University of Canterbury

Department of Mechanical Engineering

Professional Engineering Placement Written Report

Company
Core Builders Composites Limited

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Contents

1. Introduction

This document outlines the Professional Mechanical Engineering work performed by an undergraduate Mechanical Engineering student at Core Builders Composites Limited. The report details the structure of the company, the products and services and the departments that the student worked in at this innovative company. Further, the work performed by the engineering student over the 2015-2016 summer period is detailed along with the key learning experiences relevant to the Mechanical Engineering degree at the University of Canterbury, and also to the engineer's future professional career.

2. Company Structure

2.1 Organisation

Core Builders Composites Limited is located in Warkworth, approximately 45 minutes north of Auckland City, New Zealand. The professional work experience that this report details was undertaken at this site. The company's primary purpose is to design and build the America's Cup Class Yachts for Oracle Team USA Racing. The high performance nature of the racing boats has led the company to become a leader in carbon fibre composite construction technology. The company has a reputation for quality as a result of the successes of the Oracle team. The company continues to build on this knowledge and diversify into other fields of technology requiring high-tech composites knowledge.

2.2 Products and services provided

Core Builders Composites provides services for high quality manufacturing of composite tooling and parts.

They bring to New Zealand the benefits of large envelope milling. The CMS Poseidon 5-axis CNC high speed gantry manufacturing centre can machine large objects up to a size of 18m x 6m x 3m to an accuracy of up to 0.2 mm

The company has a transferrable and broad skill set that has developed from the complex construction of the Oracle Team USA America's Cup racing yachts. The company is now diversifying into other areas of design and construction that require both lightweight and high-strength solutions.

3. Past, current and future projects

3.1 America's Cup Class Racing Yachts and Components

An evolution of the America's Cup competition means that teams are no longer funded by single sponsors. Oracle Team USA is now partnered with a variety of technology and marketing partners including Red Bull, Airbus, Yanmar and Bremont, to name a few. In order for teams to save money in this expensive and competitive sport, the design of some of the major large parts of the boats has been homogenised. The key areas of the design that could give teams a competitive edge of the control systems and the shape of the dagger-boards and hydrofoil rudders remain unique to each team. These class rules were introduced as a means of reducing cost, however they are also intended to create a level playing field for the competition so that the outcome of each race is based more on the skill of the sailors and tacticians, akin to the Formula One Grand Prix.

The company's main focus is on the complete design and construction of the America's Cup yachts for Oracle Team USA and Softbank Team Japan that will compete in 2017. As can be imagined, this is no small undertaking and requires a full 50 person team of designers, engineers, project managers, logistics and freight specialists as well as machine operators and composite technicians. Additionally, the company constructs the wing elements for Artemis Racing (Sweden) and Groupama Team France, which are pictured below in figure 1.

Figure 1: Construction of the AC45 Wing elements for the America's Cup World Series Competition [1]

3.2 Google X Makani Wing

Core Builders Composites has been working with the Silicon Valley technology company Google X to develop an alternative wind energy platform. Conventional turbines have grown taller, heavier, and more expensive in order to generate more power. These large structures are expensive and complex to construct, and can only be installed economically where the winds routinely reach speeds of between 5-8 meters per second (20-28 kilometres per hour). Unfortunately, less than 15% of all land around the world meets this criteria, meaning this existing technology in its current form cannot scale. The Makani solution is a lightweight composite constructed kite which flies at a height of around 250 m and is tethered to a ground launching vehicle. The idea is that the propellers on the wing act as electricity generators and can operate more efficiently than a conventional wind turbine as wind speeds are higher and more consistent the higher into the jet stream one goes. The solution is also a lot more cost effective than current options due to its lightweight construction. It also has the added benefit of not affecting local environments in terms of land use and noise pollution. Figures 2 and 3 are an illustration of the Google X Makani Wing.

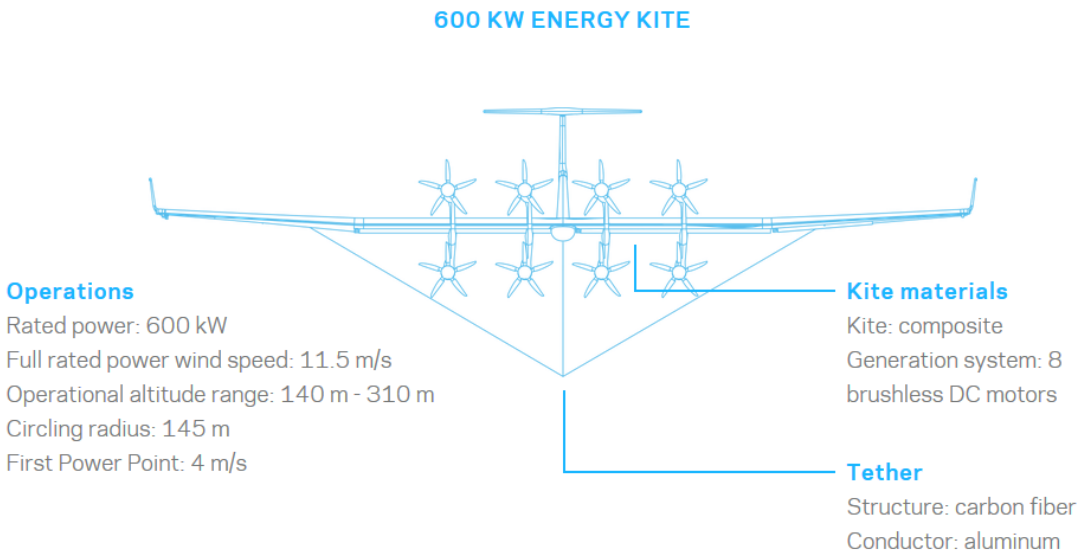

Figure 2: Illustration of the Makani Google Wing [2]

Figure 3: The Makani Google Wing in action [3]

3.3 NZ Institute of Architects Future Islands Project

An example of a non-nautical composite project that was undertaken by Core Builders Composites is the Future Islands project, designed by the NZ Institute of Architects. The works were created as part of an exhibition in Venice, Italy. Core Builders Composites was selected to construct the islands due to its significant experience in composites manufacturing and its ability to machine organic shaped moulds using its advanced CNC machining equipment. Interestingly, the material that was used for some parts of the construction was a new form of organic hemp fibre, which was selected for its lower environmental impact. This lead to some difficulties in the manufacture of the pieces, however the experienced technicians soon found a remedy to enable the alternative material to be used. Recycled carbon "chop matt" fibre is used during the build of moulds whenever possible, as high strength is not needed for this application. The company makes every effort to reduce its environmental life-cycle impact of its products and seeks to be economical wherever possible.

Figure 4: A depiction of the Future Islands on exhibit in Venice, Italy [4]

Figure 5: Future Islands Seat built at Core Builders Composites [5]

3.4 Additive manufacturing technologies

Core Builders Composites is interested in the applicability of rapid prototyping through the use of 3D-printing technologies in its construction activities. At this stage, the use of additive manufacturing for large parts such as tools for the moulds of an America's Cup boat's hull is in its infancy. Nonetheless, the company recognises the importance of this emerging technology and its potential to revolutionise its manufacturing. The company at this moment in time is heavily invested in manufacturing processes involving large CNC machining and the employment of skilled composite technicians to laminate the composite materials to create complex geometries. It is keen to maintain its standing as a high-tech composites technology and machining company. As such, 3D printing has taken place on site to rapidly prototype small components in ABS plastic, such as control boxes for the hydraulic control systems on Oracle Team USA AC50 racing yacht. This provides an easy and cost effective method of checking fits and tolerances of the component to be integrated into the boat, prior to manufacturing using conventional milling methods from high strength materials which have an associated high cost, such as titanium. External suppliers have also been called upon for metal components, such as a metal powder-sintering part made from titanium, which will be situated at the bottom of the rudder of the AC50 to connect the hydrofoil platform and allow easy height adjustment.

4. Staffing Issues and Management

4.1 Employee and management structure

Tim Smyth, who has been the co-construction manager since 2001, leads core Builders Composites. Over this time, Tim and his partner Mark Turner have managed the construction of all of Oracle Team USA's International America's Cup Class Yachts, including USA 71, USA 76, USA 87 and USA 98. They also constructed the trimaran USA 17 and the foiling AC72 catamaran that won the 2010 and 2014 America's Cup Regatta, respectively. Mark looks after the shore crew team, responsible for assembling and maintaining the racing yacht in the location where the racing is taking place. The team base is currently in Bermuda, where the next America's Cup will be held in 2017. Tim chooses to remain at the main construction site in Warkworth, New Zealand, supervising the build phase of the boats. As a student mechanical engineer, I fall under Composites Engineer Susan Lake and the mechanical engineering and design team on each project I was assigned. Table 1 below displays the management hierarchy of Core Builders Composites.

Table 1: Core Builders Composites Management structure

<table>
<tr><td colspan="3">Co-Construction Manager</td></tr>
<tr><td>Composite Engineer</td><td colspan="2">Project leader</td></tr>
<tr><td>Mechanical Engineers and Designers</td><td colspan="2">Naval Architects and Designers</td></tr>
<tr><td rowspan="2">Team Leader</td><td>Composite technicians</td><td>CAM operators</td></tr>
<tr><td>Boat builders</td><td>Machine shop engineers</td></tr>
<tr><td colspan="3">Student Mechanical Engineer and Apprentices</td></tr>
</table>

4.2 Personal Relations

Core Builders Composites has developed significant expertise in the areas of advanced composite design and construction in the competitive environment of the America's Cup. It is a worldwide leader in high performance composite innovations for high stress applications. The success of the Oracle Team USA Racing team also attracts acclaim for the company.

Accordingly, tours of the factory were often being conducted in order to share this specialist knowledge with other companies in the fields of aerospace, renewable energy technologies, transport, architecture, art and composite materials research.

4.3 Industrial Relations

The vast majority of projects at Core Builders Composites were completed entirely in house. Core Builders maintains a very good relationship with its major composite materials supplier, Gurit. They supply most types of carbon-fibre weaves that are employed in construction, as well as structural cores, adhesives and resins involved in the construction processes.

The Bermuda 2017 America's Cup authority has introduced measures to attempt to reduce the cost of construction of an America's Cup Yacht and to reduce the differences in yachts that result from greater budgets for research and development. The intention is akin to that of Formula One's ruling authority, where the boats would be more similar and more of the outcome of the racing is based on the skill of the yachtsmen, rather than technological advantages. In line with this directive, a common design platform was introduced for the major parts of the yachts in an effort to reduce the potentially large engineering and design costs. The basic structure of the yacht is common to all of the teams, however the control systems and critical hydrofoils are unique to each team.

This ruling has worked in the favour of Core Builders Composites. While it is committed to Oracle Team USA, the expertise and experience of the CBC team has meant that it has been able to secure contracts with other teams to build the common elements of their boats under the new class rulings. As such, CBC is currently manufacturing the complete Softbank Team Japan boat as well as the wings for Artemis Racing (Sweden) and Groupama Team France. It has also capitalised on its trusted reputation to help with the build of moulds for its arch rival Emirates Team New Zealand, which is manufactured by Cookson's Boats in Auckland, New Zealand.

4.4 Human Aspects

Core Builders Composites employs 50 people at its Warkworth construction site. In accordance with New Zealand employment law, workers were allowed two 15 minute smoko breaks and one 30 minute lunch break. Interaction between the top levels of management, design, engineering and construction teams made for a positive and open work environment where innovation could come from all levels of the employee hierarchy.

4.5 Health and Safety policies

New staff members undertook a full health and safety introduction at the commencement of their employment. A tour was conducted of the site and new employees were shown where personal protection equipment could be found, such as safety glasses and hearing protection for use in the workshop, as well as emergency exits and fire alarms. Specialist training instructions were given for each tool available to use. For more involved composite construction processes, more heavy-duty equipment was also available, including 3M full-face protective masks with air filters and 3M protective suits. The company paid for certain employees to receive appropriate training for other machine operations, such as forklift licenses and training courses. The factory incorporated dedicated grinding and machining bays with extraction fans to prevent avoidable exposure of the workforce to dust and noxious fumes.

The company employs a dedicated health and safety manager to ensure that a safe and productive work environment is maintained. Should any accident have occurred, first aid kits and eye baths were situated around the factory and the injury would be recorded immediately in the health and safety and ACC register to prevent the incident occurring again. Industrial cleaners and other resins and hardeners used during the construction processes presented a significant fire risk. Keeping flammable chemicals in isolated steel cupboards and having spill kits, fire extinguishers and a full fire alarm system installed around the factory mitigated this risk.

5. Work Performed

5.1 Overview

The mechanical engineering student completed a variety of professional engineering tasks over the summer internship period. These included computer based assignments utilising Microsoft office products for weight tracking tasks and 3D CAD modelling using the Rhino solid modelling software package. Design and build skills were also employed to assist with research and development testing tasks. The majority of the student's time was spent designing a purpose built clean room and managing the installation of the Eastman S125 CNC machine to facilitate the cutting of complex shapes of carbon fibre cloth prior to laminating. This was an important project for the company as it had invested over $100,000 in the machine in order to help make the build phase of the America's Cup class yachts, or other projects, more efficient. It was therefore of paramount importance that the machine was set up for optimum usability and speed of operation.

5.2 5-axis CNC machine room design and installation

The principal task completed by the engineering student was the design and installation of a purpose built clean-room to house a new Eastman S125 Static Table Cutter CNC machine. Figure 6 below is an illustration of the complete CAD engineering drawings of the designed-for-purpose clean room that were completed during the design phase of the project. This was completed using the Rhino solid modelling software package.

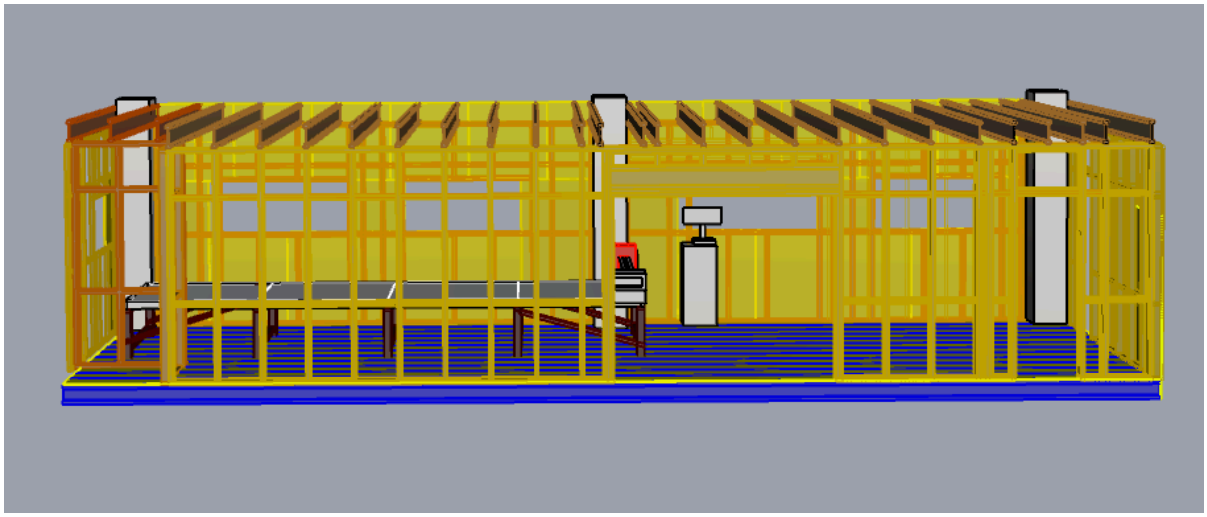

Figure 6: An illustration of the CAD design completed for the clean-room by the student

Significant consideration was given to the usability of the CNC machine while designing the room. It was positioned for easy access to the 230 V 3-phase 50-hertz power supply that was necessary for the machine to operate. Figure 7 below is an illustration of the Eastman S125 CNC machine ordered by Core Builders Composites and installed by the student.

Figure 7: The Eastman S125 CNC cutting machine [6]

The Eastman table incorporates a vacuum blower system that operates a series of vacuums on the table surface that are specifically positioned to hold the part that is being machined securely in place. Typically, the vacuum blower assembly is positioned under the machining table surface. However, in this case a redesign of the system was undertaken and the blowers were situated outside of the room to minimise noise and heat produced during operation. Figure 8 below is a depiction of the vacuum blower system arrangements available for the table. They are manufactured by Cincinnati Fan Corporation.

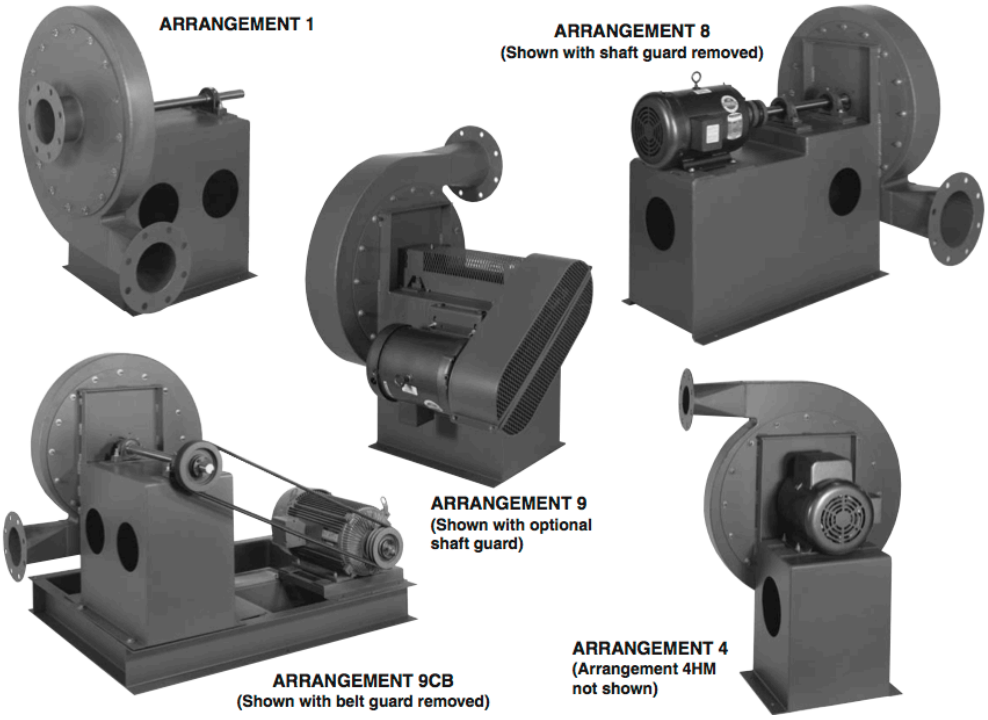

Figure 8: Vacuum blower fan arrangements

The room was constructed from 4 mm ply and 3m x100 mm x 50 mm sections of wood. Polystyrene foam previously used for mould fabrications was recycled and used as insulation for the walls and ceiling of the room. A Mitsubishi heat pump was installed in the room to ensure the comfort of the workers. Every effort was made in the design of the room to maximise the efficiency of the workers in the room and also of the machine. It is important to have good temperature control of the work environment when manufacturing composites in order to prevent expansion or contraction of the parts and the resulting errors that can occur during machining. Consideration of the environment was also a factor and the room was designed with insulation to minimise the effort of cooling and heating the room and the resulting long-term energy costs.

5.3 Weight tracking

Microsoft Office Excel program was employed to complete this section of the professional work internship. Weight tracking consisted of using a very accurate set of scales to measure and record the weights of all components that are fabricated for inclusion in the America's Cup Class Yachts. The student completed weight tracking assignments for the wing components of the America's Cup Teams Groupama Team France, Softbank Team Japan, Artemis Racing (Sweden) and Oracle Team USA, all of which were being constructed at the Warkworth Core Builders Composites construction site. Accuracy was a key component of this important task. The data for the weights of all the parts is collected by the America's Cup ruling body and compared for discrepancies. It is a class rule that all yachts must use pre-specified weights of carbon fibres and other materials, and must be the same overall weight, plus or minus a specified amount to allow for manufacturing tolerances. The lighter and stronger the construction, the faster the boat. Knowledge of how to make the boats lighter and faster using advanced materials technology and construction techniques exist,

however the ruling body has made an effort to make all boats as similar as possible in this cup campaign. This is to ensure that costs do not become a barrier for new teams to enter the competition and to provide a platform for the racing to be as competitive and as exciting as possible. This is a challenging proposition for the design and engineering team who must concentrate on the design of the dagger-foils and control systems in order to maximise the competitive advantage of their teams' boat.

5.4 Research and Development

A portion of the student engineers' professional work assignments included conducting testing on components of the dagger-board parts of the AC45S and AC50 yachts for high stress applications. Although expansion and contraction are not a major issue in the manufacture of composites, flexing and stressing can be a big concern. The nature of the tests that were conducted involve confidential information that is sensitive to copying from other teams stills undergoing design testing. As such, it is not discussed further in this report. Other research that was conducted in this department involved investigating key product quality issues including exposure to ultraviolet radiation, weathering and durability, all of which are highly applicable for racing yachts in the marine environment.

5.5 Comparison to 2014-2015 summer work

The work completed at Core Builders Composites for the second summer period over the 2015-2016 summer break built upon the knowledge and respect earned over the first summer. However, there were a number of new learning experiences for the student in different departments of the company that ensured that the work experience was valuable and different from the first period of work.

The first summer's work was very practically orientated and provided an excellent pathway into completing professional work assignments. The second period of work required computer skills to be employed and problem solving skills learnt in design courses to be applied, especially in the design of the purpose built clean room for the 5 axis CNC machine. Technical skills were honed in terms of CAD drawing and data analysis using excel spreadsheets. Additionally, the project management of the construction of the room and the installation of the room provided an opportunity to build on the people and relationship skills developed in the first summer. The responsibility of this project and the associated needs to meet time restrictions will prove to be excellent experience for the student engineer in his future professional career.

5.6 Constructive criticism

Overall, Core Builders Composites is an exciting and innovative company. The significant challenge of creating a boat that will be fast enough to win the America's Cup requires a well coordinate team of passionate people who are committed to finding a high performance solution through technical expertise. As such, the company maintained a very positive working culture with people from a variety of backgrounds brought together to tackle a common goal. The nature of the competition means that there are significant project milestones with deadlines that cause stress to the team, particularly if part of the

construction schedule does not go exactly to plan, as can happen with untried techniques. The company paid very good attention to the health and safety of all its employees, however when under the stress of these time deadlines some shortcuts were very occasionally taken which could have been deemed to be riskier than necessary, such as in the transport of heavy parts using forklifts or multiple workers lifting a part. The success of the team in this high pressure environment is indicative of its commitment to design and innovation, a positive company culture and the ability to muster the collective efforts of a broadly skilled team in a safe and efficient manner.

6. Conclusion

The professional engineering internship completed over the 2015-2016 summer work period afforded a number of key learning experiences for the student. A variety of assignments were completed, of which the most notable were the design and installation of a built-for-purpose 5-axis CNC machining room, weight tracking of America's Cup Yacht components as well as research and development tasks. The knowledge and relationships developed over the preceding summer were developed further and were proven to be an effective platform for new challenges in terms of design and responsibility to be undertaken.

The student gained a first-rate appreciation of the scheduling and project management necessary to complete a team project within time restraints. An insight of this was provided in the form of the high pressure America's Cup Competition environment, which was an excellent example. Undoubtedly this exposure and the associated learning experiences will be a landmark at the beginning of the student's career and will prove to be invaluable in the professional environment of the future.

7. References

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I hereby certify that this report, except where indicated, is entirely my own work.

Signed:

George Legget April 4th, 2016