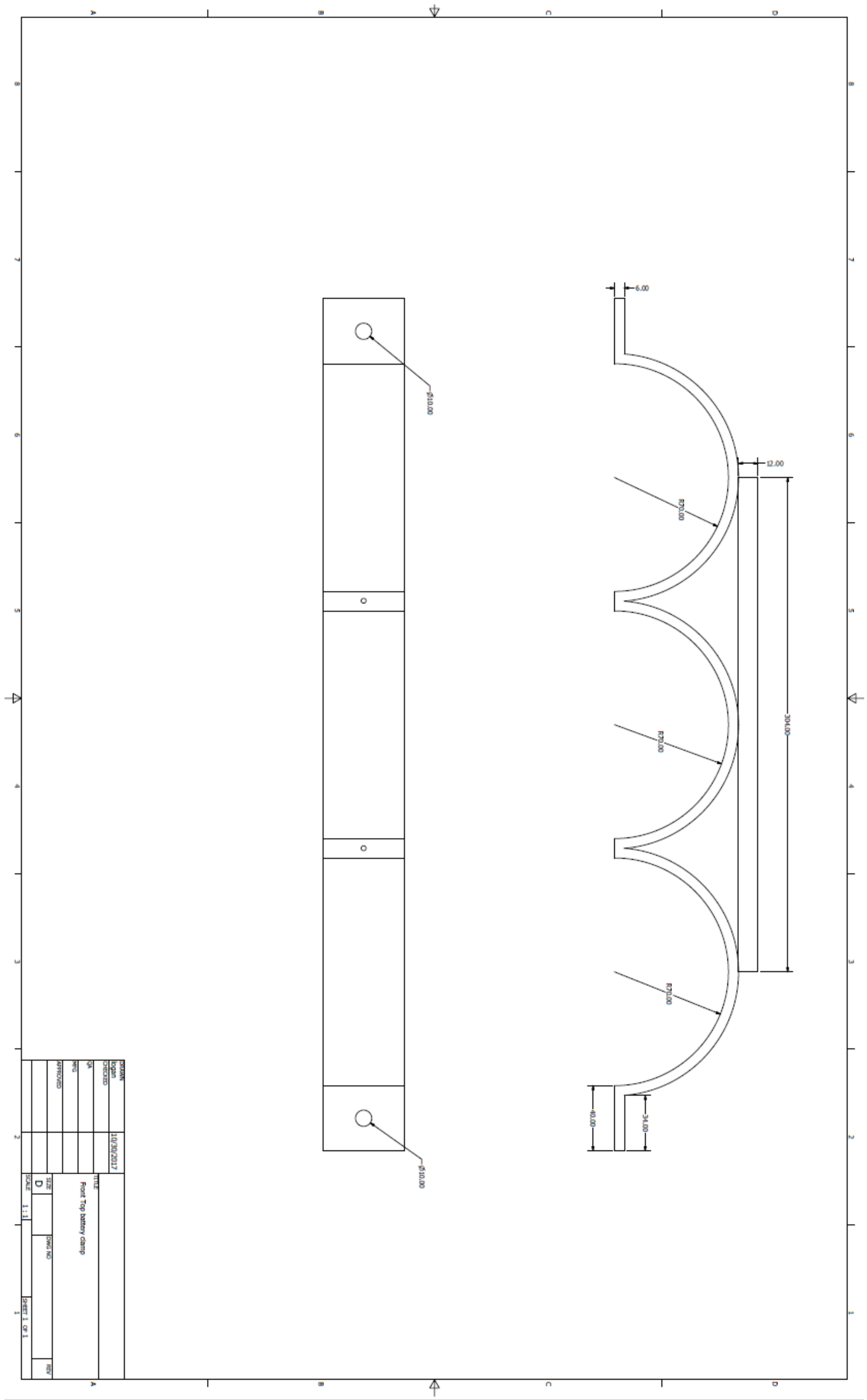
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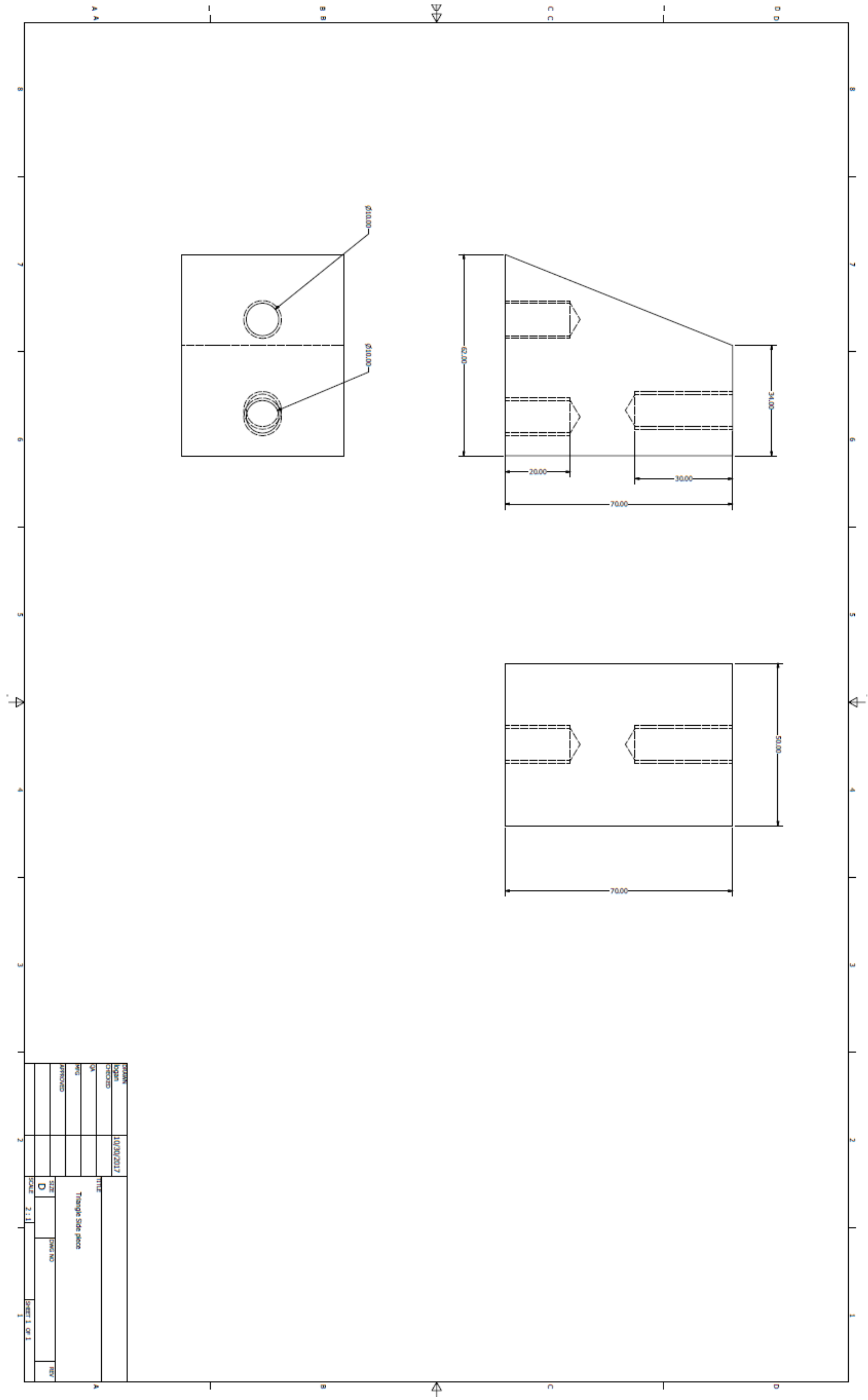

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