South Metropolitan TAFE
Munster Campus

Applied Engineering

AGV Mecanum Platform

Advanced Diploma in Engineering - Mechanical

	Author	Student Number (I.D)	Date
1.	Bryce Richards	P136265	
2.	Robert Williams	P445885	
3.	Cyprian Sino	P241310	
4.	Gurkaran Singh	M234676	
5.	Purnima Samararatne	M227958	
6.	Zixiao Tang	M234547	
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Abstract

Written by Gurkaran Singh.

The report documents the design project of the AGV Mecanum Platform to be made at South Metropolitan TAFE. The platform is an autonomous vehicle which will be capable to lift the lab equipment and relocate it within the set perimeter. The platform capable of lifting 1 tonne uses bolt screws connected to a motor to lift the platform and has four Mecanum wheels which are independently controlled by four electric motors, giving the AGV an ability to move in any direction without turning the wheels.

The design process involved individual team members working in tandem to produce a final collaborative product. One team member worked on the wheel, another on the chassis, lifting mechanism, etc.

The project was concluded with a final mechanical design which was partially prototyped.

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Introduction

Written by Bryce Richards.

In the manufacturing industry the use of automation is growing, especially in the world's industrialised societies. This is largely due to the ever-increasing labour cost in these areas of the world. Equipment components are typically referred to as 'automated' because they perform their operations with a reduced level of human participation compared with the corresponding manual process. In some highly automated systems, there is virtually no human participation.[1]

Common benefits of industrial automation include:

- Increased labour productivity
- Reduced labour cost
- Mitigated effects of labour shortages
- Reduction/elimination of routine manual and clerical tasks
- Improved worker safety
- Improved product quality
- Reduced manufacturing lead time
- Accomplishment of processes that cannot be done manually
- Competitive advantage

The purpose of this report is to detail the collaborative design project performed at South Metropolitan TAFE over the 2017-2018 period. This project was focused on design of an AGV platform for use on campus. The report will describe what AGV Platforms are, the design concept for the project, design problems and their solutions, and the design process itself. It will finish with a discussion of the final state of the project and recommendations for future work.

AGV Platforms

Written by Bryce Richards.

AGV platforms are a branch of automatically guided vehicles commonly used in industrial environments. These platforms are typically rectangular, and have an integrated lifting mechanism used for 'work-in-process' movements. Work-in-Process movement is an application wherein AGV's can be used to move material from the warehouse to production/processing lines or from one process to another.[2] A typical AGV platform is rated for a low maximum payload relative to its size, is powered electrically via on-board batteries, and with prices ranging up to $30,000USD for units capable of lifting 500kg.[3]

Design Concept

Written by Bryce Richards.

The Mecanum AGV will be capable of automatically transporting a lab from the storage room to the fluids laboratory, or from the fluids laboratory to the storage room. There will be a number of specified pickup and set-down locations in each room. A user will select a 'From' and 'To' location and the Mecanum AGV will transport the lab accordingly.

Design criteria were as follows:

- Maximum dimensions will be 795mm(W) x 800mm(L) x 250mm (H)
- Maximum rated capacity of the Mecanum AGV will be 1000kg
- Maximum speed of the Mecanum AGV will be 3kmph
- The maximum exposed incline on which the Mecanum AGV will operate will be 1°
- The maximum lift height of the Mecanum AGV will be 100mm
- The location Mecanum AGV will be accurate to +/-25mm

All technical drawings will be to AS1100.

Problems associated with the design

Written by Bryce Richards and Robert Williams.

Client amendments were a major problem during the project. These were difficult to manage as the original project team did not develop a formal scope document or Gantt chart. These changes included:

- Change to maximum payload from 500kg up to 1000kg
- Changes in scope to the operating environment of the AGV
- Late addition of IP65 requirement (waterproofing)

Lack of administrative project management was a problem. As above, the original project team did not develop a formal scope document or Gantt chart. These were developed in the 16th week of the project, at which point these were developed and rolled out.

An issue associated with the design was the choice of the initial lifting system. Initially a pneumatic lifting system was chosen, this consisted of an airbag with an on-board compressor. This options was chosen for its ease in installation and maintenance, its high capacity and cost compared to other systems. The airbag recommended by the supplier for our purpose is shown in FIGURE A. On further discussion with Michael Wernik a price of $397 for the airbag and $348 for the compressor. There is no official quote from this supplier as it was received over the phone, but the email correspondence is shown in FIGURE K.

The issue that arose with this system was learning from the supplier that an on board receiver would be require as the compressor would not be capable of sustaining the lift, as the volume of the airbag at 100psi and full lifting height is 4 litres, a receiver with an 8 litre capacity was required, as the compressor could only be used for filling the receiver. This was an issue as the client scope was to fit through a standard door frame, meaning the maximum length and width could not exceed 1000mm x 800. The Supplier sent through receivers shown in FIGURE L. On further inspection of this it was found that it was not possible to fit a receiver and keep within the scope size limits. For this all options were exhausted, one option was to use the SHS as a receiver but this was deemed unfeasible due to the cost of pressure testing and the complex welding involved. This then resulted in a redesign of the lifting mechanism, as the implementation cost of the pneumatic lifting mechanism outweighed the cost of a redesign.

Design Components & Material Selection

Mecanum Wheel

Rollers

Roller designed by Robert Williams

One of the first tasks on this project was to design the Mecanum Wheel, one major part of this design was the individual rollers as this can have a huge effect on the stability of the vehicle. If the mecanum wheel is not a complete total circle it can cause a rough and bouncy drive. Due to the fact that in the initial scope the vehicle was to lift 500kg and then increase to 1000kg, the even drive of the vehicle was a major concern as the instability of the load would pose a risk to pedestrians. A Risk matrix in figure was used to analyse the risk of an uneven drive, form the matrix below it was deemed the risk of an uneven drive was deemed as a medium risk due to the maximum lifting height being a maximum of 80mm, to ensure safety the wheel was designed to minimise this risk.

Risk Matrix

Consequences \ Likelihood	Very Likely	Lively	Unlikely	Highly Unlikely
Fatality	High	High	High	Medium
Major Injuries	High	High	Medium	Medium
Minor Injuries	High	Medium	Medium	Low
Negligible Injuries	Medium	Medium	Low	Low

Likelihood

- **Very likely** (exposed to hazard continuously).
- **Likely** (exposed to hazard occasionally).
- **Unlikely** (could happen but only rarely).
- **Highly unlikely** (could happen, but probably never will).

Consequences

- **Fatality**
- **Major or serious injury** (serious damage to health which may be irreversible, requiring medical attention and ongoing treatment).
- **Minor injury** (reversible health damage which may require medical attention but limited ongoing treatment). This is less likely to involve significant time off work.
- **Negligible injuries** (first aid only with little or no lost time).

Figure 1.1 Risk Matrix [4]

Initially using a standard ellipse in the design of the roller incurred problems as the gap in the roller was deemed to be too large and would cause issues with the stability of the vehicle. Through further research a method shown in FIGURE M,[5] with some trial calculations shown in the calculation section this method was inconclusive. Another method trialled was the use of AutoCAD and geometry to calculate the angel curvature of the ellipse and give a full shape of the roller, this method is shown in FIGURE N. This method proved most successful and was the chosen design strategy as it gave minimal spacing between rollers. Figure 1.3 shows the assembled mecanum wheel.

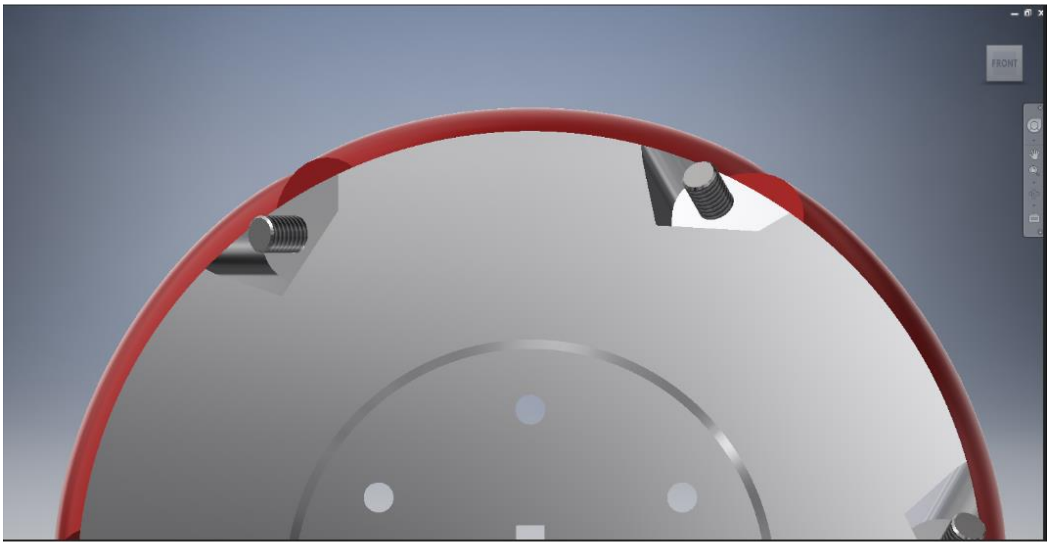


Figure 1.3 Mecanum Wheel assembly

One factor that was required by the client was to keep the number of rollers to a minimum of 6, this was required to keep manufacturing costs to a minimum. This impacted the design of the roller as the size and shape of the roller had an effect on the number of rollers in contact with the ground at any one time. Looking at off the shelf products, it is shown to have a higher number of rollers to ensure a larger contact area and a smooth drive.

With the designed shape of the roller bearing selection is important as the outer diameter is ⌀22mm and a 3mm gap between the bearing and the outer diameter is required. This gives a maximum ⌀19mm bearing size. The shaft diameter is 8mm, the bearing selection is shown in the calculations section. The calculation shown is for the initial scope of 500kg. The bearing selected shown in the FIGURE O is rated to handle the load capacity NSK bearing 698 ZZ was selected, the scope was then changed by the client to 1000kg. The increased capacity created a problem as the bearings selected are not capable of handling the load required. One solution to this was to redesign the roller but quotes were obtained from State wide bearings and BSC to have the unit price of the bearings, $4.50 + GST was the best price received. It was decided to then add 2 more bearings to each roller, 4 in total as there is no available bearing that matches the require criteria. Since the additional cost of the bearings are cheaper than the cost of a total roller redesign. The final roller drawing, and design is shown in the FIGURE P. Aluminium 6061 was the best material to use as it is lighter and cheaper than steel and has a UTS of 300 MPa[6].

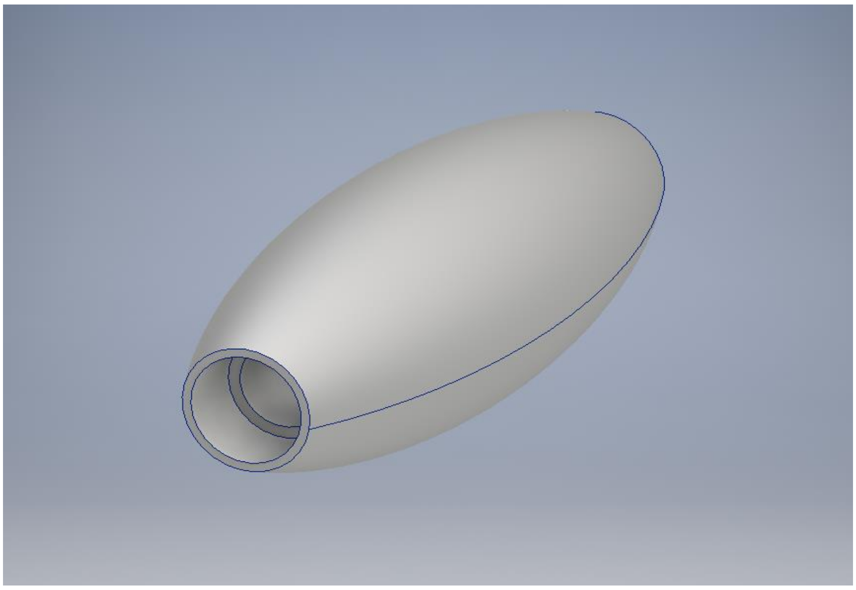


Figure 1.4 Final Roller Design

Polyurethane

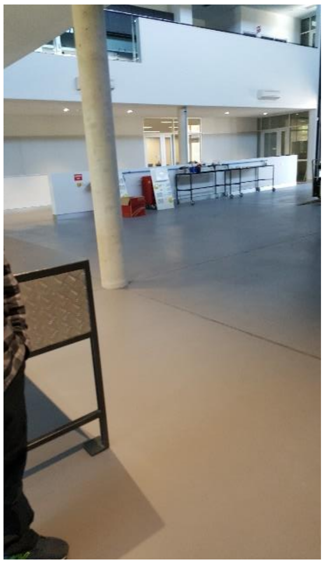


Figure 2.1 Photo of main working area for AGV

The main working area for the AGV is a concrete floor shown in figure 2.1, it shows a concrete floor. As the friction between the concrete and the aluminium roller is too low, a material with a higher coefficient of friction needed to be introduced to reduce slip on the vehicle. It was decided to cast the rollers with a 5mm coating of Polyurethane to increase friction and reduce slip. The hardness of the Polyurethane is an important factor, if the deflection of the material is too high the Poly will drag and reduce the efficiency of the vehicle, and if the Poly is too hard, the friction of the wheels will be too low causing the vehicle to slip. Using figure 2.2 below a hardness of 95 on the Shore a Durometer was chosen.

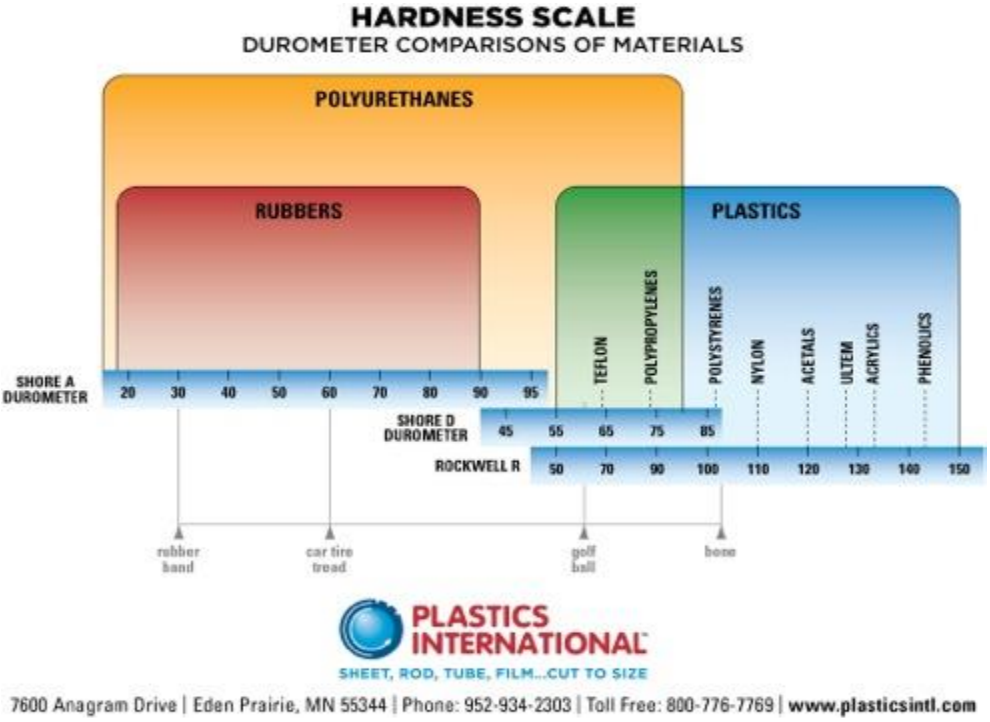


Figure 2.2 Polyurethane hardness scale

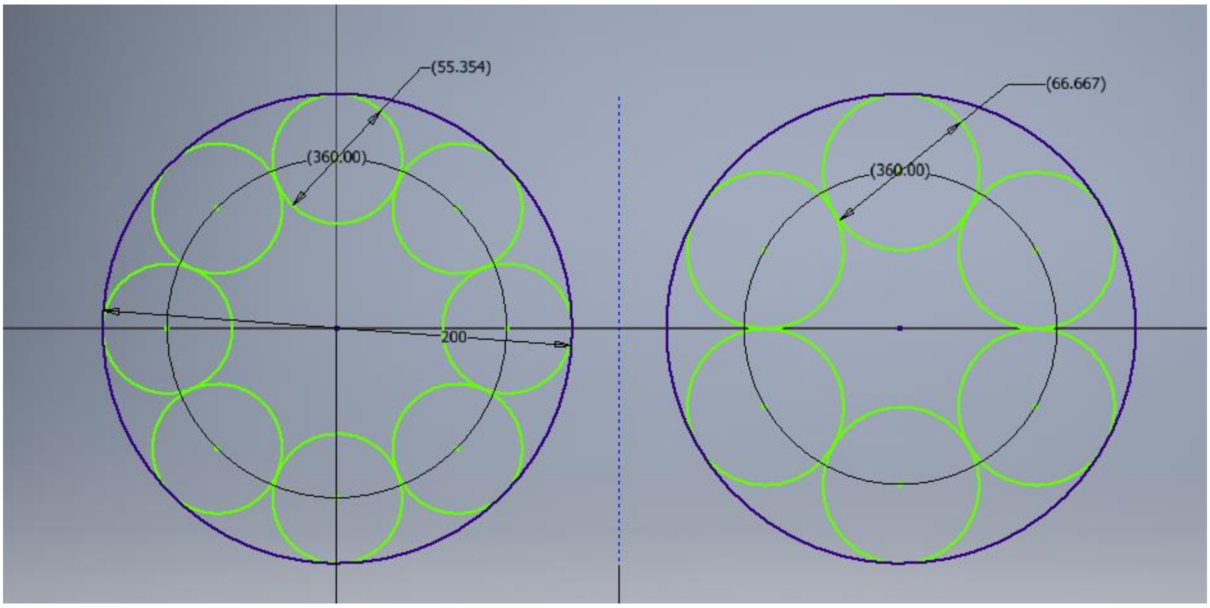
To reduce the cost of casting the rollers in Polyurethane the rollers will be given the elliptical shaping by in house machinists. By doing this the rollers will be cast in a cylindrical shape and given the final finish in house. This reduces the cost as there is no need for specific casting moulds to be manufactured.

Cheek Plates, Hub and Axles designed by Bryce Richards. Written by Bryce Richards.

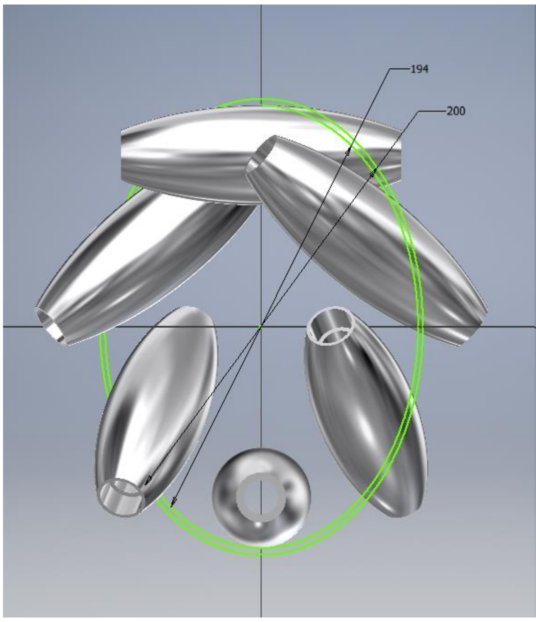
CHEEKPLATE.ipt

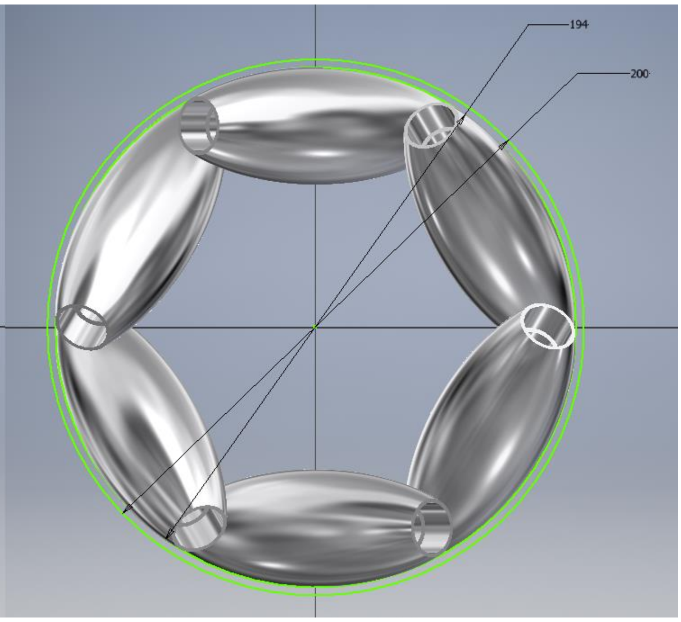
Design of the mecanum wheel itself took 13 weeks. Many designs were tested to ensure a 'bumpless' rotation. The typical mecanum wheel is designed with small gaps or height differential between rollers. This results in vibrations whilst driving, reducing equipment life and increasing operation noise. We elected to create a design with minimal/no vibration due to this design element. The initial scope was for a wheel with 6 rollers, 200mm diameter, 22mm bearings.

Ross Jarvis instructed us that there must be a minimum of 5mm clearance between rollers. Based on this we confirmed that the maximum roller diameter would be 56mm. This also locked in the 6 roller maximum. I have inserted an Inventor sketch below illustrating the geometry of these issues / decisions.



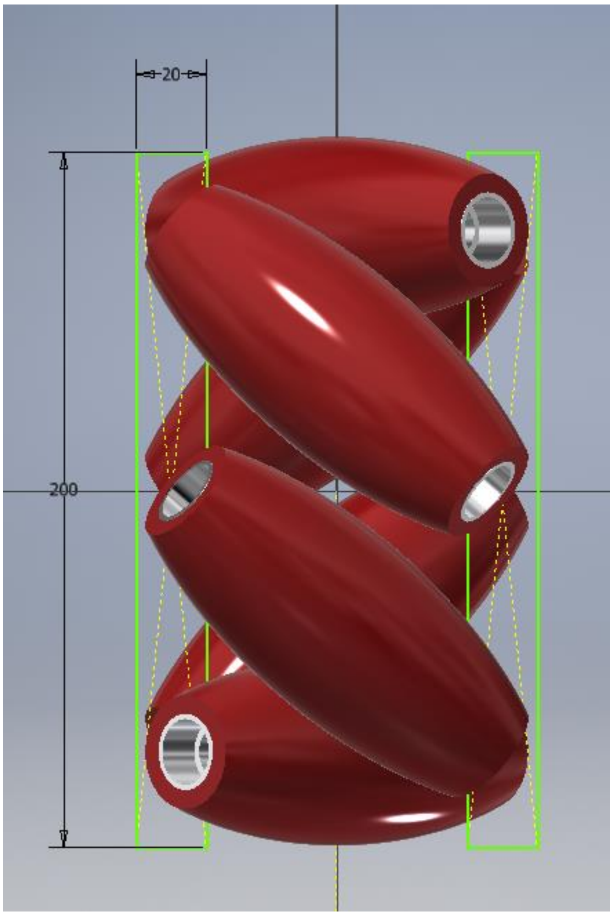
Following this I arrayed the 6 rollers at the design angle of 45° at a diameter which would effect a resultant 200mm as per the original scope.



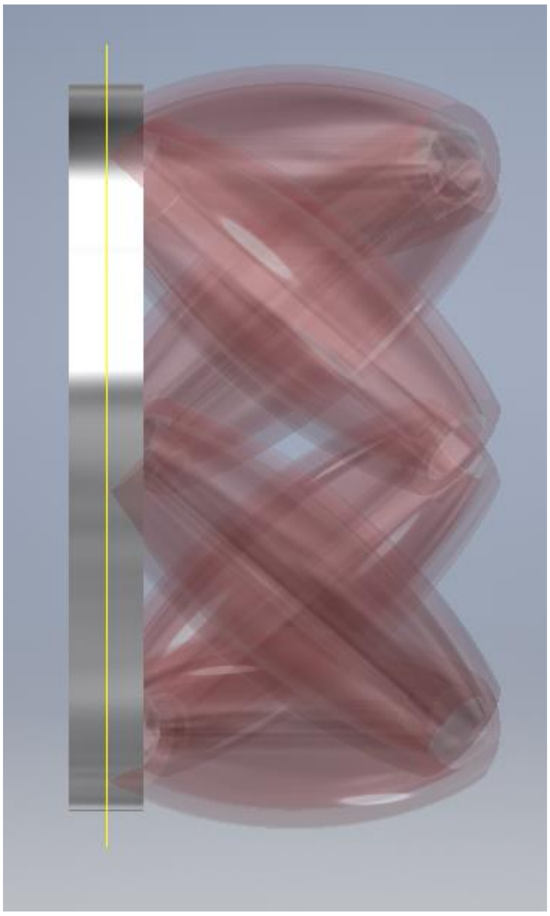


I then applied the Polyethylene cover to the rollers to get a final shape on the array.

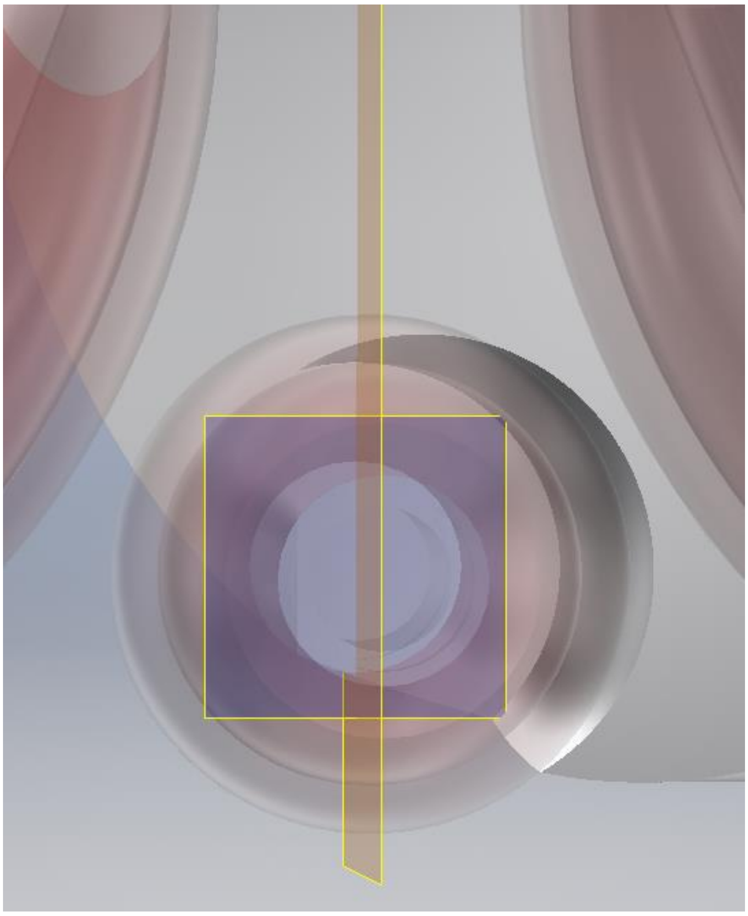
Next I checked with Adam Fiannaca (lecturer) and the thickest available aluminium plate would be 20mm. I superimposed a 20x200mm rectangle over the design to basically sight whether this was feasible for use in the cheekplate design. It was (not that the centreline of all shafts is basically contained within the green rectangles) so I proceeded to design the cheek plates.



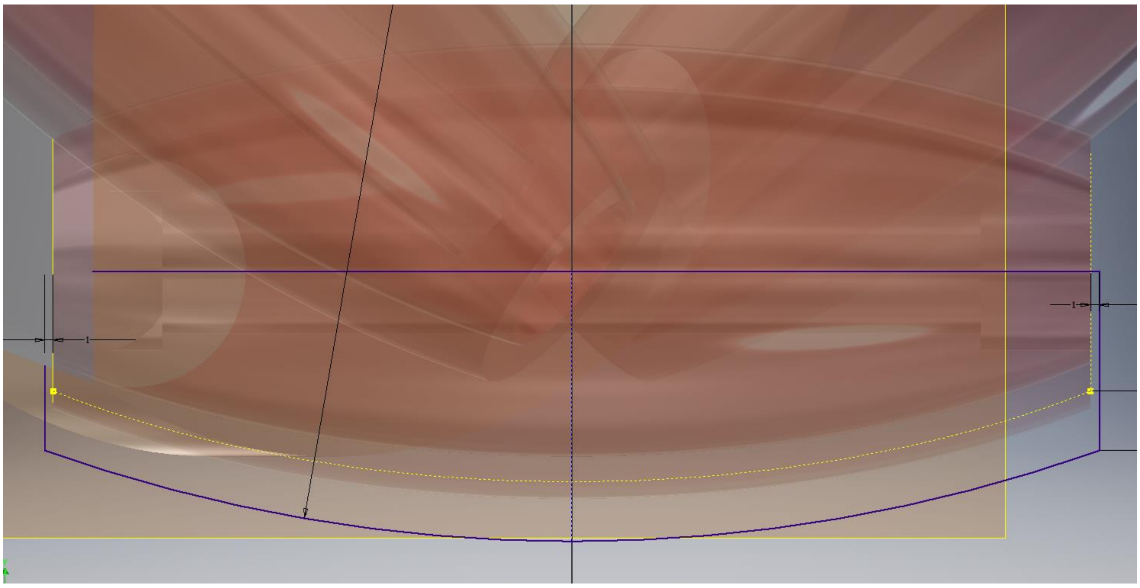
I then saved the above assembly and started a new *derived* part. The idea was similar to how I set up the rectangles in the above diagram. Now that we knew where the rollers would sit, build a circular plate in-context then cut out the shape of the rollers from that plate. This would ensure that everything remained aligned (as the geometry of the design was quite complex). As per the below I created an offset plane 50mm out from the XY plane (no real science, looked about right by eye, easy to move later provided I keep the design in-context). I then drew the 194mm circle on this plane (diameter of the rollers without polyethylene covers) and extruded to a total width of 20mm, centre-out. This created overlap between the rollers and the new plate which could be cut out of the plate later.



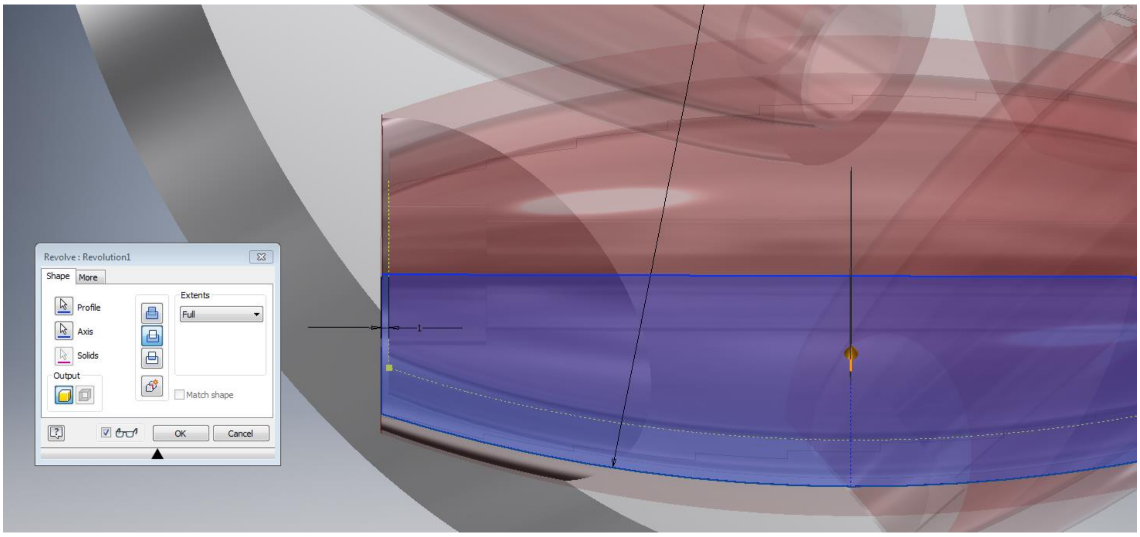
This next part was more complicated as I needed a plane down the middle of an angled roller offset from the centre of the plane space. I created a custom work plane on the face of the roller. By picking a roller which coincided with the Y axis this let me then create a midplane between the custom plane and Y axis. This plane was aligned with the centre of the roller.



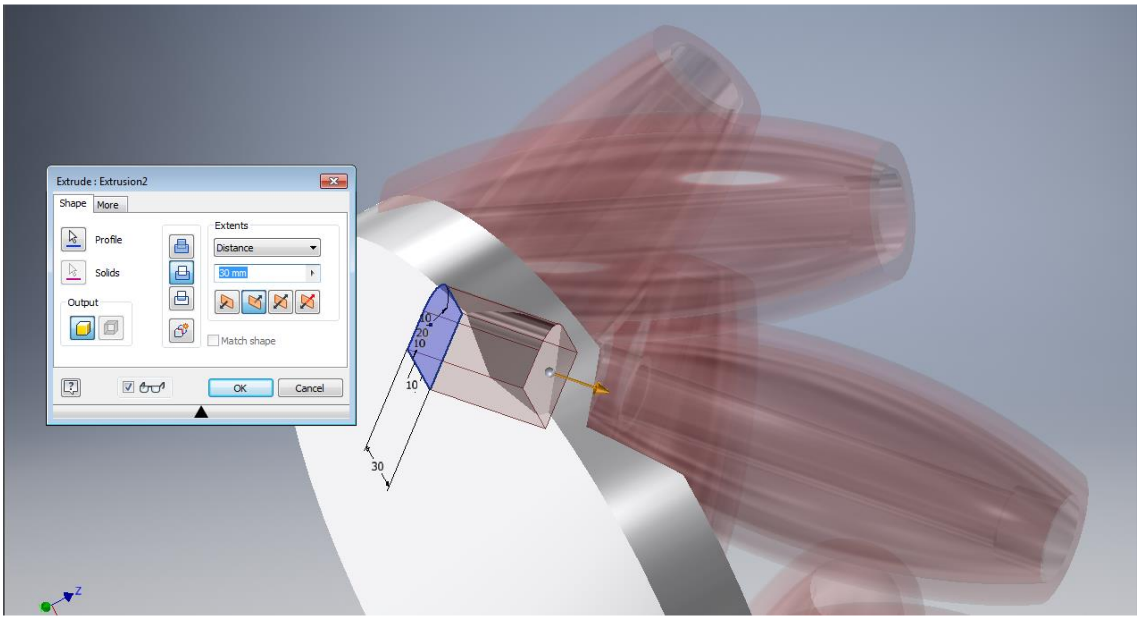
Next I drew the shape to cut out of the plate. This needed to be based on the geometry of the roller but with adequate clearance so that the roller could rotate inside of this cavity and not jam if small rocks or debris were to be caught. We held discussions with Adam Fiannaca and Ross Jarvis relating to this element of the design and we decided that 5mm of clearance along the curved surface and 1mm clearance on the face would be sufficient. I projected the polyethylene cover, offset that curve, and then made the requisite changes to create a fully contained polygon.



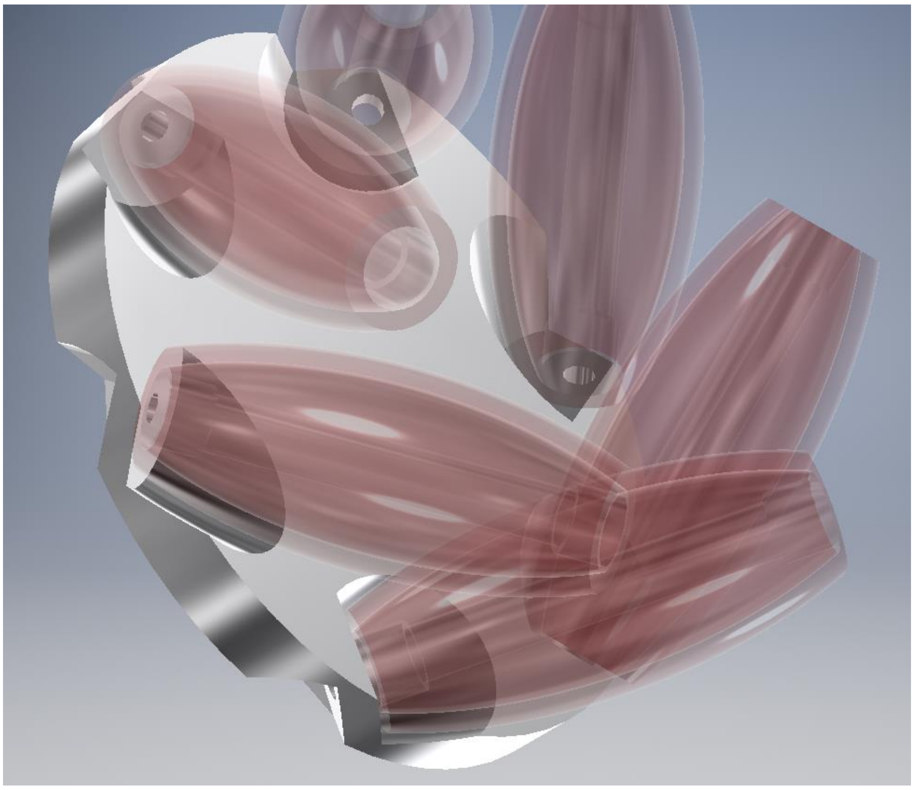
I then used the revolution tool to cut this shape out of the plate.



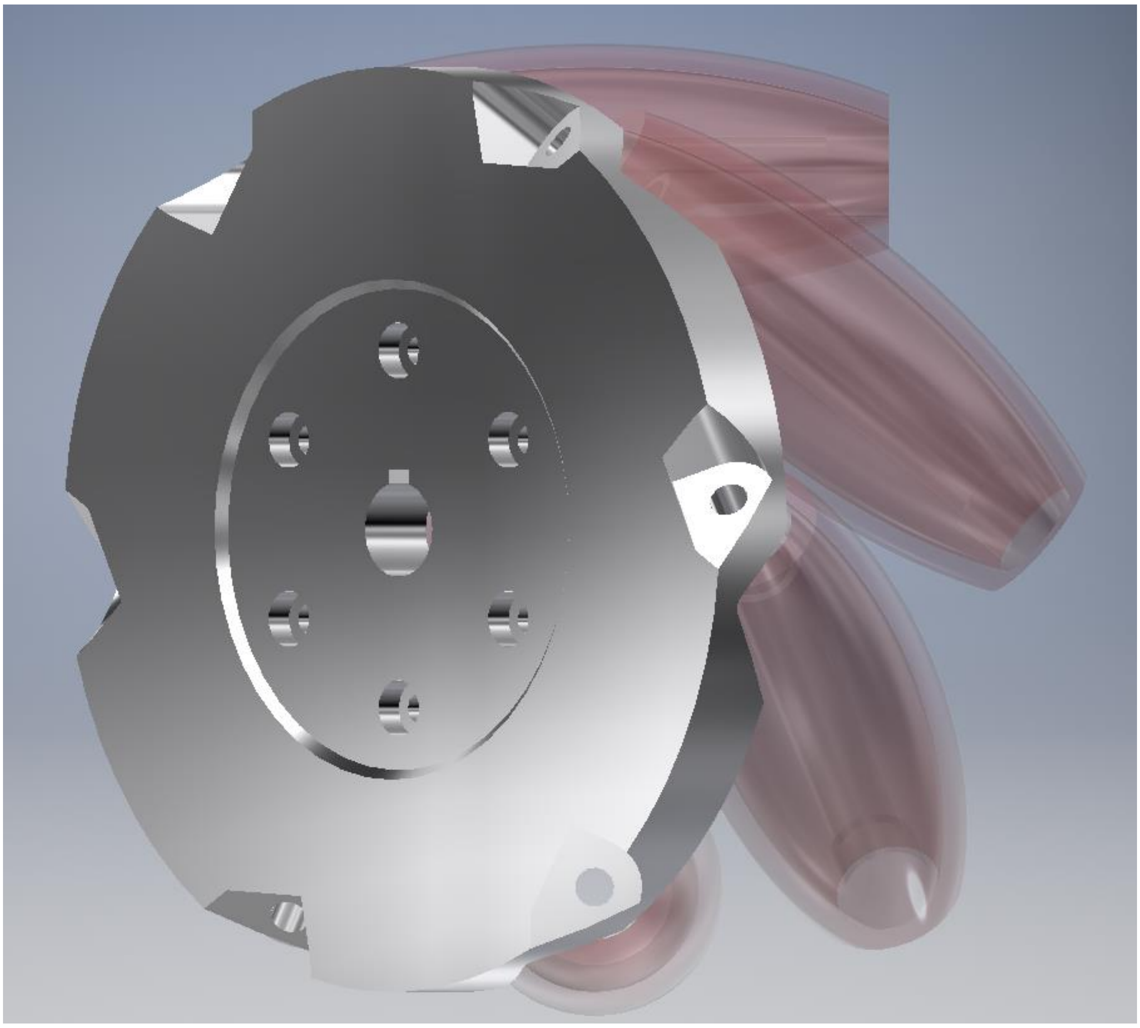
Next I offset the earlier custom plan out an arbitrary distance, drew a shape aligned to the roller axle, then extrude-cut back in to create a surface on which we could place a nut to secure the roller shaft.



I now used the circular pattern tool to create 6 of both cuts aligned to the face of each roller. The circle was the 194mm original plate extrusion.

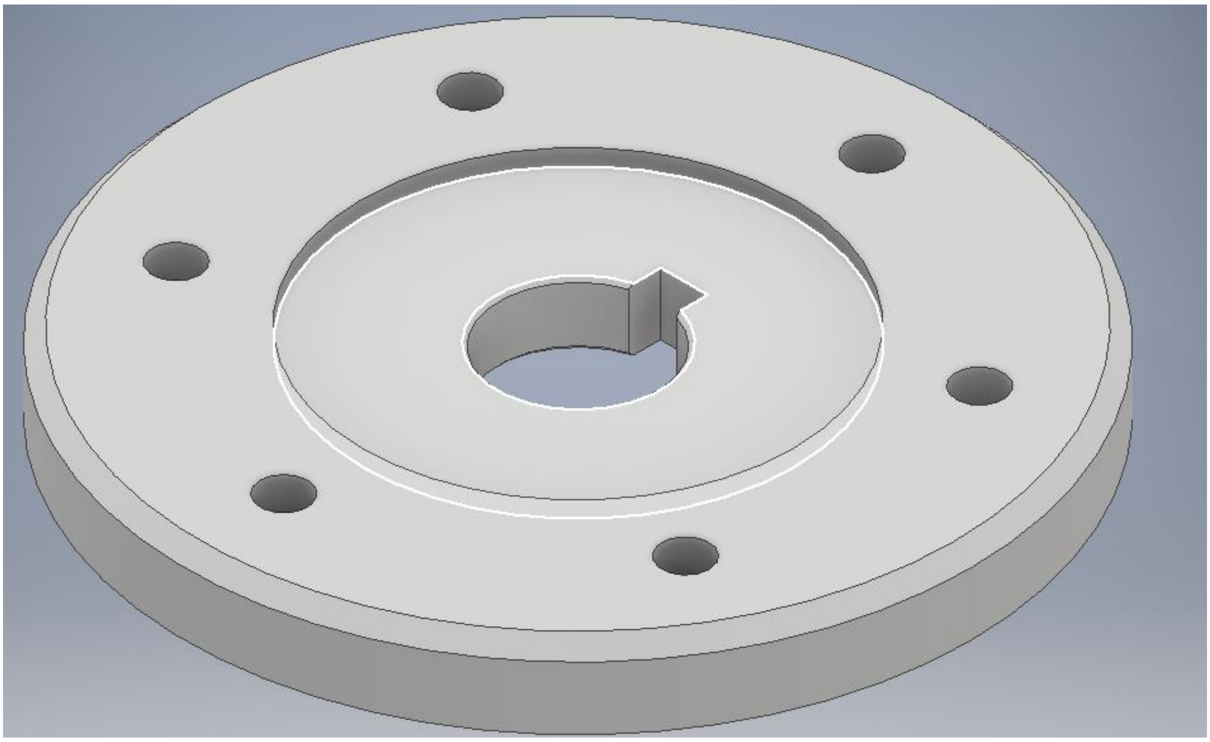


Finally I added mounting holes for the hub, a keyhole for the main axle, chamfers and radius as required. This concluded the design of the check plate. I also produced 2D drawings for quotation purposes.



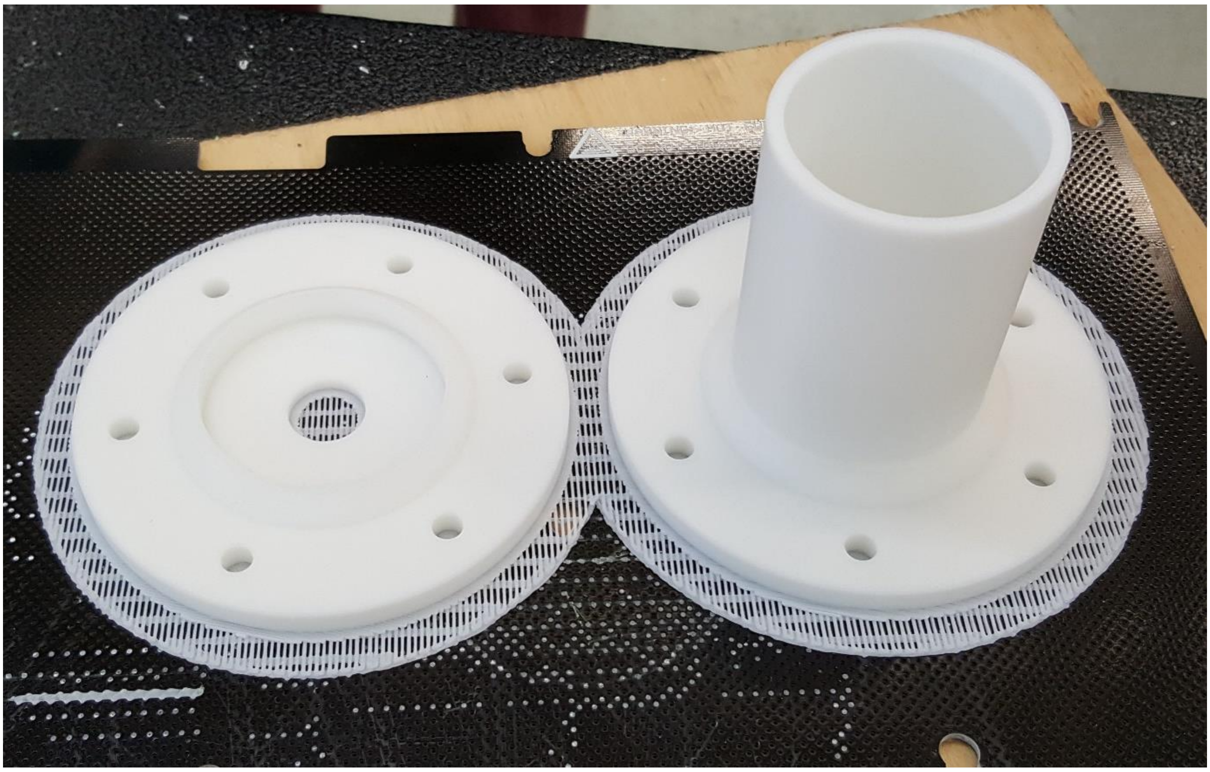
Hub designed and written by Cyprian Sino.

Hub design had to be done to suit the cheek plate and decision was to be made whether to produce a hub as a single unit or as parts. After choosing the material as aluminium we decided as a group to have the hub in three parts comprising two end flanges and a pipe in the centre which would be welded to the flanges.



The small step or recess on the ipt is where the pipe will be mounted and welded on. An stp file was created form this to enable for 3D printing when we produced the prototype wheel.

Fig. B is the drawing which l made for the manufacturing of this part, we used this drawing to get a quote for machining. All parts which needed to be sourced from outside we made drawings like the one above and send them for machining prize so as to determine our budget. All of the drawings were done to AS 1100 standards.



This is the hub after 3D printing and ready to clean and use on the model. The actual hub will have separate flanges which are going to be welded together onto an aluminium pipe of the same grade, in our case we are going to go for Al 6061.

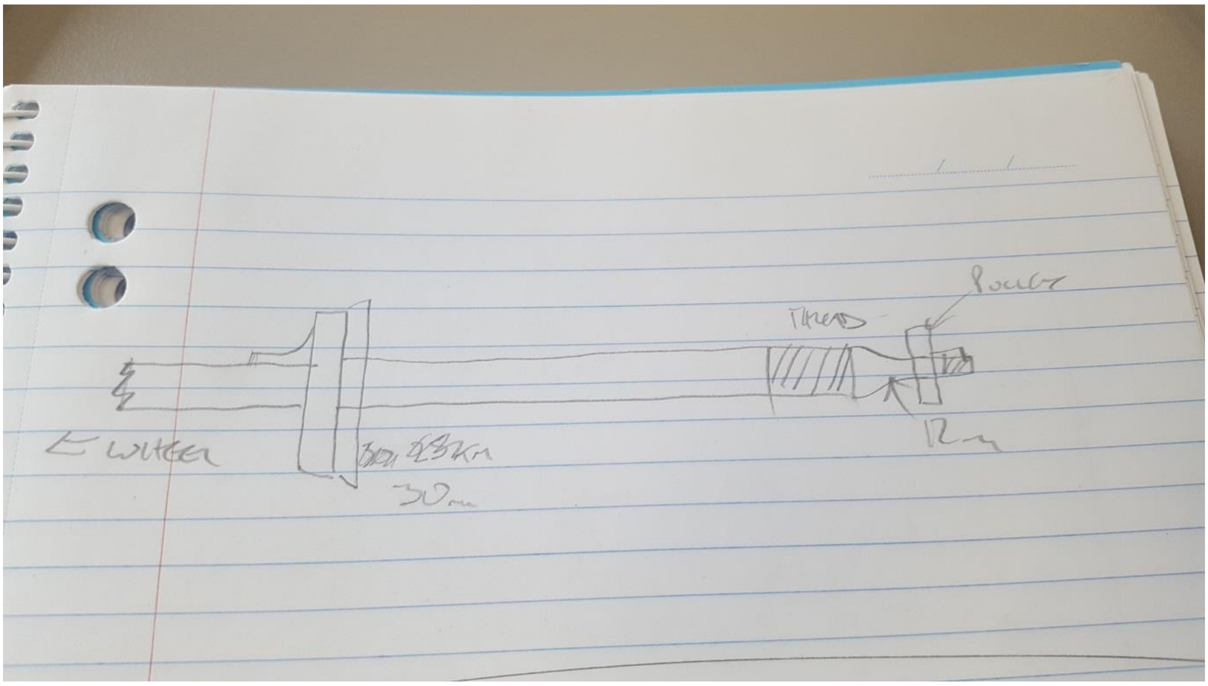
Wheel Shaft

Written and designed by Bryce Richards.

WheelShaft.ipt

Design of the wheel shaft (that is, the primary axle) was essentially predicated on the size of other components.

Initial ideation was performed by myself and Adam. We discussed creatively what method should be used to secure the wheel to the axle, the axle to the frame, and the axle to the drive system. The following is a sketch from that session:

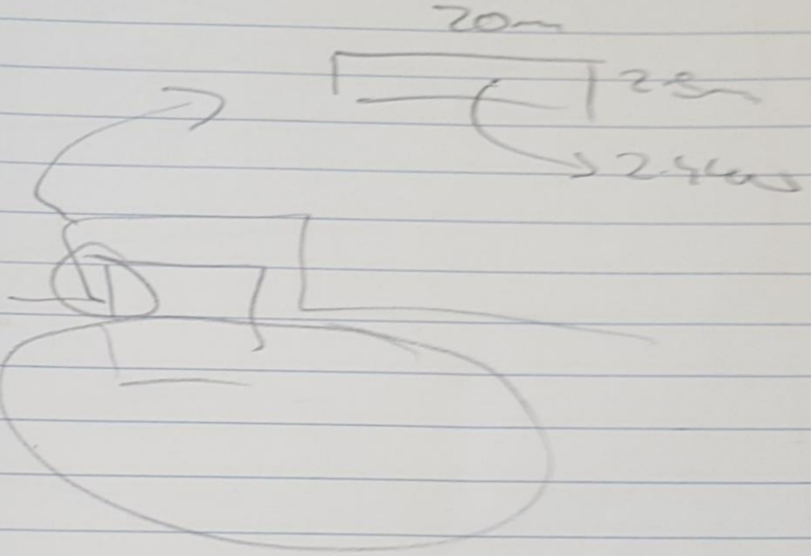


From here we sourced lengths for the wheel, hub and pulley and produced a technical drawing for fabrication. The shaft was designed with a standard 6mm x 6mm key for the wheel and 4mm x 4mm key for the pulley. As the cheekplate was made from 6061 aluminium we also checked the load mathematically to ensure that the plates would not compress / wear.

T / (D/2)

24 / (20/2)

= 2.4 kN



2400 / 0.02 × 0.0025

48 MPa => 241 MPa

480 => 120

Frame

Designed by Bryce Richards

Design of the frame was simple but with a number of dependencies. This was started early as a 'placeholder' due to the design being bottom-up with an understanding that there would be a need for later revisions as other parts such as the lifting device were finalised. At a basic level it needed to fit through the required doorway, under the platforms to be lifted, and stay rigid under the specified load.

All parts were designed to use standard sizes of mild steel SHS. This was due to high availability, low cost, easy recyclability, and ease of manufacturing.

MecanumChassis2.iam:

Based on the scope document the maximum size of the Mecanum AGV was 795mm (w) x 800mm (l) x 250mm (h).[8] These dimensions were used to create a simple wireframe and the Inventor Frame Editor was used to produce an SHS model. An assumption was made that the wheels would each be 125mm wide, therefore leaving 545mm of width for the frame. Design size was set to 800x545mm. Initially 45x45x1.6mm SHS was selected. An iterative process was used via which a size of SHS was selected, tested in the 'Frame Analysis' environment, then revised accordingly. The process repeated until a final selection was made of 35x35x1.6mm SHS which could tolerate the 500kg load with < 300MPa stress.

Two changes were necessary to the frame as the project progressed:

1.) Once the design for the wheel hub was finalised it became apparent that the full 545mm was not available. The width of the frame was therefore reduced to 515mm to allow space for outboard nuts on the axle.
2.) Late in the project Ross revised the scope up from a 500kg maximum payload to 1000kg maximum payload. Due to this it was necessary to increase the SHS thickness to 3mm.

LiftPlate.iam:

The lift plate followed the basic design of the chassis described above including late-stage reductions in width and increases in thickness. Design of this part was ultimately dependent on the lifting mechanism. The size of the gearbox for the lifting device determined the final size of the lifting plate – this caused the team to move the position of the legs of the lift plate to align with this device.

Following the above a group of 2D drawings were produced for fabrication. These were of the top and bottom of the chassis, and then the lifting plate (see figures A, B and C). These 2D drawings were used to cut and weld the selected 35x5x3mm SHS as required.

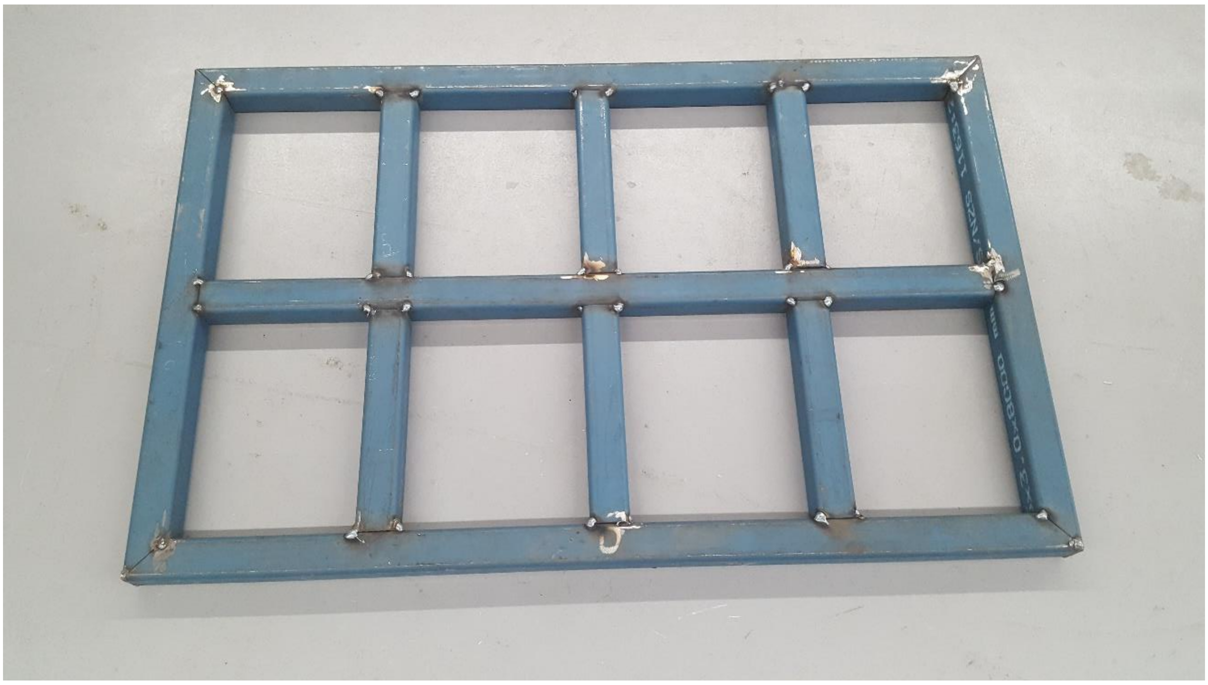
Cutting SHS to length:

Cutting SHS 45° angles:

Preparation for welding SHS:

Top frame welded:

Base frame welded:



Lifting Mechanisms

Electro-mechanical: Gearbox, motor, ball screw, bearings, linear rail, etc.

Place content here.

Designed by Bryce Richards.

The design of an electro-mechanical lifting system was iterative, due to issues such as parts availability and prohibitive costs. Initial part selection was of a screw jack. These are pre-fabricated worm-gears with integrated ball screws and lifting devices. They are used commonly in industry for high-precision positioning of heavy loads. Unfortunately these proved to be prohibitively expensive in the sizes we were looking for as they are simply not a common component (use case is very small). Price of the E-Series Power Jacks[ix] model was quoted at $2154.89 each[x], or $8619.56 for the set of 4 required for the design. Due to this we elected to not use an off-the-shelf component and design a device ourselves.

We had a group discussion (Bryce Richards, Robert Williams and Adam Fiannaca) regarding design of a custom lifting device. It was decided that we would use a worm gear (i.e. 90° gearbox) mated to a ball-screw. We had a maximum design height of 160mm and needed an effective lift height minimum 75mm.

Initially we looked at an inline coupling to a gear shaft. We selected a Ruland MCLX12-12-F[xi] for this purpose, but ultimately the coupled design proved larger than 160mm so we moved to a through-shaft design.

We looked at a variety of worm gears such as the Ketterer Worm Gear[xii], and the PBX-081[xiii], before ultimately deciding on the TIDEFEEL TS-58GZ868D[xiv]. This selection was due to the very low purchase price ($54USD) and simple design. Our intent was to remove the OEM output shaft and replace it directly with a machined ball screw.

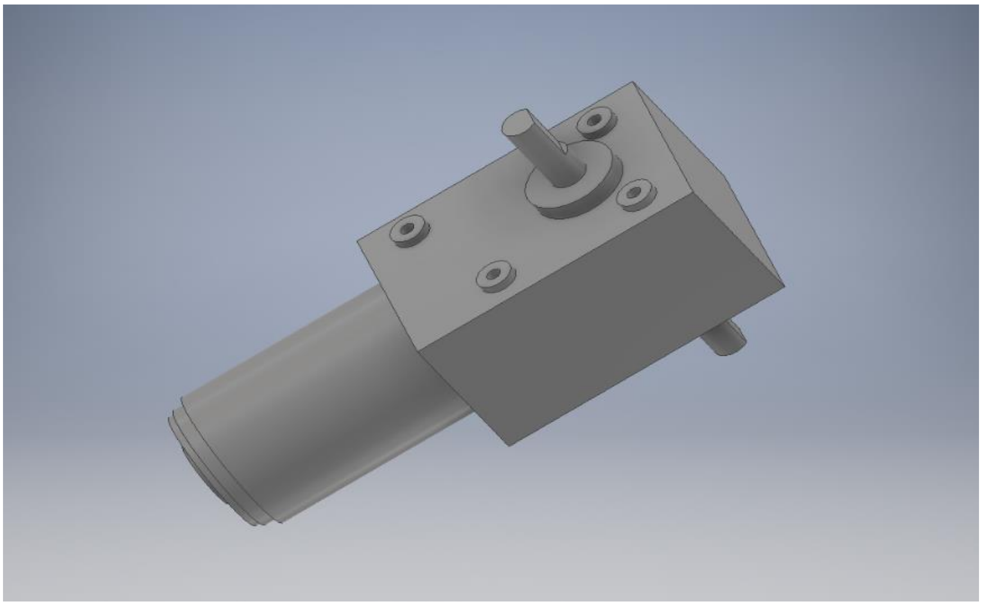
Lifting Mechanisms

Gearbox

Written by Purnima Samararatne (M227958)

To design the gearbox in inventor which later would be placed on the frames, we were looking for a high torque shaft gear box motor the one Bryce told me look for was a TS-58GZ868D this is a good motor as it can change the shaft rotation direction.

Also this gearbox has some good characteristics as the gearbox itself is in the shape of a rectangle it can easily be placed on our frames and with self- locking, the output shaft can’t rotate when the switch is off that is the self-locking. The website I was looking at gave me dimensions of the gearbox which I had to make 3-D version in inventor.



I applied some material to the drawing

Drive System

Synchronous Pulleys and belts

Designed and written by Cyprian Sino.

The design required for us to look into getting a small compact set of pulleys and belt with enough grit to move the AGV vehicle carrying 500kg upwards, so using the initial calculation on the excel chart on GitHub l set out to draw and produce an assembly which would fit on the already finished frame without moving the motor or wheels. The (f, x) parameter table below is the one l used to design synchronous pulleys. The user parameters helped draw a different size by just inputting numbers in the equation. The user parameters helped me come up with the correct assembly to fit into the fixed gearbox, motor and wheel assembly. This chart also helped me on my tooth design and moulding, l also got material from an attachment l uploaded on GitHub-mecanum doc (Catalogue for pulley and belt selection).

Parameter Name	Consumed by	Unit/Type	Equation	Nominal Value	Tol.	Model Value
Model Parameters						
d0	Flange2:da_D0, Flange1:da...	mm	da_z * da_pb / PI	39.788736		39.788736
d1	Pulley Sketch	mm	da_a	0.500000		0.500000
d2	Pulley Sketch	mm	da_hg	1.250000		1.250000
d3	Pulley Sketch	deg	2 ul * da_fi	50.000000		50.000000
d4	Pulley Sketch	mm	da_bw	1.800000		1.800000
d5	Base Body	mm	da_bf	17.500000		17.500000
d6	Base Body	deg	0 deg	0.000000		0.000000
d8	Tooth	deg	0 deg	0.000000		0.000000
d9	Tooth Fillet	mm	da_rb	0.400000		0.400000
d10	Tooth Fillet	mm	da_rt	0.600000		0.600000
d11	Teeth	ul	da_z	25.000000		25.000000
d12	Teeth	deg	360 deg	360.000000		360.000000
d15	Axial	mm	0 mm	0.000000		0.000000
Flange1:da_wf	Left flange	mm	da_wf	1.000000		1.000000
Flange1:da_hf	Left flange	mm	da_hf	1.200000		1.200000
Flange1:da_D0	Left flange	mm	d0 - 2 ul * da_a	38.788736		38.788736
Flange1:da_BendAng	Left flange	deg	10 deg	10.000000		10.000000
Flange2:da_wf	Right flange	mm	da_wf	1.000000		1.000000
Flange2:da_hf	Right flange	mm	da_hf	1.200000		1.200000
Flange2:da_D0	Right flange	mm	d0 - 2 ul * da_a	38.788736		38.788736
Flange2:da_BendAng	Right flange	deg	10 deg	10.000000		10.000000
d16	Planar	mm	0 mm	0.000000		0.000000
d17	Sketch2	mm	25 mm	25.000000		25.000000
d18	Sketch2	mm	14 mm	14.000000		14.000000
d19	Extrusion3	mm	10 mm	10.000000		10.000000
d20	Extrusion3	deg	0.0 deg	0.000000		0.000000
d21	Sketch3	mm	14 mm	14.000000		14.000000
d23	Extrusion4	deg	0.0 deg	0.000000		0.000000
d24	Sketch4	mm	2.3 mm	2.300000		2.300000
d25	Sketch4	mm	5 mm	5.000000		5.000000
d27	Extrusion5	deg	0.0 deg	0.000000		0.000000
d28	Chamfer1	mm	0.5 mm	0.500000		0.500000
d31	Fillet2	mm	1 mm	1.000000		1.000000
User Parameters						
da_z	d11, d0	ul	25.00000000 ul	25.000000		25.000000
da_pb	d0	mm	5.00000000 mm	5.000000		5.000000
da_fi	d3	deg	25.00000000 deg	25.000000		25.000000
da_hg	d2	mm	1.25000000 mm	1.250000		1.250000
da_bw	d4	mm	1.80000000 mm	1.800000		1.800000
da_rb	d9	mm	0.40000000 mm	0.400000		0.400000
da_rt	d10	mm	0.60000000 mm	0.600000		0.600000
da_a	Flange2:da_D0, Flange1:da...	mm	0.50000000 mm	0.500000		0.500000
da_bf	d5	mm	17.50000000 mm	17.500000		17.500000
da_wf	Flange2:da_wf, Flange1:da...	mm	1.00000000 mm	1.000000		1.000000
da_hf	Flange2:da_hf, Flange1:da_hf	mm	1.20000000 mm	1.200000		1.200000

Add Numeric | Update | Purge Unused

Link | Immediate Update

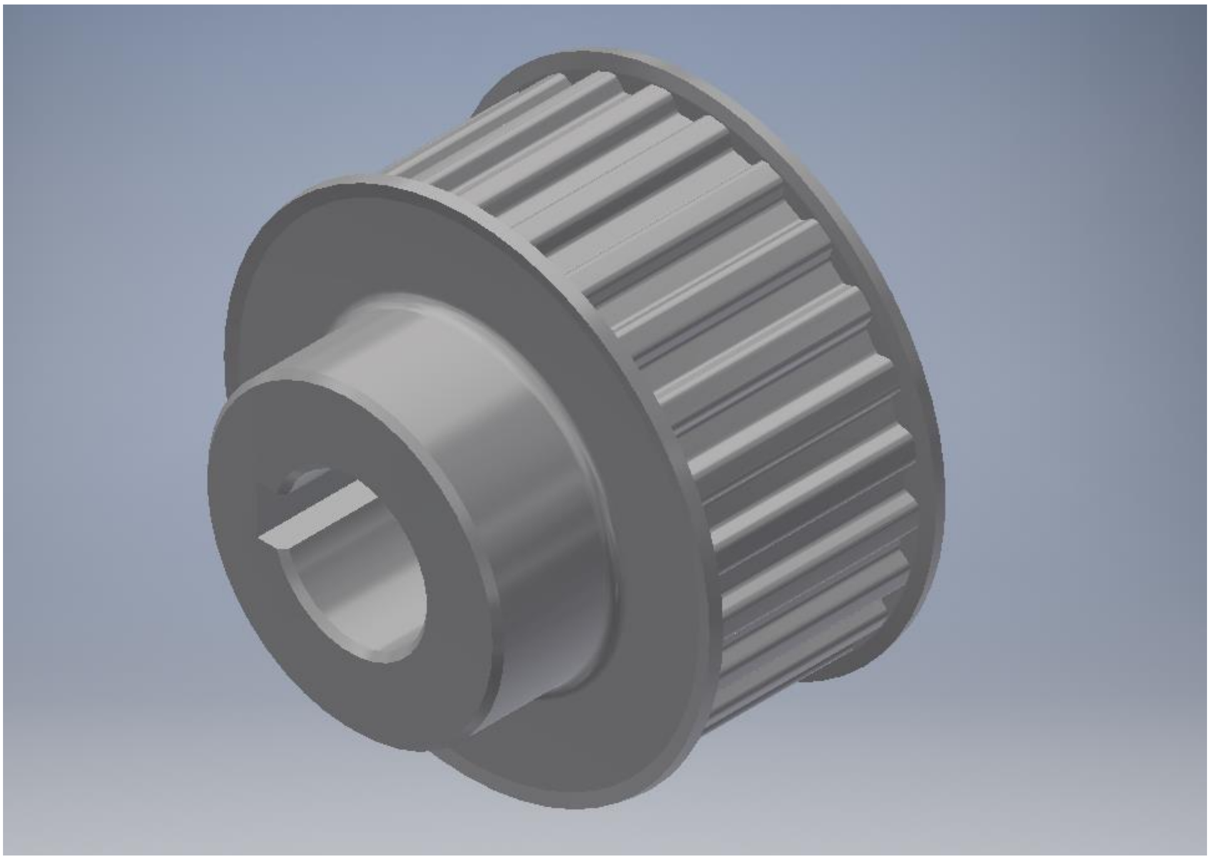
FIGURE H is just a simple drawing of the pulley l made as l did not need to do a manufacturing drawing. The synchronous pulleys are pre-manufactured and you only need to specify the size from the catalogue the bore and keyway size to order.

Pulley Information

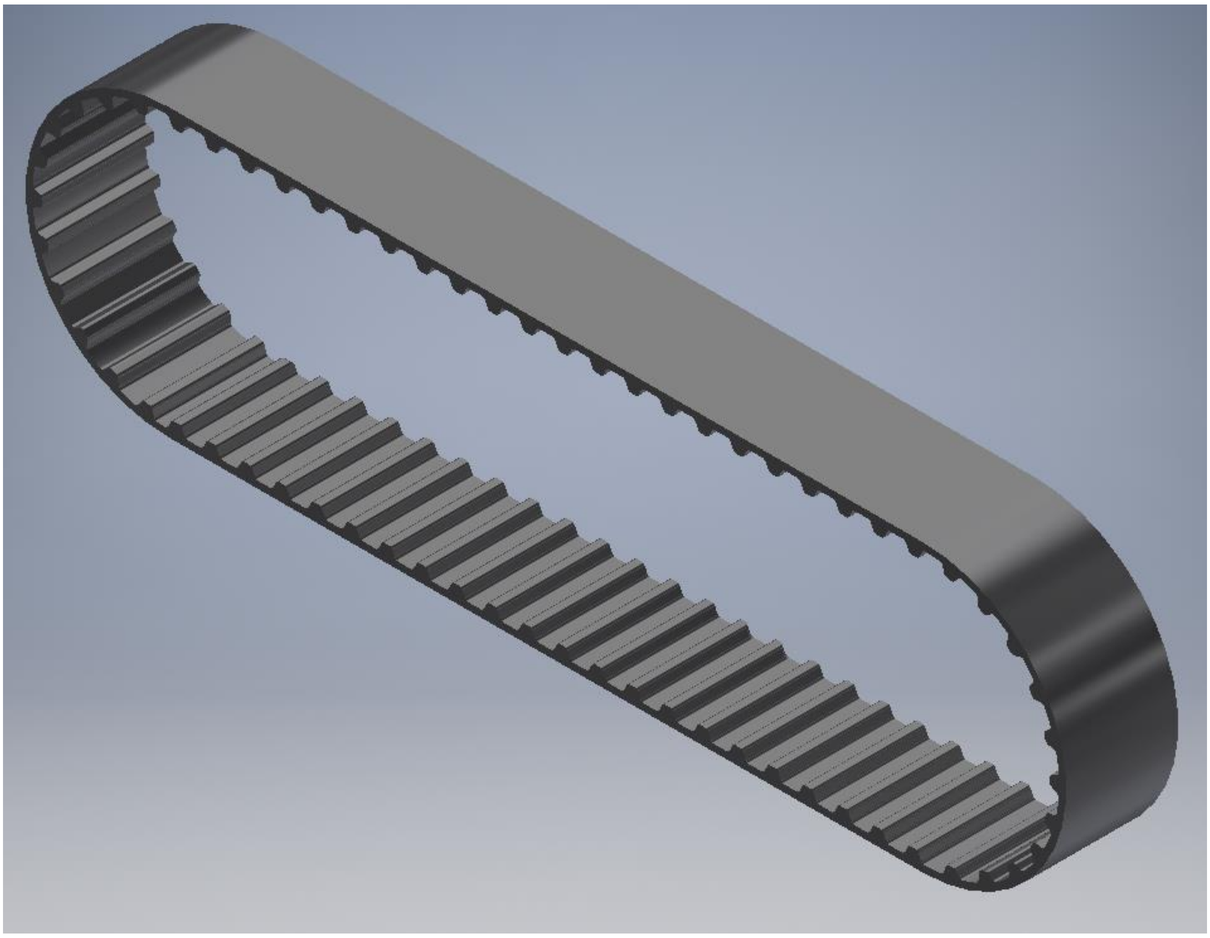
- ★ Type --------------------------------- 27T5/ 25-2 (-2 means type 2 which is Aluminum)
- ★ Number of teeth----------------- 25
- ★ Bore size---------------------------- 14mm for the motor side.

  ---------------------------- 12mm for the wheel side.

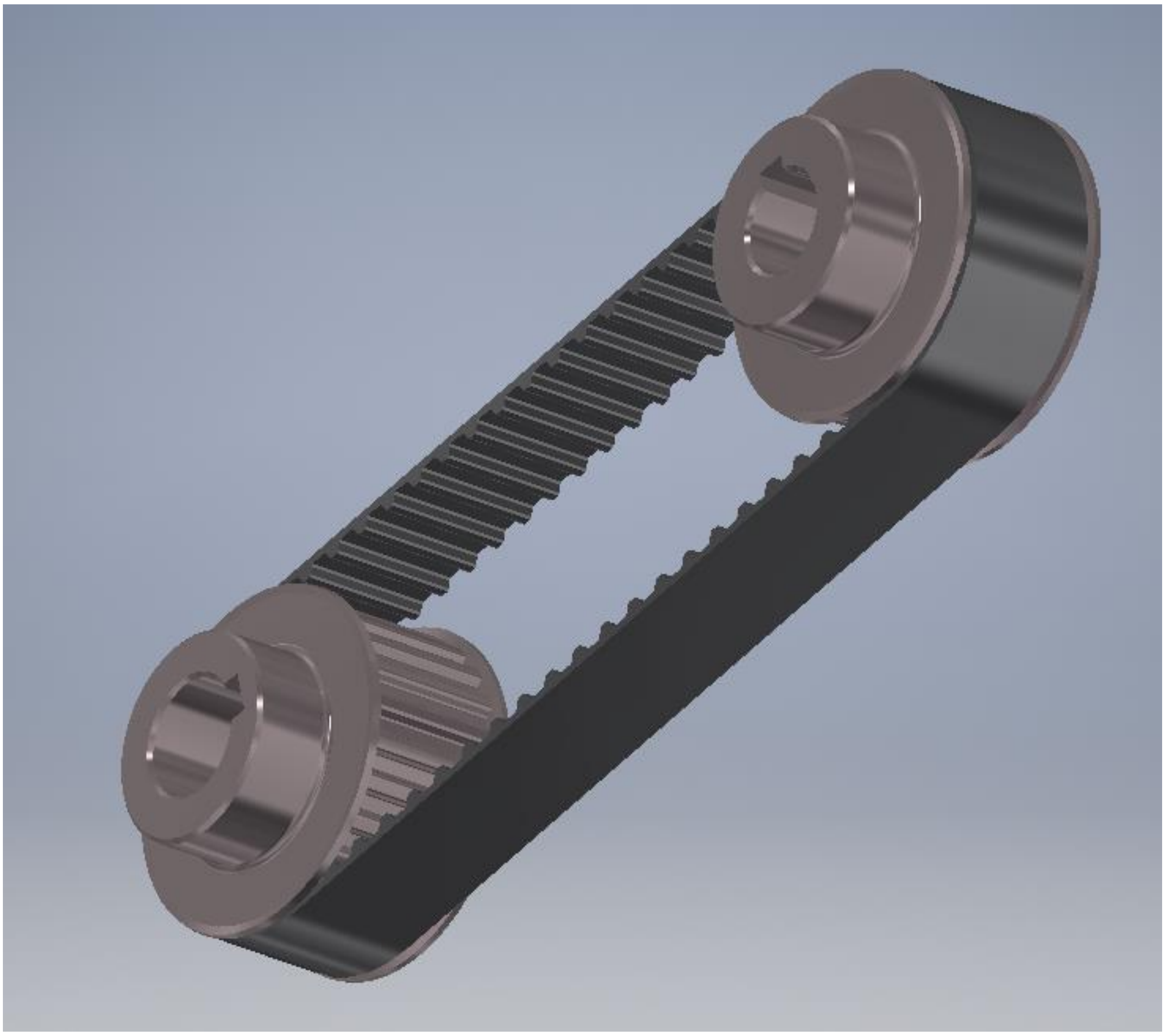
- ★ **1 x pulley for the motor.**
- ★ **1x pulley for the wheel side.**
- ★ **Pulley to be made of Al 6061.**
- ★ **Motor side pulley to have a 5mm standard keyway cut.**
- ★ **Wheel side pulley to have a 4mm standard keyway cut.**



This is the ipt part of the pulley that l designed and the only difference between the two pulleys is the bore size and keyway size, one has a 12mm bore with a 4mm keyway and the other has a 14mm bore and a 5mm keyway



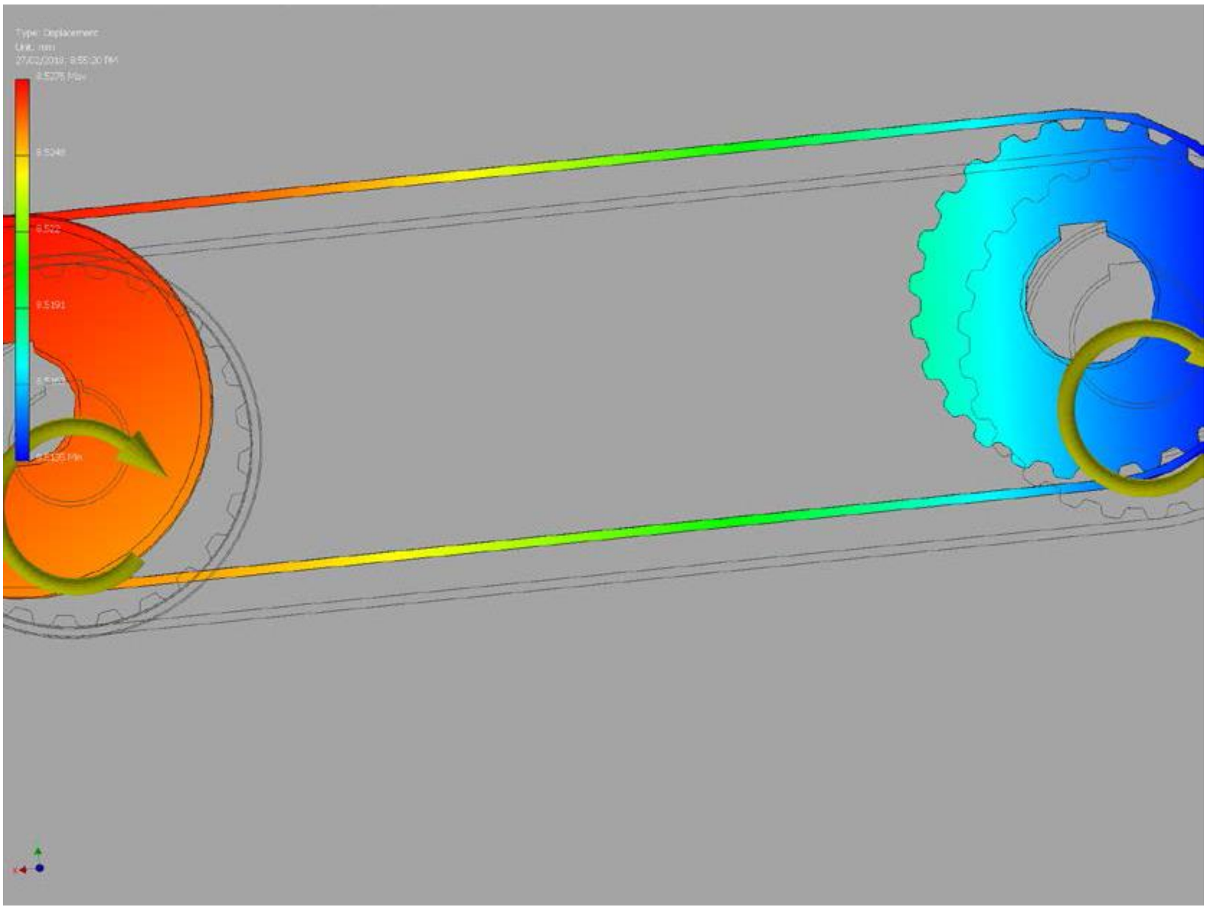
This the ipt for the belt which l designed. This belt can also be ordered from supplier without giving them a dwg drawing. All l needed to do is look up in the supplier catalogue for the belt which l had finally designed that is the number of teeth and the width and get a part number. I then used the part number to get a quote, which was easier on my part because l did not need to produce a drawing.



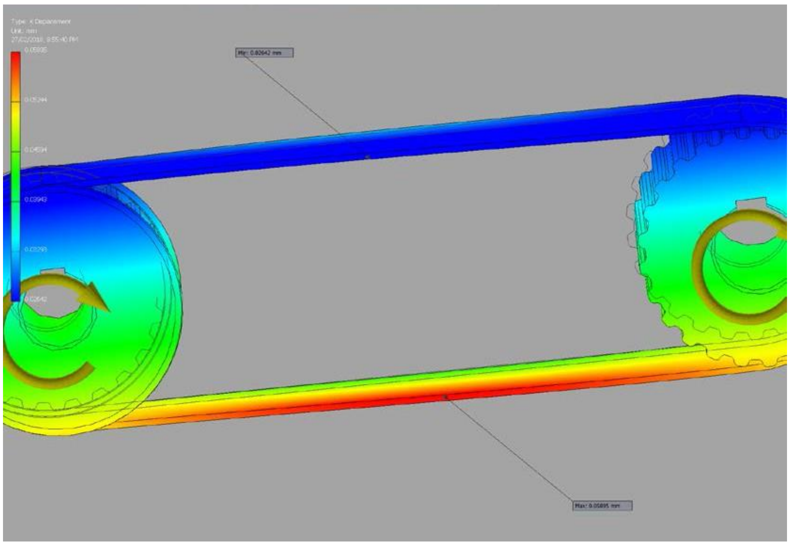
This is the full assembly of the pulleys and belt ready to pop onto the main assembly of the AGV. This assembly fits straight on as the centre distance on it is exactly as is on the assembly. I have changed the appearance of the pulleys just to make it look good but is actually made of 6061 Aluminium which is machinable.

I did some stress analysis of the belt and pulley assembly and these are some of the results, the full report is on GitHub (Mecanum doc)

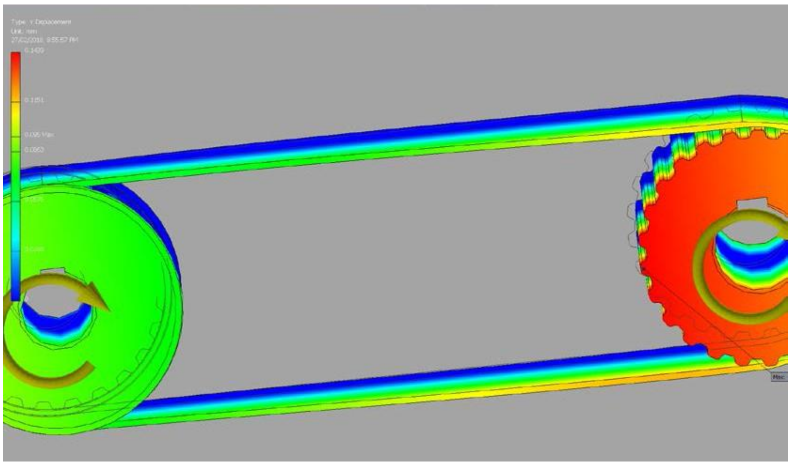
Name	Aluminium 6061-AHC	
General	Mass Density	2.7 g/cm^3
	Yield Strength	275 MPa
	Ultimate Tensile Strength	310 MPa
Stress	Young's Modulus	68.9 GPa
	Poisson's Ratio	0.33 ul
	Shear Modulus	25.9023 GPa
Part Name(s)	Sync pulley.ipt	
Name	Polyethylene, High Density	
General	Mass Density	0.952 g/cm^3
	Yield Strength	20.67 MPa
	Ultimate Tensile Strength	13.78 MPa
Stress	Young's Modulus	0.911 GPa
	Poisson's Ratio	0.392 ul
	Shear Modulus	0.327227 GPa
Part Name(s)	Synchronous Belt	
Name	Steel	
General	Mass Density	7.85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	210 GPa
	Poisson's Ratio	0.3 ul
	Shear Modulus	80.7692 GPa
Part Name(s)	Synchronous Pulley1	



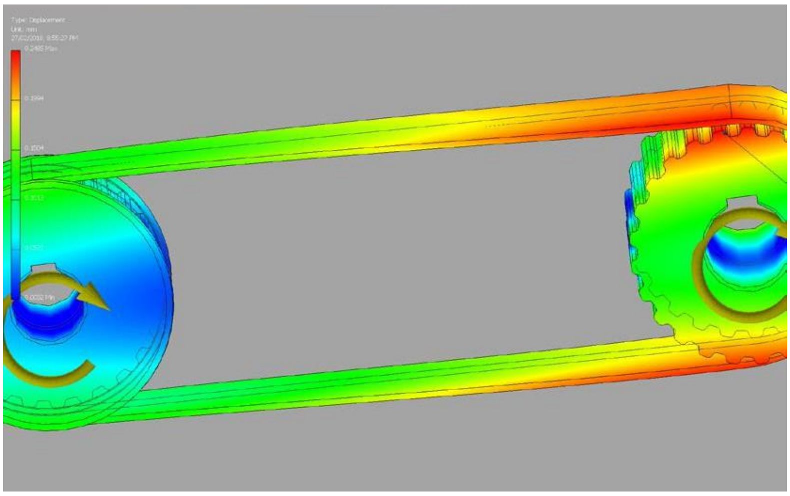
F2 1.03 Hz X Displacement

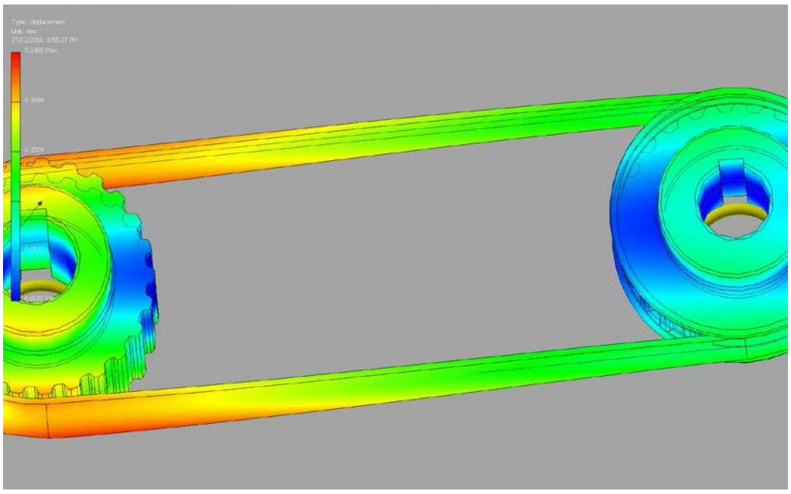


F2 1.03 Hz Y Displacement



F4 1.05 Hz Displacement





For the full report and more please refer to the GitHub mecanum doc ‘Modal analysis of synchronous pulleys and belt’ by Cyprian Sino.

I also got a quote for the boring of the pulleys to required size, the cutting of keyways and the belt is in FIGURE T.

Motor

Written by Zixiao Tang (m234547)

Mecanum wheel mobile lift platform, based on mecanum wheel system. This kinds of mobile platform can move forward, sideways and oblique movement. Even zero radius turn movement.

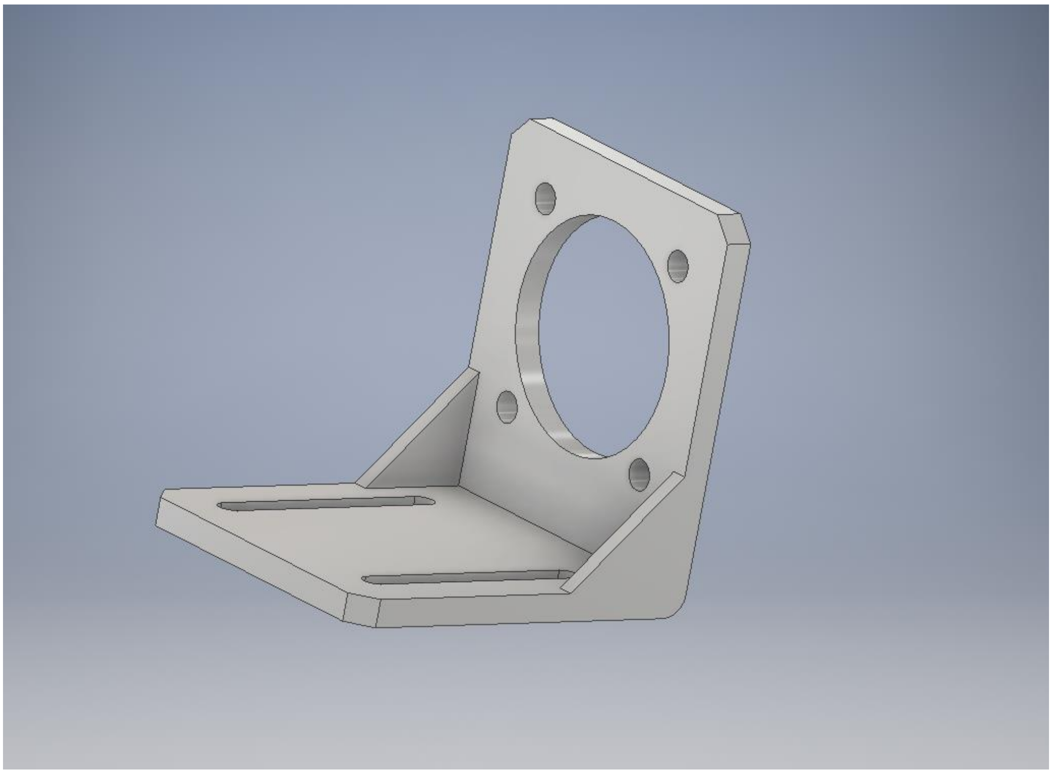
The requirements needed to find the correct motor for the mecanum wheels was done by use of calculating the required torque and thereafter finding a motor which could handle said torque.

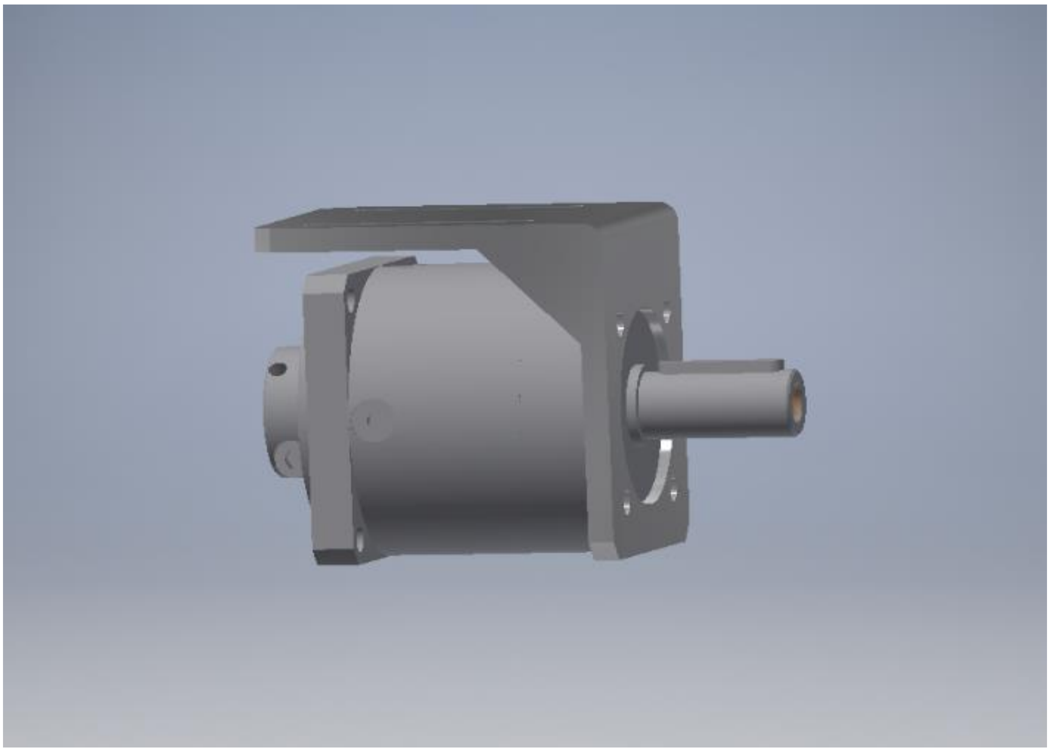
The calculations found that in order for the device to move at about 2 Km/h (max), the required torque when crabbing was 13,77 NM and needed an angular velocity of about 52 rad/s. Thereafter it was advised to find a stepper motor for said torque and angular velocity.

The stepper motor which was found was a Bipolar Stepper Motor. This motor was found on stepper online from the following link: https://oceancontrols.com.au/MOT-126.html

In our group design the gearbox needed to connect mecanum wheel and step motor as well. The gear box which was we chosen was ENCONOMIC INLINE PLANETARY GEARBOXES PTN060. This gearbox was found online from the following link[15]

The steel bracket lets us securely mount typical NEMA 23-size stepper motors and gearbox to our project. The bracket features two slots for various mounting solutions and includes four M4 x16mm screws, washers, and nuts for securing the motor to the bracket. The steel bracket we can't find the exactly one online to matching our gearbox, So we design it, 65mm long, 60mm wide and 65mm high, 5mm thickness , the picture are showing below.





The bracket will be built in workshop. [16]

Control System

Written by Gurkaran Singh (M234676)

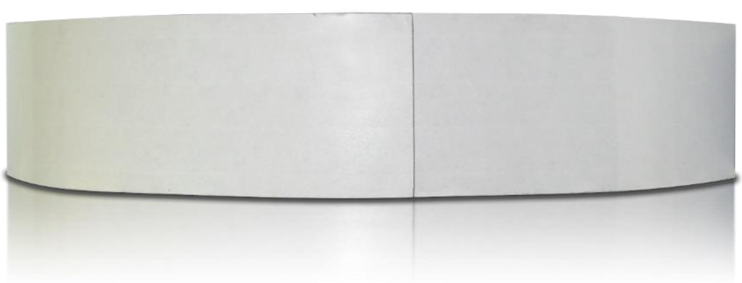
Out of different navigation systems, group agreed on navigation with Magnetic Tape Guidance with Dead-Reckoning. It is a reliable and budget friendly system. The whole idea is to lay down a magnetic tape on the floor on the path where the AGV is supposed to go and it will use Dead-Reckoning to know how far away it is from the destination or when to turn. Magnetic tape was chosen over the optical guidance. Optical Guidance was dropped because of the maintenance, as the paint could get scratched off easily and even the dust can cause sensor to not sense the path. Magnetic Tape Guidance is an easy to lay and low maintenance system. It is easy to change the path if needed to. Further, the tape laid on the floor can be epoxy coated for protection.

Sensors

- **Magnetic Track Sensor**

This sensor is capable of detecting and reporting the position of a magnetic field along its horizontal axis with an operating height of 10mm-60mm. The sensor accurately measures its lateral distance from the centre of the track, with millimetre resolution. The sensor can detect and manage 2-way forks and can be instructed to follow the left or the right track using commands issued via the serial/USB.[17]

- **Magnetic Tape Roll**



The magnetic tape roll is 45.7 m long by 0.0508 m wide with south side up. The tape can simply laid on the floor forming a path for the platform.[18]

- **Motor Controllers**

The motor controller divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any position sensors or the feedback, which allows every motor to perform independently. This will allow each mecanum wheel to operate independently, allowing the platform to go straight or crab.[19]

- **Collision Avoidance**

AGV operating in a work environment with people moving around it, should be able to detect any obstacles in its path, to avoid any collisions. One of the common collision avoidance method is to use optical sensors, which uses an infrared transmitter/receiver. Transmitter emits a pulse to illuminate the surrounding environment, then sensors on the vehicle detect changes to the surrounding environment between successive and the information is fed to the control unit. Control unit uses the information to calculate the distance to nearby objects. If the distance falls within a certain range the system will take action.

- **Encoders**

An encoder is a device which converts information from one format to another. In this case the encoders will be used to translate rotary motion of the wheels to digital signal, which can be used in monitoring or controlling motion parameters such as speed, rate, direction, distance or position.[20]

Calculations

CALCULATION SHEET
BHT GROUP PTY LTD

PROJ No.
CLIENT
PROJECT
SUBJECT
CALC No.
SHEET

REVISION	DATE	BY	CHECKED	REVISION	DATE	BY	CHECKED

$R = 200$

$r = 48$

$D = 152$

$F_{10} = \sqrt{2.(152)^2 + 10^2}$
$= 215.2$

$F_{20} = \sqrt{2(152)^2 + 20^2}$
$= 215.9$

$F_{30} = \sqrt{2.(152)^2 + 30^2}$
$= 217.0$

$F_{40} = \sqrt{2.(152)^2 + 40^2}$
$= 218.65$

$F_{50} = \sqrt{2.(152)^2 + 50^2}$
$= 220.70$

$G_{10} = \sqrt{4.(152)^2 + 10^2}$
$= 304.16$

$G_{20} = \sqrt{4.(152)^2 + 20^2}$
$= 304.66$

$G_{30} = \sqrt{4.(152)^2 + 30^2}$
$= 305.5$

$G_{40} = \sqrt{4.(152)^2 + 40^2}$
$= 306.6$

$G_{50} = \sqrt{4(152)^2 + 50^2}$
$= 308.1$

$T_{10} = \frac{\sqrt{2}.200}{215.2}$
$= 1.314$

$T_{20} = \frac{\sqrt{2}.200}{215.9}$
$= 1.310$

$T_{30} = \frac{\sqrt{2}.200}{217.0}$
$= 1.303$

$T_{40} = \frac{\sqrt{2}.200}{218.65}$
$= 1.2936$

$T_{50} = \frac{\sqrt{2}.200}{220.70}$
$T_{50} = 1.282$

$h_{10} = 11.57$

$h_{20} = 23.1$

$h_{30} = 34.5$

$h_{40} = 45.8$

$h_{50} = 57$

$R_{r_{10}} = 47.75$

$R_{r_{20}} = 47.2$

$R_{30} = 46.3$

$R_{40} = 44.5$

$R_{50} = 43.1$

PROJ No. AGV Plat Form	LES LANGKILDE ENGINEERING SERVICES INNOVATIVE SOLUTIONS IN DESIGN
CLIENT South Metro Tafe	
ACTIVITY Mecanum Wheel	CALCULATION NUMBER
PROJECT	FILE
SUBJECT Roller – Bearing Selection	SHEET OF

REVISION	DATE	BY	CHECKED	APPROVED	REVISION	DATE	BY	CHECKED	APPROVED

Total mass = 500kg

No. of Wheels = 4

60:40 load distribution.

~~mass 500~~

mass on each wheel = $\frac{500}{2}$

~~= 125~~

= 250

~~500 250~~ × 0.6

mass on two wheels = 300

$\frac{300}{2}$

mass per wheel = 150kg (including 60:40 load distribution.

force on Wheel = 150 × 9.81

= 1471.5N

∴ minimum Cr Required = 1471.5N.

Shaft diameter = Ø8mm

Bearing Selection – Deep Groove Ball Bearing

NSK ~~66~~698 – 2RS

This is a Ø19mm outer

Ø8mm Shaft

6mm thickness.

With a dynamic load of 2240N

Some calculations used in calculating the number of teeth in pulley and belt

Number Teeth in Mesh (TIM) = $Z_1\left[0.5 - \frac{(Z_2 - Z_1)p}{18.85A}\right]$

Z_1 =Number of teeth on small pulley

Z_2 =Number of teeth on bigger pulley in my case the pulleys are the same and have the same number of teeth.

P = pitch

A = Actual centre distance

Z_1 and Z_2 = 25

P = 5mm

A = 107.50mm

Therefore $25[0.5-(\frac{(25-25)5}{18.85x107.5}]$

=12.5

Effectively that's **13 teeth in mesh**

For drives with pulleys of equal numbers of teeth.
Calculate Number Teeth in Belt Nc = 2. Ao/p + Z1

Nc = number of teeth in belt

Ao = Approximate centre distance in mm

P = belt pitch in mm

Z_1 = Number of teeth in small pulley

Therefore $2\mathrm{x}\frac{108}{5} + 25$

= 68.2

Number of teeth in belt is equal to **68**

It was also noted that the N_c was always to be greater than $0.9(Z_1+Z_2)$

$$A = \frac{p}{4}\left(N_A - \frac{Z_1 + Z_2}{2} + \sqrt{\left(N_A - \frac{Z_1 + Z_2}{2}\right)^2 - \frac{2.027\,(Z_2 - Z_1)^2}{10}}\right)$$

A= Actual centre distance

$N_{A=}$ number of teeth on belt

Z_1 and Z_2 number of teeth on pulleys

P = pitch of belt in mm

Therefore A= $\frac{5}{4} x\,(68 - \frac{25+25}{2} + \sqrt{\left(68 - \frac{25+25}{2}\right)} - 2.027(25-25)2/10$

=**<u>107.50mm</u>**

Costings

Written by Robert Williams, Gurkaran Singh

The scope specified that the total cost of the project should be kept to a minimum, this played a role in the design of the vehicle. Throughout the project design concepts were presented to the project manager, quotes were obtained and if it was deemed to be too expensive other avenues were explored. For example the lifting mechanism changed from pneumatic to electro mechanical initially off the shelf screw jacks was the chosen option, the quote came back from the supplier at $1958.99 per unit with 4 required. This changed the design concept from off the shelf to a self-designed lifting mechanism to reduce the total cost.

Table 1.1 below shows the costings obtained from suppliers, the costings are not complete as there is no quotes for the electronics, screws and nuts and bolts. All obtained quotes from suppliers and email correspondence are shown in the FIGURE Q, R. All mild steel pricing was taken from best buy steel website[21]

Component	**Use/ Notes**	**Material**	**Cost per Unit including GST ($)**	**Amount Required**	**Total Cost ($)**	**Supplier**
Mecanum Wheel						
Bearings	698-ZZ JP (8-19-6)		$4.40	96	$422.40	State-wide Bearings
Roller	Supply and Machine	Aluminium 6061	$38.50	24	$924.00	Bluechip CNC
Cheek Plate	Supply and Machine	Aluminium 6061	$302.50	8	$2,420.00	Bluechip CNC
Hub Flange	Supply and Machine	Aluminium 6061	$82.50	8	$660.00	Bluechip CNC
Polyurethane	Cast	Shore A 95 Duro	$38.50	24	$924.00	Polyurethane Processors
⌀8mm Round Bar	12.5m, 6m Lengths sold	Mild Steel 300+	$14.15	3	$42.45	Best Buy Steel
⌀30 Round bar	1.6m, 6m Lengths sold	Mild Steel 300+	$76.20	1	$76.20	Best Buy Steel
Mecanum Wheel Total					$5,469.05	
Frame						
12m of SHS	35x35x3 (sold 8m lengths)	Mild Steel	$61.75	2	$123.50	Best Buy Steel
Bearing housing base	Supply and Machine	Aluminium 6061	$100.00	4	$400.00	Bluechip CNC

Bearing housing jack plate	Supply and Machine	Aluminium 6061	$120.00	4	$480.00	Bluechip CNC
Bearing housing plate	Supply and Machine	Aluminium 6061	$90.00	4	$360.00	Bluechip CNC
bearing	7204 B JP (20-47-14)		$22.00	8	$176.00	State-wide Bearings
Drive Pulley	Supply and Machine		$147.10	4	$588.40	NAISMITH
Frame Total					$2,127.90	
Lifting Mechanism						
Gear Box	TS- 58GZ868		$53.60	4	$214.40	Alibaba
Trust Bearing	NTB 1226 (12-26-7.5)		$5.54	4	$22.16	RS Components
Ball screw and Lead nut	16mm Diameter		$22.80	4	$91.20	Alibaba
Lifting Mechanism Total					$327.76	
Control System					$0.00	
Magnetic Field Sensor			$485	1	$485.00	Roboteq
Magnetic Tape (10 m)			$46.40	2	$92.80	Aliexpress
Motor Controller			$1.68	4	$6.72	Aliexpress
Encoder			$12.18	4	$48.72	Aliexpress
Control System Total					$633.24	

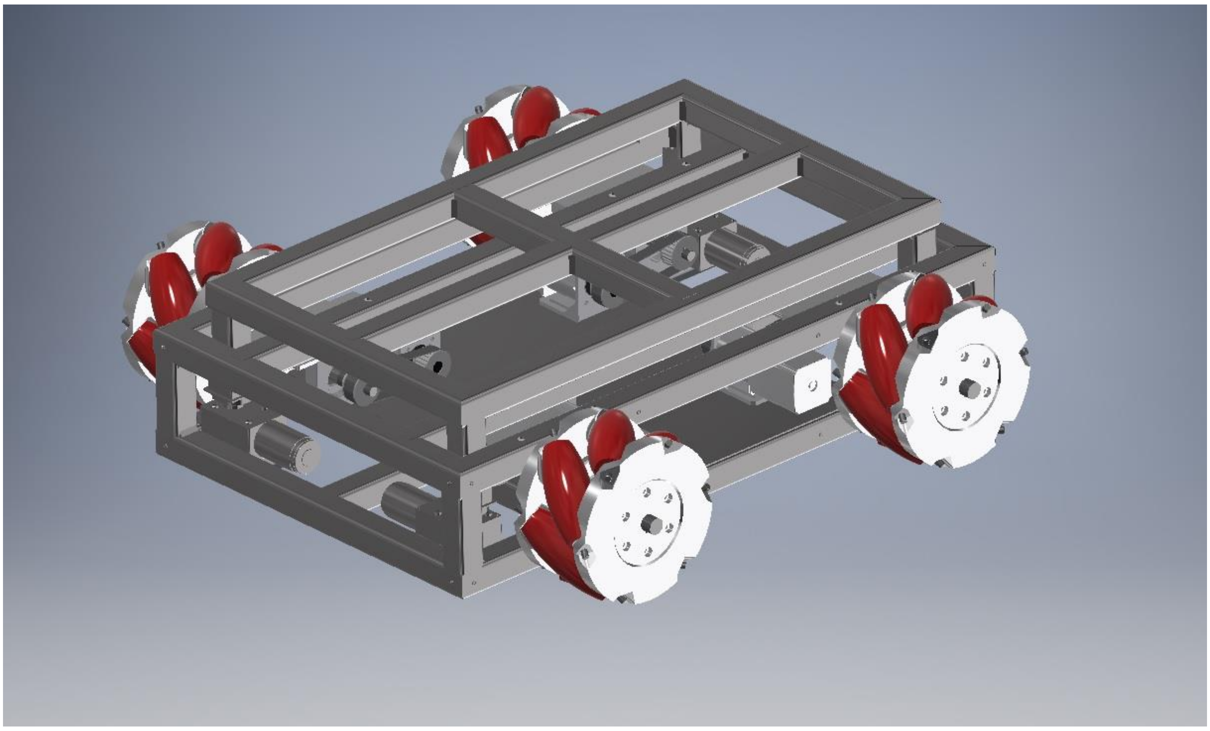
Discussion and Conclusion

Written by Bryce Richards, Gurkaran Singh

At the end of the defined project period we had not completed the design. The mechanical design is mostly finished but some small elements such as linear rails and IP65 enclosures have not yet been selected. Additionally the electronics like sensors, limit-switches and micro-controllers have not been selected. Also the program has not been written due to the lack of electronic components.

Mechanically the design will lift the required loads. It is much smaller than comparable commercial units, and also has a production cost of <$8k, whereas commercial units will cost up to $30k and not be small enough for the intended use-case.

The finished design to date:



Recommendations

Details on the state of the project are articulated above. The next step should be selection of suitable rectangular rail and working these in to the FinalAssembly.iam assembly. Space is available but may require design changes to the frame to accommodate.

References

APA referencing style

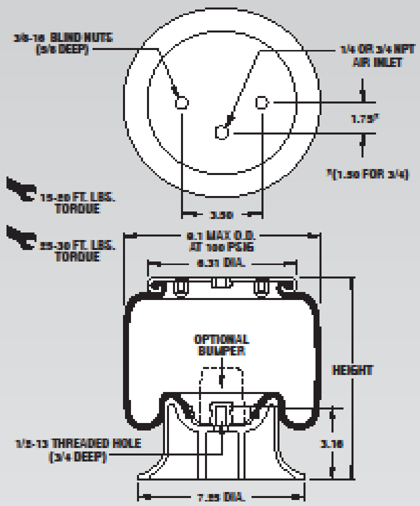
List of Figures

Appendix

FIGURE A

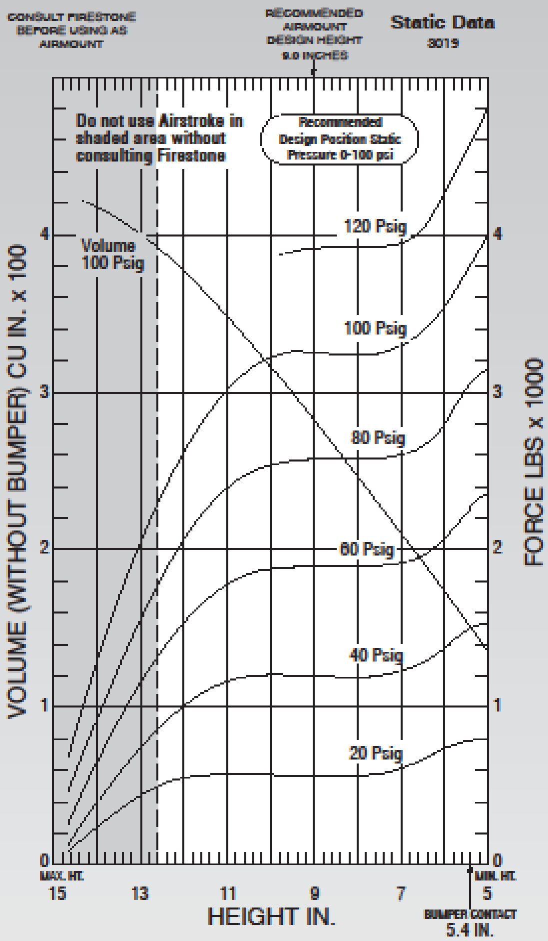
Description		Assembly Order No.
Two Ply Bellows	Blind nuts, 1/4 NPT, bumper	AB0050

Assembly weight .... 6.5 lbs.



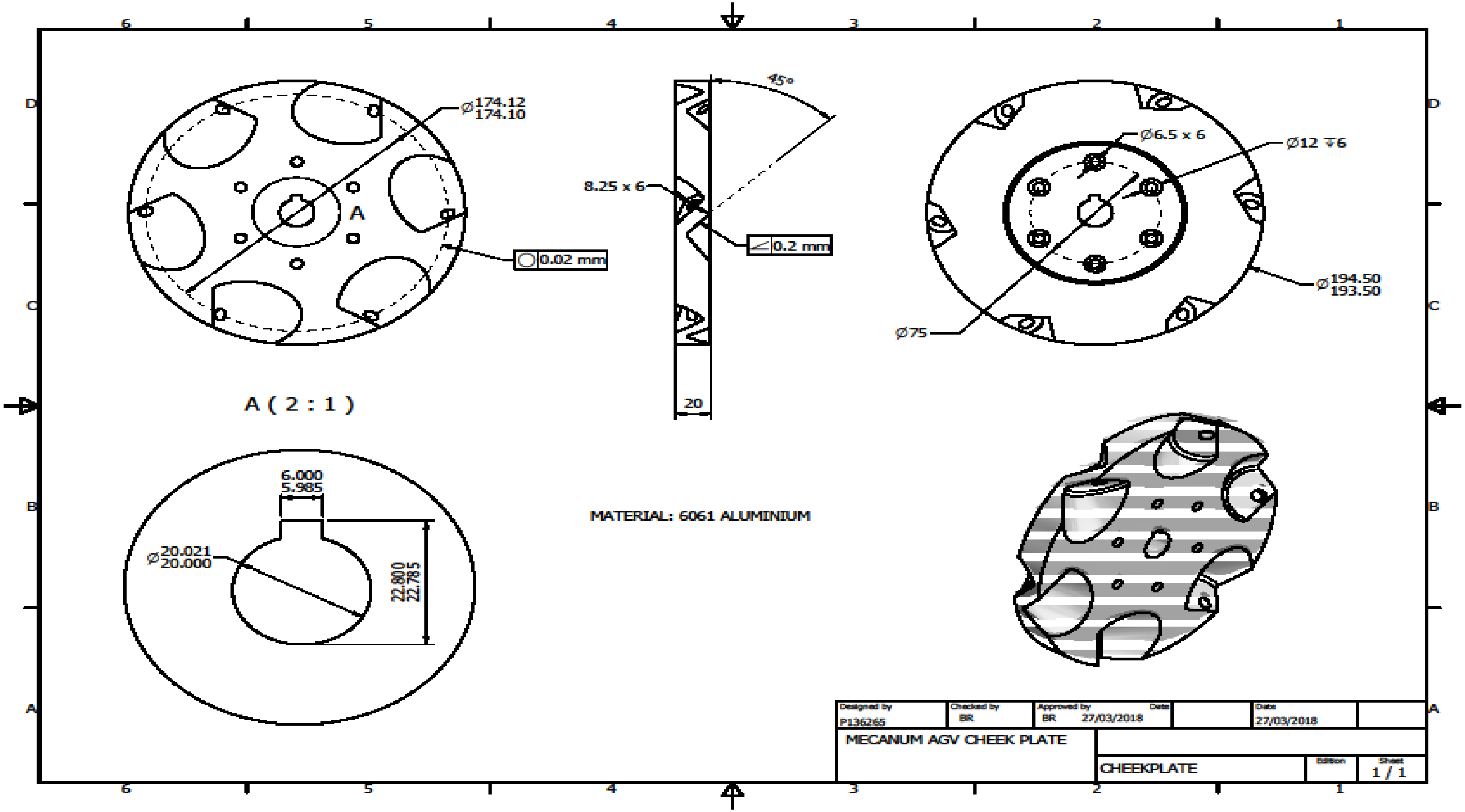
NOTE: Bellows will not compress properly with less than 10 PSIG internal pressure.

NOTE: A bead plate part is shown. This part is also available with a bead ring. Bolts are not included.



Dynamic Characteristics at 9.0 in. Design Height (Required for Airmount isolator design only)				
Volume @ 100 PSIG = 280 in³			Natural Frequency	
Gage Pressure (PSIG)	Load (lbs.)	Spring Rate (lbs./in.)	CPM	HZ
40	1,170	250	85	1.42
60	1,890	396	86	1.44
80	2,570	535	86	1.43
100	3,240	658	85	1.41

Force Table (Use for Airstroke™ actuator design)						
Assembly Height (in.)	Volume @ 100 PSIG (in³)	Pounds Force @20 PSIG	@40 PSIG	@60 PSIG	@80 PSIG	@100 PSIG
12.0	376	540	1,010	1,530	2,040	2,600
11.0	347	570	1,160	1,770	2,380	3,010
10.0	314	590	1,210	1,880	2,540	3,220
9.0	280	590	1,190	1,890	2,570	3,240
8.0	246	580	1,200	1,890	2,570	3,240
7.0	211	620	1,240	1,920	2,600	3,300
6.0	176	740	1,380	2,060	2,790	3,530



Ø174.12
174.10
0.02 mm
A
A (2 : 1)
45°
8.25 x 6
0.2 mm
20
Ø6.5 x 6
Ø12 ↧6
Ø194.50
193.50
Ø75
6.000
5.985
Ø20.021
20.000
22.800
22.785
MATERIAL: 6061 ALUMINIUM
Designed by
P136265
Checked by
BR
Approved by
BR
27/03/2018
Date
Date
27/03/2018
MECANUM AGV CHEEK PLATE
CHEEKPLATE
Edition
Sheet
1 / 1

FIGURE B.

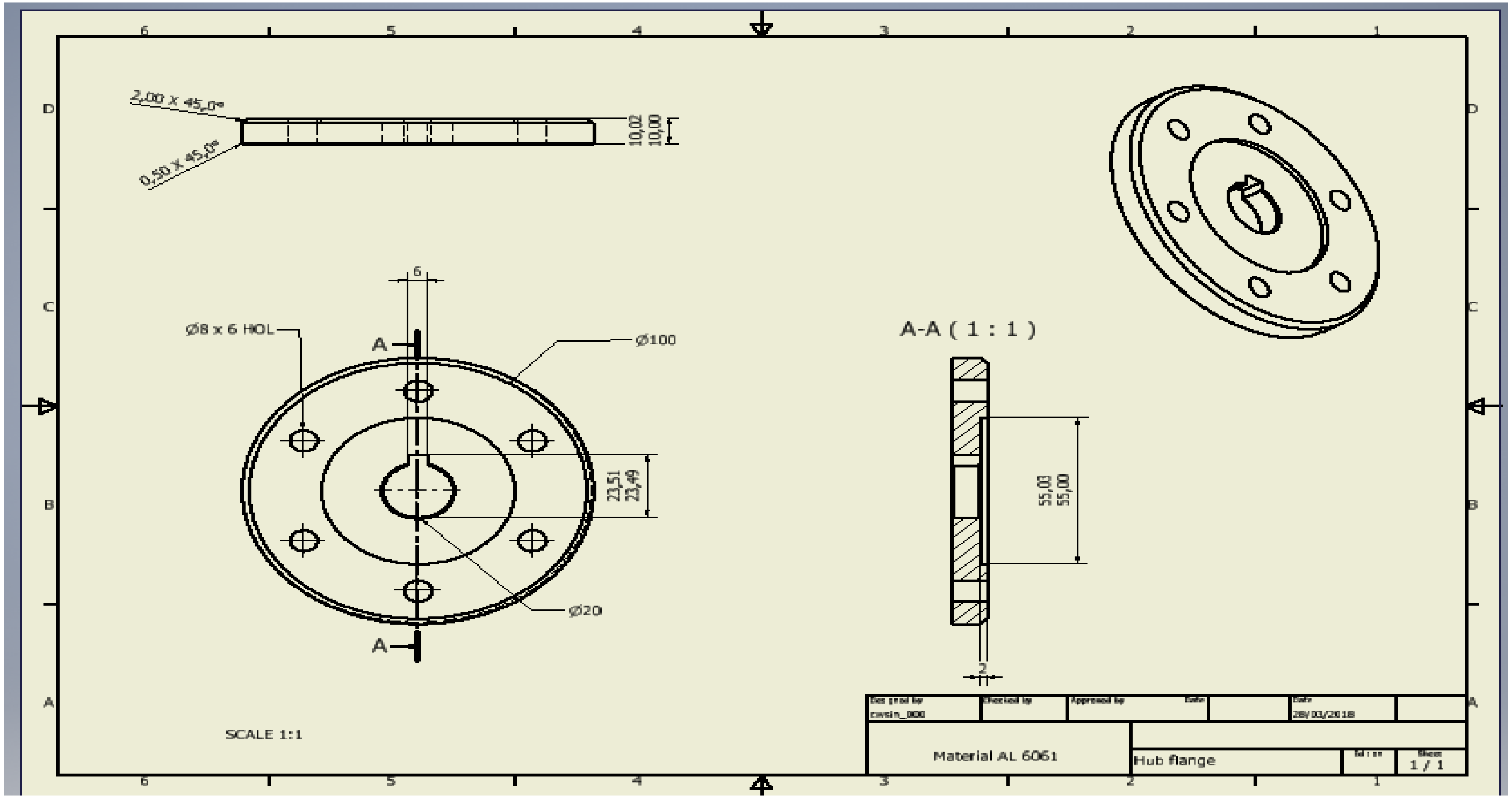
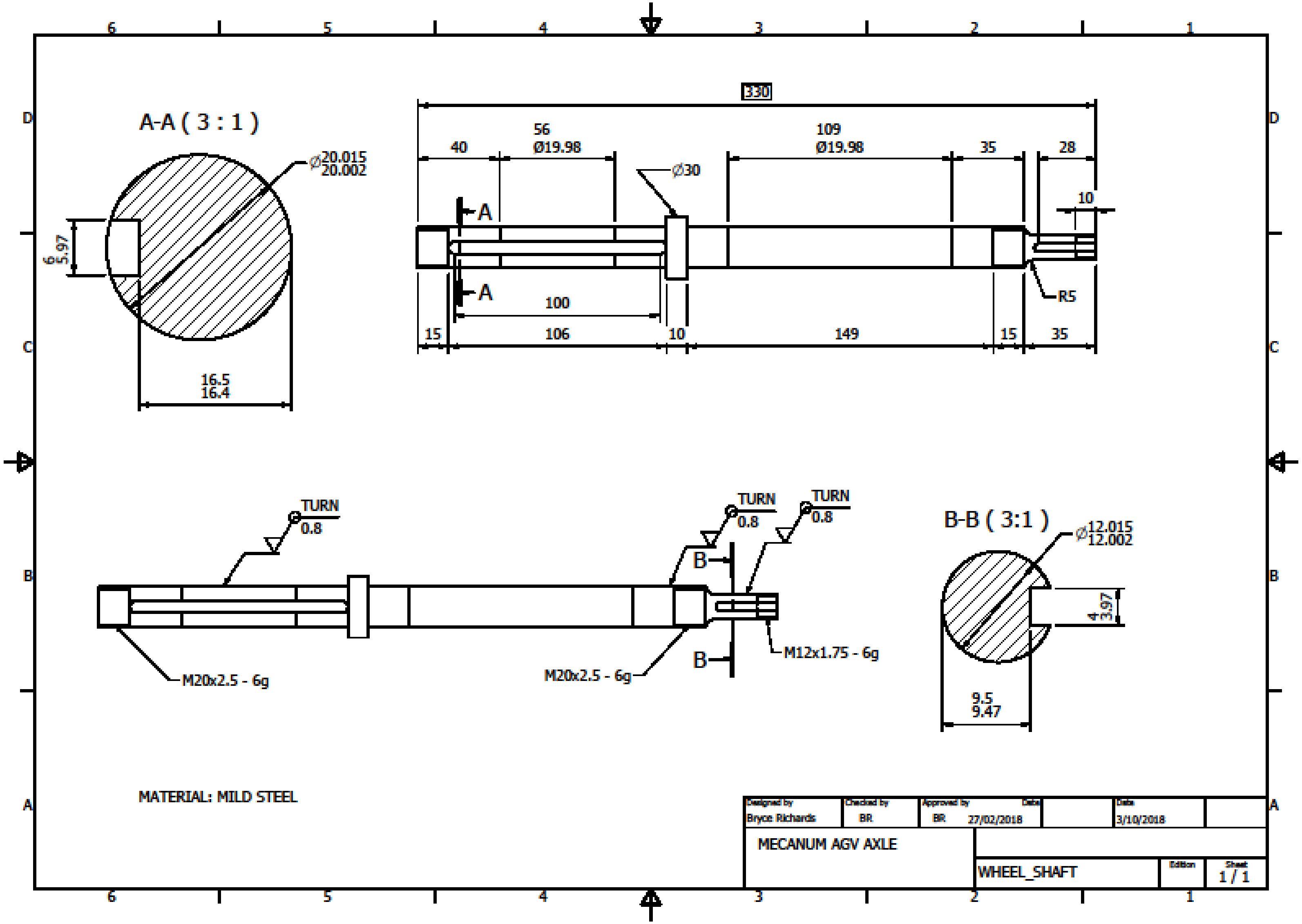

2,00 X 45,0°
0,50 X 45,0°
10,02
10,00
6
Ø8 x 6 HOL
A
Ø100
23,51
23,49
Ø20
A
A-A (1 : 1)
55,03
55,00
2
SCALE 1:1
28/03/2018
Material AL 6061
Hub flange
1 / 1

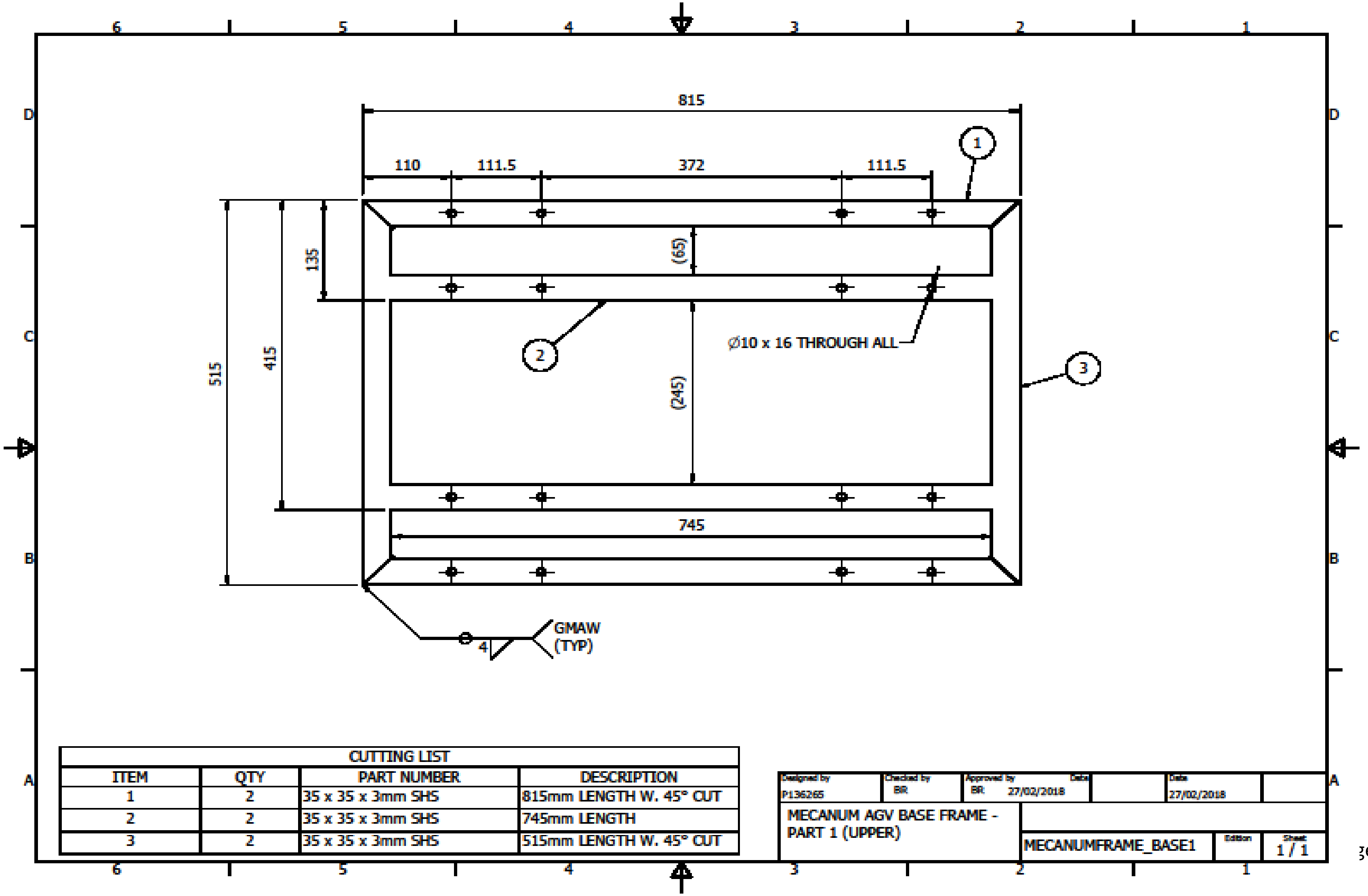
FIGURE C

FIGURE D



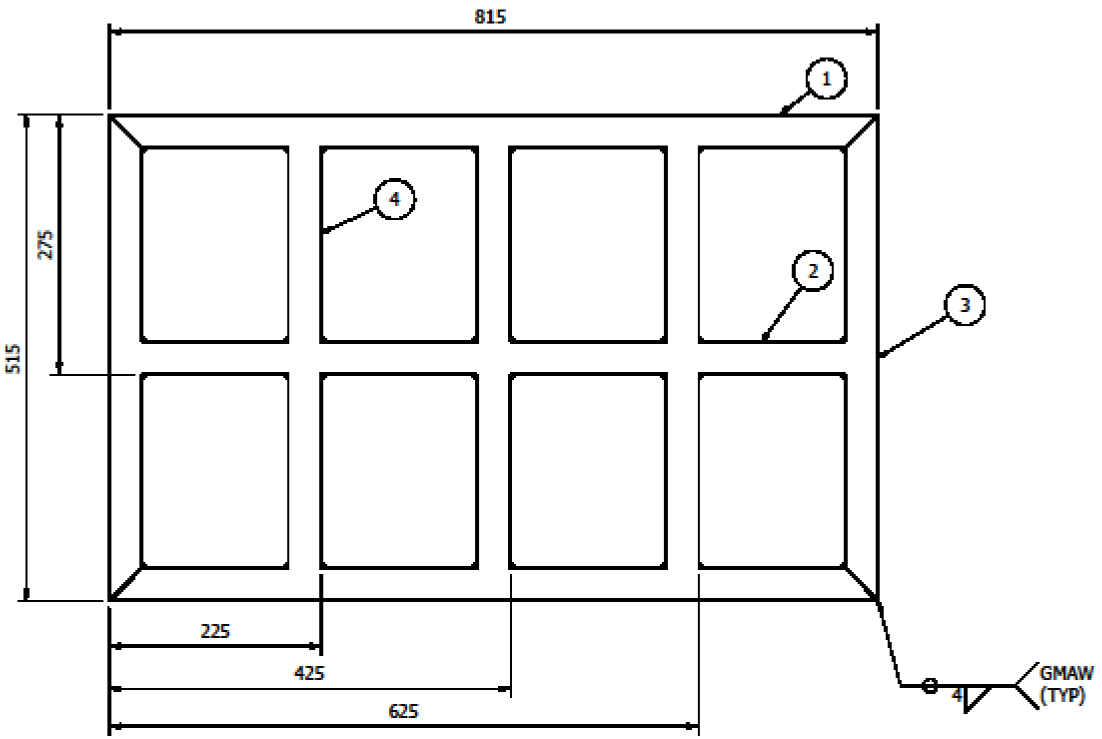
A-A (3 : 1)
Ø20.015 20.002
6 5.97
16.5 16.4
330
40
56 Ø19.98
Ø30
109 Ø19.98
35
28
10
A
A
100
R5
15
106
10
149
15
35
TURN 0.8
TURN 0.8
TURN 0.8
B
B
M20x2.5 - 6g
M20x2.5 - 6g
M12x1.75 - 6g
B-B (3:1)
Ø12.015 12.002
4 3.97
9.5 9.47
MATERIAL: MILD STEEL
Designed by
Bryce Richards
Checked by
BR
Approved by
BR
27/02/2018
Date
Date
3/10/2018
MECANUM AGV AXLE
WHEEL_SHAFT
Edition
Sheet
1 / 1

FIGURE E



CUTTING LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	35 x 35 x 3mm SHS	815mm LENGTH W. 45° CUT
2	2	35 x 35 x 3mm SHS	745mm LENGTH
3	2	35 x 35 x 3mm SHS	515mm LENGTH W. 45° CUT

FIGURE F



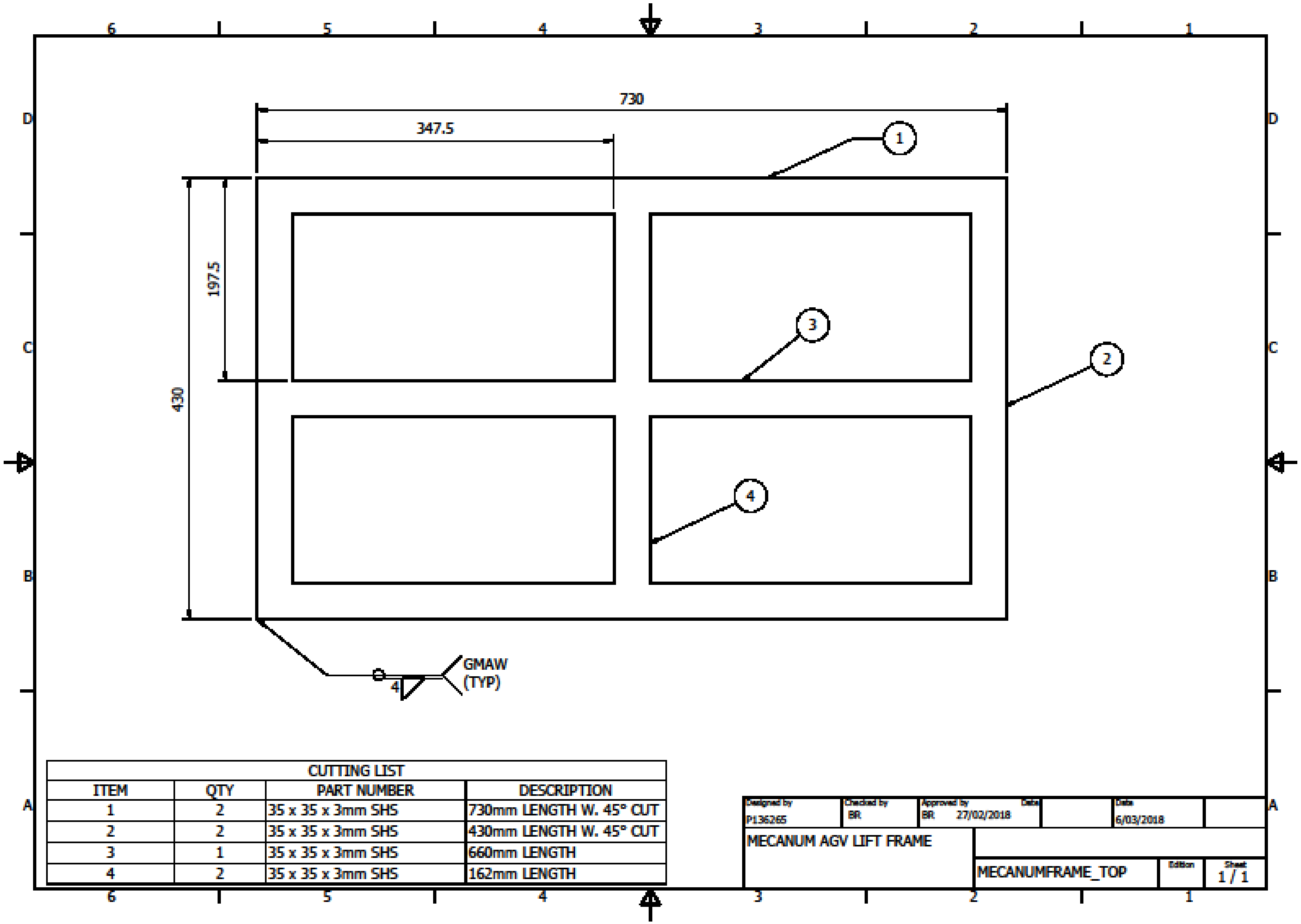
CUTTING LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	35 x 35 x 3mm SHS	815mm LENGTH W. 45° CUT
2	1	35 x 35 x 3mm SHS	745mm LENGTH
3	2	35 x 35 x 3mm SHS	515mm LENGTH W. 45° CUT
4	6	35 x 35 x 3mm SHS	205mm LENGTH

Designed by	Checked by	Approved by	Date	Date
P136265	BR	BR 27/02/2018		27/02/2018

MECANUM AGV BASE FRAME - PART 2 (LOWER)

MECANUMFRAME_BASE2 | Edition | Sheet 1 / 1

FIGURE G.



CUTTING LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	2	35 x 35 x 3mm SHS	730mm LENGTH W. 45° CUT
2	2	35 x 35 x 3mm SHS	430mm LENGTH W. 45° CUT
3	1	35 x 35 x 3mm SHS	660mm LENGTH
4	2	35 x 35 x 3mm SHS	162mm LENGTH

FIGURE H.

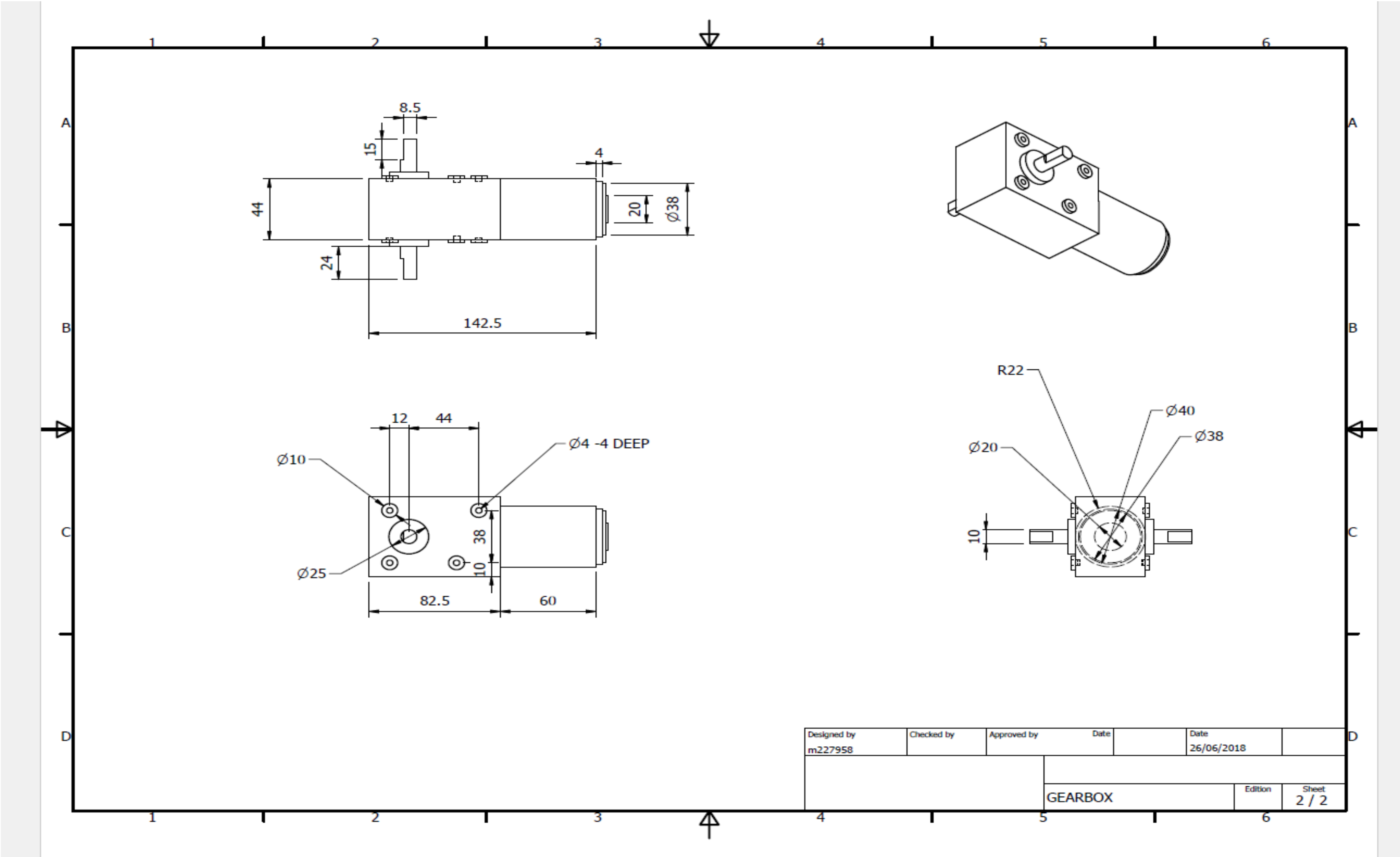

8.5
15
4
44
20
Ø38
24
142.5
12
44
Ø4 -4 DEEP
Ø10
38
Ø25
10
82.5
60
R22
Ø40
Ø38
Ø20
10
Designed by
m227958
Checked by
Approved by
Date
Date
26/06/2018
GEARBOX
Edition
Sheet
2 / 2

FIGURE I

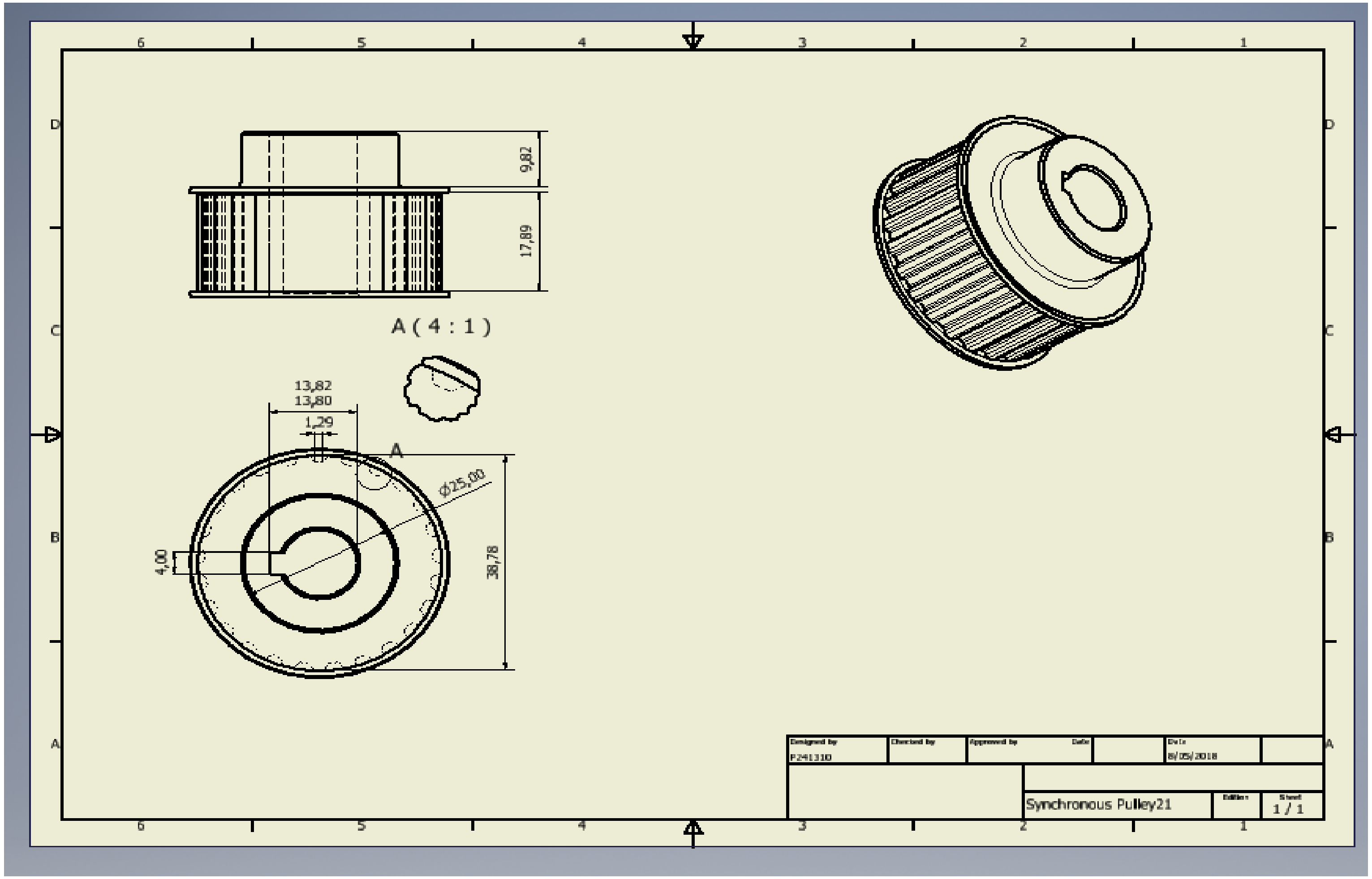
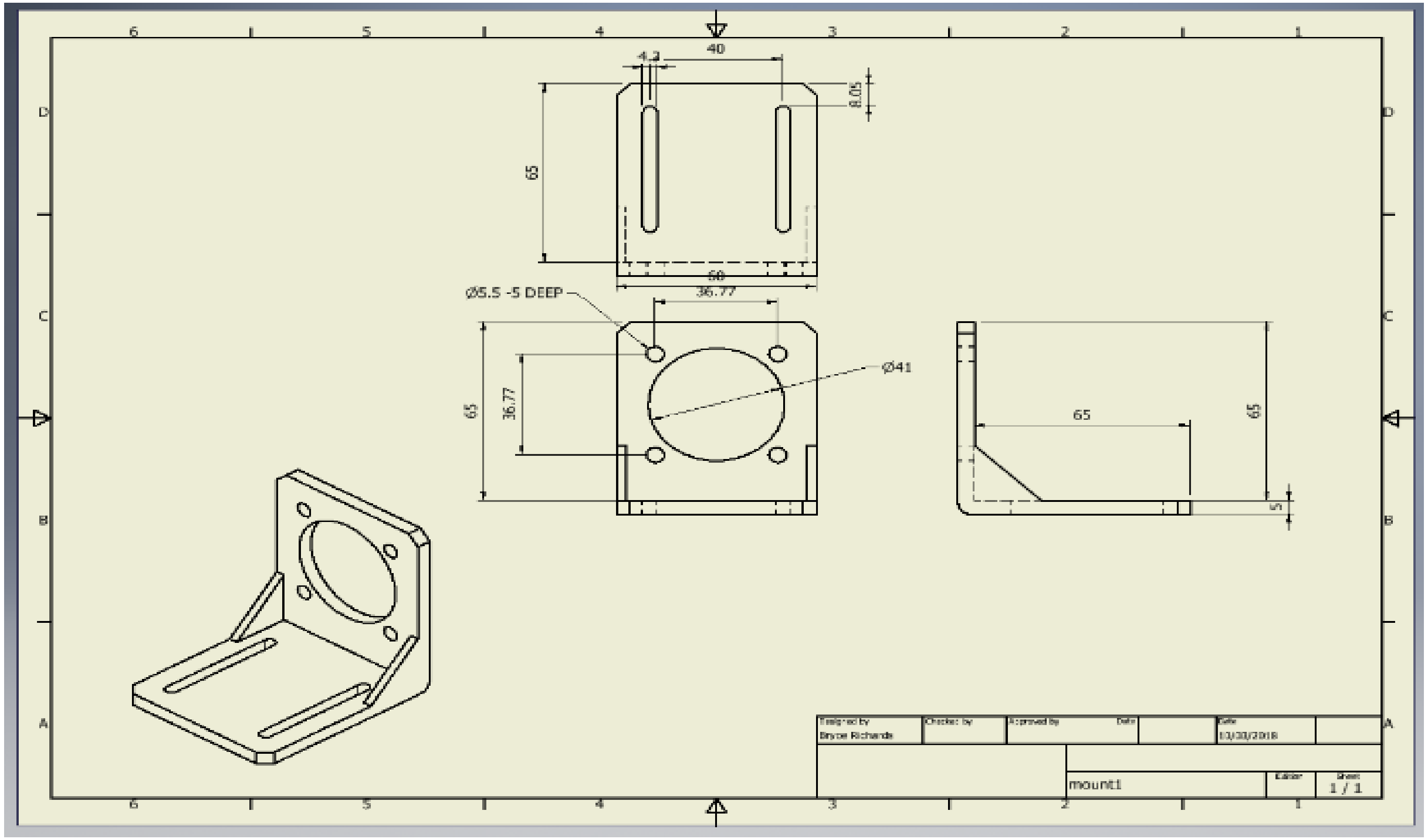

9,82
17,89
A (4 : 1)
13,82
13,80
1,29
A
Ø25,00
4,00
38,78
Designed by
P241310
Checked by
Approved by
Date
Date
8/05/2018
Synchronous Pulley21
Sheet
1 / 1

FIGURE J



4.2
40
8.05
65
60
36.77
Ø5.5 -5 DEEP
Ø41
65
36.77
65
65
5
Designed by
Bryce Richards
Checked by
Approved by
Date
10/30/2018
mount1
Edition
Sheet
1 / 1

FIGURE K

6/5/2018 Gmail - Airstroke actuator style 274 Quote

Gmail **Robert Williams <williams.a.robert@gmail.com>**

Airstroke actuator style 274 Quote

3 messages

Robert Williams <williams.a.robert@gmail.com> 13 February 2018 at 12:36
To: saleswa@airsprings.com.au

Hi Michael,

I am currently doing a project at South Metro Tafe, I am in the design stage of an Autonomous Vehicle with a lifting mechanism that should be capable of lifting 1000 kg. At the minute we have decided the 274 model is the best option. I need to get a total cost for the project so if I could get a price on that. Can you recommend the best air compressor to use, at the moment we are looking at the boss air suspension.

Any further information you can give me or advice would be much appreciated.

Regards,
Robert Williams

SalesWA <SalesWA@airsprings.com.au> 13 February 2018 at 14:58
To: Robert Williams <williams.a.robert@gmail.com>

Hi Robert

Can you please email me phone n0

Also air spring

274????? What brand and type is this

Regards

Michael Wernik

Sales Manager - WA Airsprings

2,125 / 129 Welshpool Road

WELSHPOOL, WA 6106

Ph- (08)9350 6811 Fax- (08)9350 6444

saleswa@airsprings.com.au

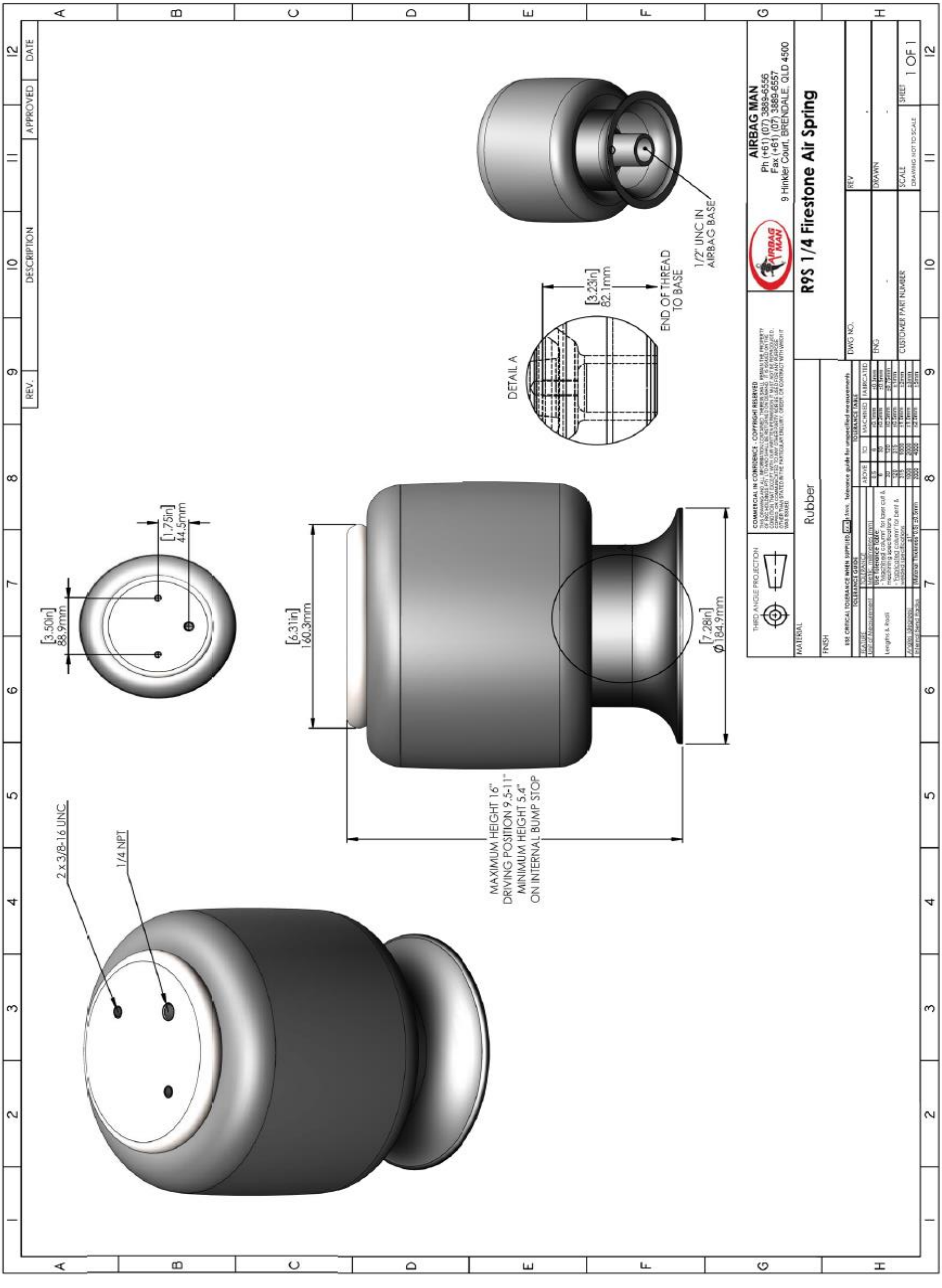
WA AIR SPRINGS (AUST) PTY LTD
ACTUATION • ISOLATION • RIDE

My mobile no. is 0450905003
I think it is Firestone, I have attached the assembly order number sheet I got from the website.

Regards,
Robert
[Quoted text hidden]

274M.pdf
56K

FIGURE L



REV.
DESCRIPTION
APPROVED
DATE
2 x 3/8-16 UNC
1/4 NPT
[3.50in] 88.9mm
[1.75in] 44.5mm
[6.31in] 160.3mm
[7.28in] Ø184.9mm
MAXIMUM HEIGHT 16"
DRIVING POSITION 9.5-11"
MINIMUM HEIGHT 5.4"
ON INTERNAL BUMP STOP
DETAIL A
[3.23in] 82.1mm
END OF THREAD TO BASE
1/2" UNC IN AIRBAG BASE
THIRD ANGLE PROJECTION
MATERIAL
Rubber
FINISH
AIRBAG MAN
Ph (+61) (07) 3889-6556
Fax (+61) (07) 3889-6557
9 Hinkler Court, BRENDALE, QLD 4500
R9S 1/4 Firestone Air Spring
DWG NO.
REV
ENG
DRAWN
CUSTOMER PART NUMBER
SCALE
DRAWING NOT TO SCALE
SHEET
1 OF 1

FIGURE M

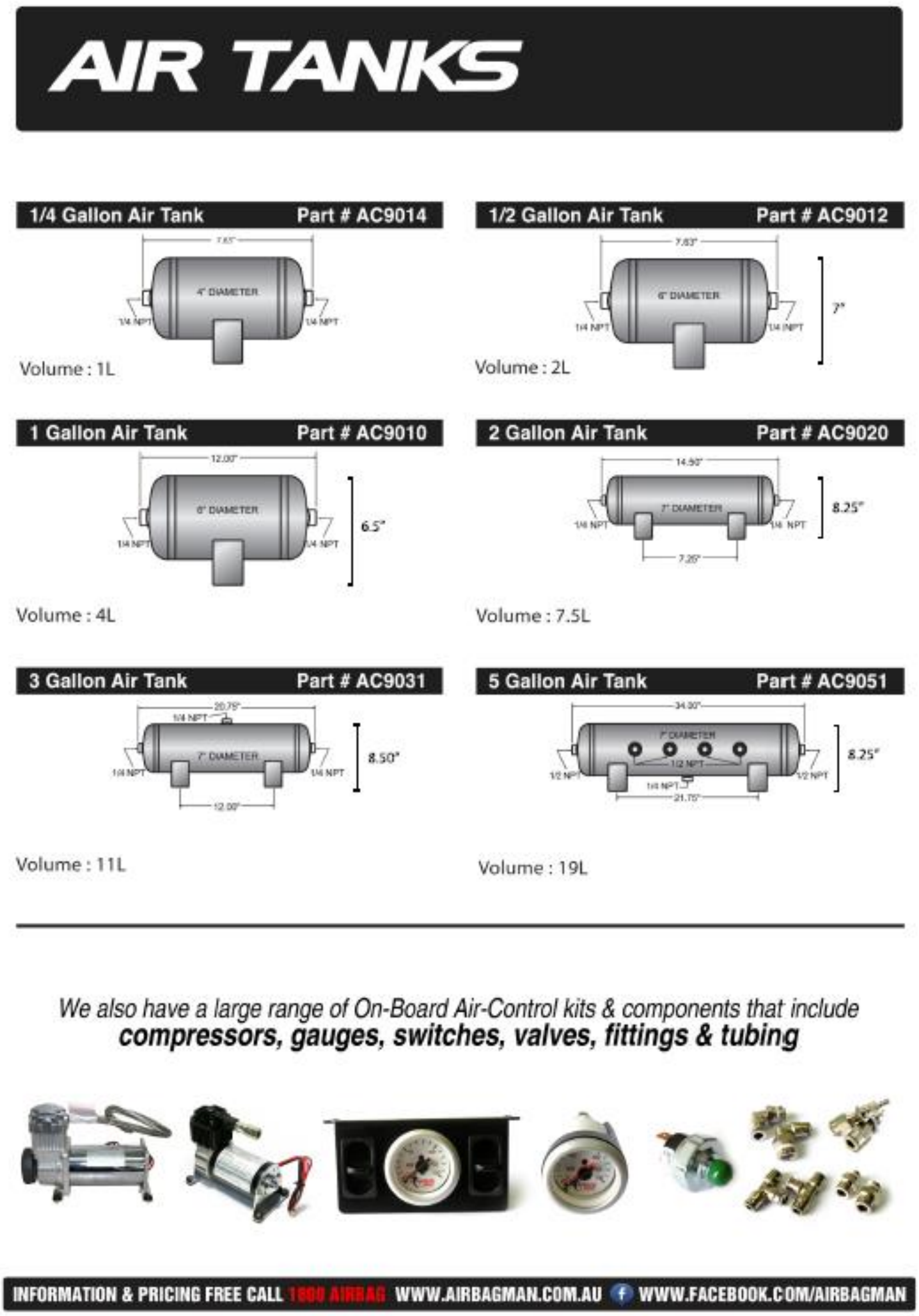

AIR TANKS
1/4 Gallon Air Tank
Part # AC9014
Volume : 1L
1/2 Gallon Air Tank
Part # AC9012
7"
Volume : 2L
1 Gallon Air Tank
Part # AC9010
6.5"
Volume : 4L
2 Gallon Air Tank
Part # AC9020
8.25"
Volume : 7.5L
3 Gallon Air Tank
Part # AC9031
8.50"
Volume : 11L
5 Gallon Air Tank
Part # AC9051
8.25"
Volume : 19L
We also have a large range of On-Board Air-Control kits & components that include
compressors, gauges, switches, valves, fittings & tubing
INFORMATION & PRICING FREE CALL 1800 AIRBAG WWW.AIRBAGMAN.COM.AU WWW.FACEBOOK.COM/AIRBAGMAN

FIGURE N

Mecanum wheel with 45° rollers

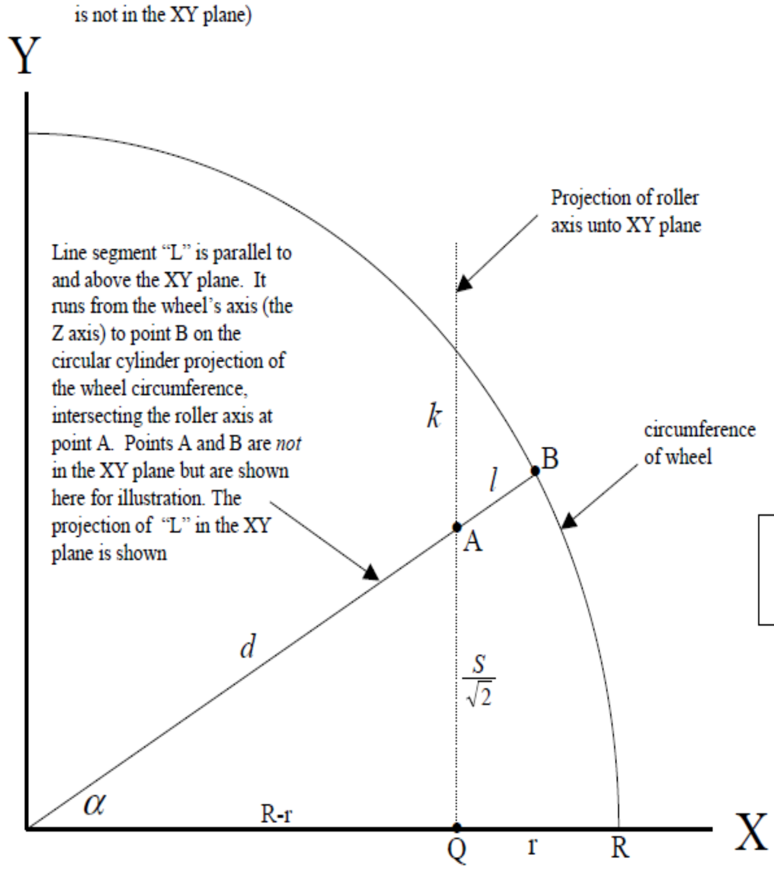
Wheel is lying in the XY plane

R wheel radius

r roller max radius

S distance along roller axis to intersection with Line "L"

θ angle between Line "L" and the roller axis (this angle is not in the XY plane)



Pick a value for **R** and a value for **r**,

Then make the following computations as you vary the value of the parameter S from zero to half the length of the roller axis:

$$\alpha = \tan^{-1}\left(\frac{S/\sqrt{2}}{(R-r)}\right)$$

$$d = \frac{R-r}{\cos(\alpha)}$$

$$l = R - d$$

$$\theta = \cos^{-1}\left(\frac{\sin(\alpha)}{\sqrt{2}}\right)$$

See notes on following page

$$\boxed{h = S + \frac{l\sin(\alpha)}{\sqrt{2}} \qquad Rr = l\sin(\theta)}$$

The above are parametric equations. S is the parameter. Pick values for S and compute a table of *Rr* vs *h*. "*Rr*" is the roller radius at a distance "*h*" from the center of the roller measured along the roller axis

FIGURE O

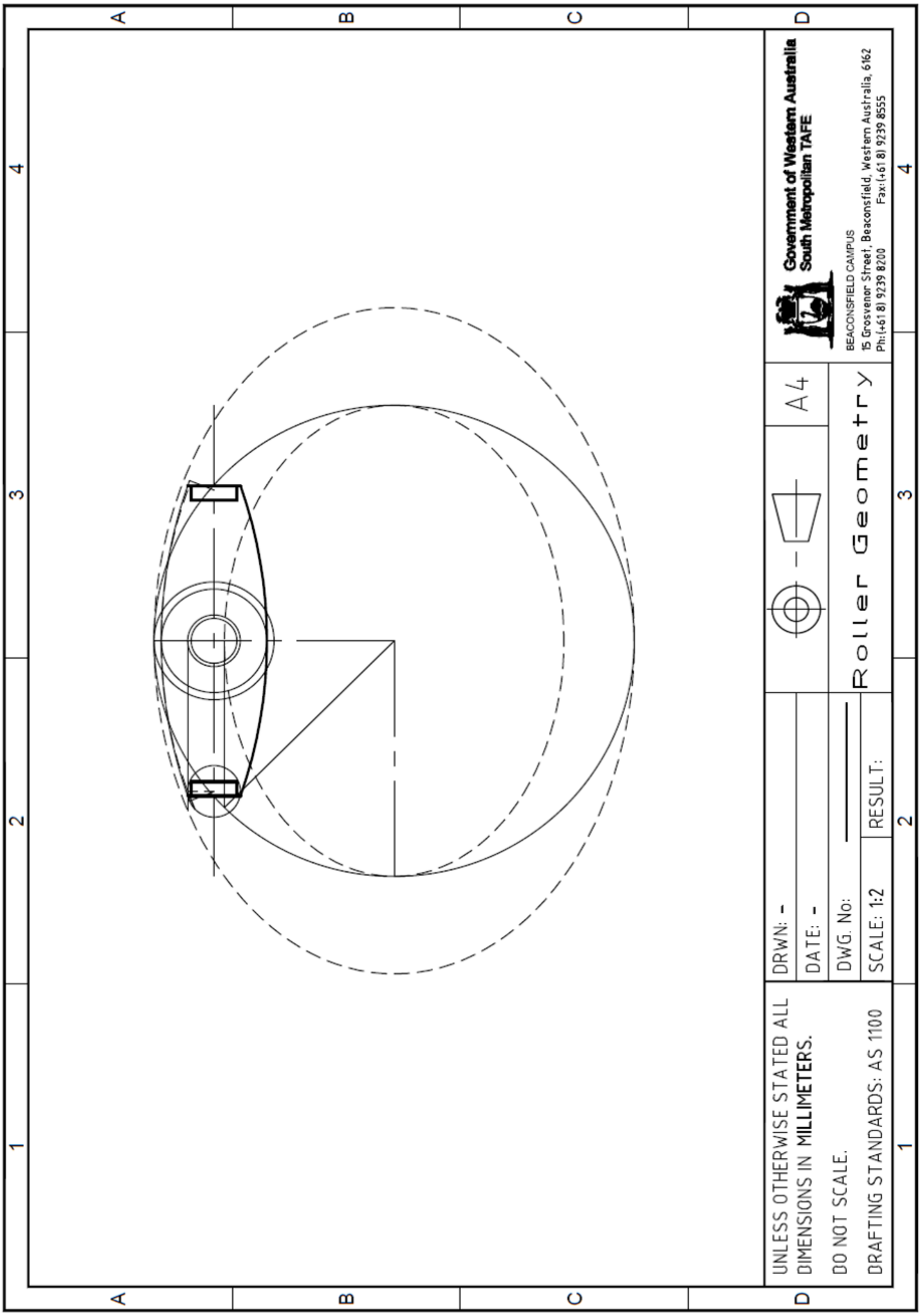

Government of Western Australia
South Metropolitan TAFE
BEACONSFIELD CAMPUS
15 Grosvenor Street, Beaconsfield, Western Australia, 6162
Ph:(+61 8) 9239 8200 Fax:(+61 8) 9239 8555
A4
Roller Geometry
UNLESS OTHERWISE STATED ALL DIMENSIONS IN MILLIMETERS.
DO NOT SCALE.
DRAFTING STANDARDS: AS 1100
DRWN: -
DATE: -
DWG. No:
SCALE: 1:2
RESULT:

FIGURE P

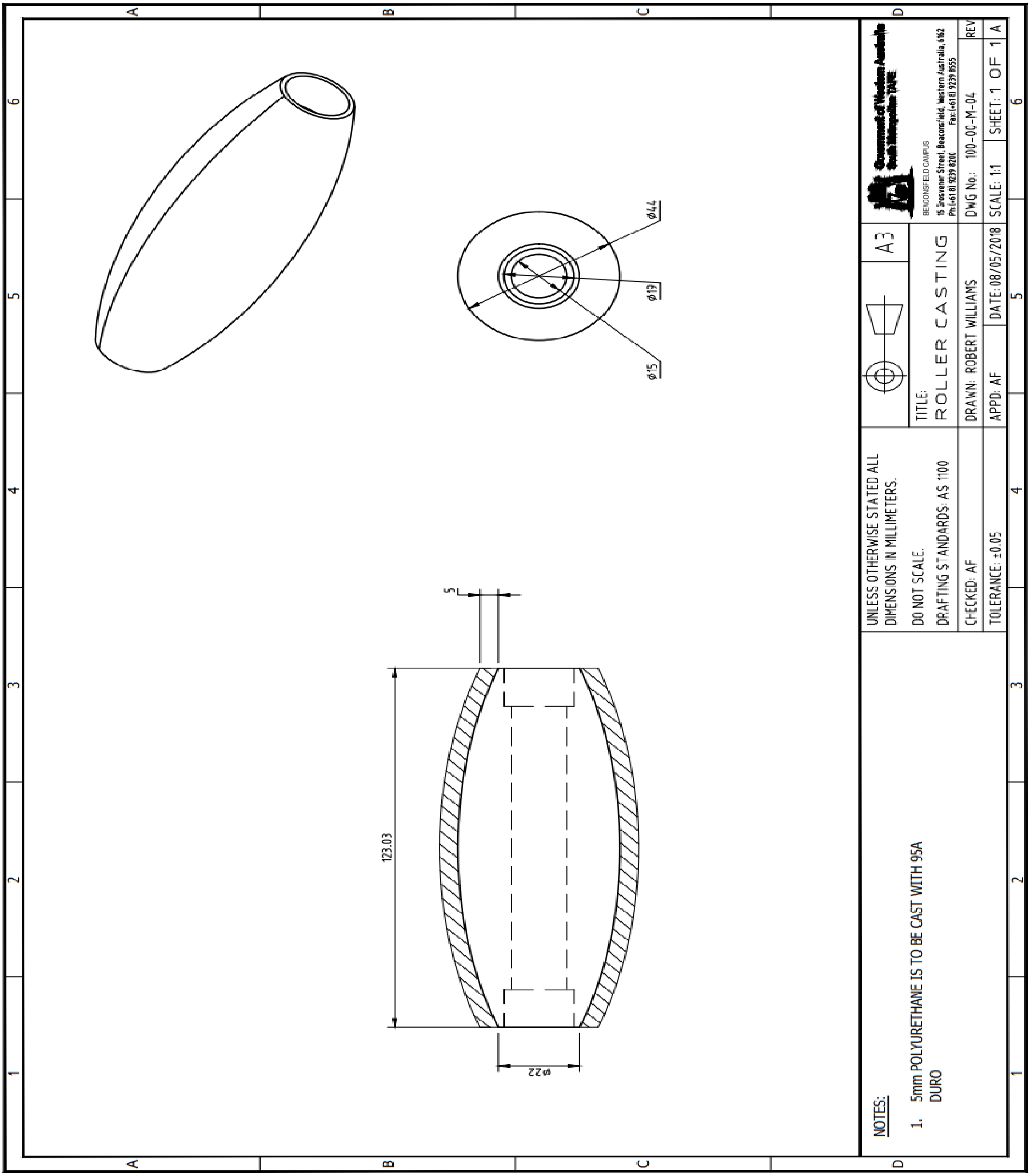

ø44
ø19
ø15
5
123.03
ø22
NOTES:
1. 5mm POLYURETHANE IS TO BE CAST WITH 95A DURO
UNLESS OTHERWISE STATED ALL DIMENSIONS IN MILLIMETERS.
DO NOT SCALE.
DRAFTING STANDARDS: AS 1100
CHECKED: AF
TOLERANCE: ±0.05
A3
TITLE:
ROLLER CASTING
DRAWN: ROBERT WILLIAMS
APPD: AF
DATE: 08/05/2018
BEACONSFIELD CAMPUS
15 Grosvenor Street, Beaconsfield, Western Australia, 6162
Ph: (+61 8) 9239 8200 Fax: (+61 8) 9239 8555
DWG No.: 100-00-M-04
SCALE: 1:1
SHEET: 1 OF 1
REV
A

FIGURE Q

From: Robert Williams [mailto:williams.a.robert@gmail.com]
Sent: Tuesday, 8 May 2018 11:47 AM
To: PUP Admin
Subject: Requesting Quote

[Quoted text hidden]

Robert Williams <williams.a.robert@gmail.com> 8 May 2018 at 13:16
To: PUP Admin <admin@pup.com.au>

Hi Alan,

Here is a drawing of the roller to be cast which we will use in our Mecanum wheel.
The Hatched area represents the polyurethane, but to reduce cost it can be cylindrical, and I will have it machined in house to the desired size.
As long as the widest part has a minimum of 10 mm thick all around.

Let me know if you require any further clarification.

Cheers,
Robert
[Quoted text hidden]

roller.pdf
235K

PUP Admin <admin@pup.com.au> 8 May 2018 at 13:49
To: Robert Williams <williams.a.robert@gmail.com>

Good afternoon Robert

We will cast 95 shore A Polyurethane onto your Rollers nominal 65mm diameter.

Machine finishing not included.

24 off @ $35.00 each plus GST

Total $924.00 payable on collection.

Regards

Alan Meldrum

FIGURE R

Gmail

Robert Williams <williams.a.robert@gmail.com>

bearing Quote

9 messages

Robert Williams <williams.a.robert@gmail.com> 13 February 2018 at 11:28
To: Frank Mayer <mayer.f@statewidebearings.com.au>

Hi Frank

I am looking for a quote for bearings for a project I am currently involved in at south metro tafe. I need a price for 698-2RS JP
Currently I need 96 units but could increase to 128. The project is still in the design phase but manufacturing should commence in 8 weeks.

Regards,
Robert Williams

Frank Mayer <mayer.f@statewidebearings.com.au> 13 February 2018 at 12:46
To: Robert Williams <williams.a.robert@gmail.com>

Hi Robert,

96-128 x 698-2RS JP $4.50ea + GST.

1 x BAG 3Kkg $16.00 + GST.

Delivery 2-3 Working Days ARO STPS.

Regards,

Frank Mayer
Power Transmission Sales

Statewide Bearings

67 Kewdale Road

Kewdale WA 6105

T (08) 9352 2200

F (08) 9352 2244

STATEWIDE BEARINGS

FIGURE S

Frank Mayer <mayer.f@statewidebearings.com.au>
To: Robert Williams <williams.a.robert@gmail.com>

13 March 2018

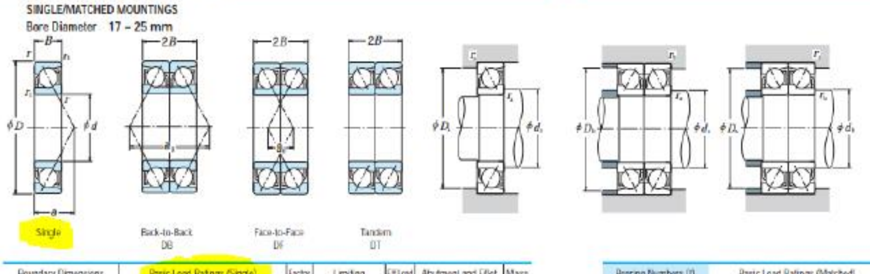
Best we can offer is the following.

2 x 7204 B JP $20.00ea + GST. Ex-Stock Kewdale.

https://mail.google.com/mail/u/0/?ui=2&ik=f3d9fc47e0&jsver=uCCkJJ8n4pE.en_GB.&cbl=gmail_fe_180516.06_p8&view=pt&search=inbox&th=16... 2/3

ANGULAR CONTACT BALL BEARINGS **NSK**

SINGLE/MATCHED MOUNTINGS
Bore Diameter 17 – 25 mm



Dynamic Equivalent Load $P = XF_r + YF_a$

Contact Angle	iF_a/C_{0r}*	e	Single, DT $F_a/F_r \le e$ X	Y	Single, DT $F_a/F_r > e$ X	Y	DB or DF $F_a/F_r \le e$ X	Y	DB or DF $F_a/F_r > e$ X
15°	0.178	0.38	1	0	0.44	1.47	1	1.65	0.72
	0.357	0.40	1	0	0.44	1.40	1	1.57	0.72
	0.714	0.43	1	0	0.44	1.30	1	1.46	0.72
	1.07	0.46	1	0	0.44	1.23	1	1.38	0.72
	1.43	0.47	1	0	0.44	1.19	1	1.34	0.72
	2.14	0.50	1	0	0.44	1.12	1	1.26	0.72
	3.57	0.55	1	0	0.44	1.02	1	1.14	0.72
	5.35	0.56	1	0	0.44	1.00	1	1.12	0.72
25°	—	0.68	1	0	0.41	0.87	1	0.92	0.67
30°	—	0.80	1	0	0.39	0.76	1	0.78	0.63
40°	—	1.14	1	0	0.35	0.57	1	0.55	0.57

*For i, use 2 for DB, DF and 1 for DT

Static Equivalent Load $P_0 = X_0F_r + Y_0F_a$

Contact Angle	Single, DT X_0	Y_0	DB or DF X_0	Y_0
15°	0.5	0.46	1	0.92
25°	0.5	0.38	1	0.76
30°	0.5	0.33	1	0.66
40°	0.5	0.26	1	0.52

Single or DT mounting when $F_r > 0.5F_r + Y_0F_a$ use $P_0 = F_r$

Boundary Dimensions (mm) d	D	B	r min.	r_1 min.	Basic Load Ratings (Single) (N) C_r	C_{0r}	(kgf) C_r	C_{0r}	Factor f_0	Limiting Speeds (¹) (min⁻¹) Grease	Oil	Eff.Load Centers (mm) a	Abutment and Fillet Dimensions (mm) d_a min.	D_a max.	r_a max.	Mass (kg) approx.
17	30	7	0.3	0.15	4 750	2 800	485	286	—	30 000	40 000	9.0	19.5	27.5	0.3	0.017
	30	7	0.3	0.15	5 000	2 940	510	299	14.8	34 000	48 000	6.6	19.5	27.5	0.3	0.017
	35	10	0.3	0.15	6 400	3 800	655	390	—	22 000	30 000	12.5	19.5	32.5	0.3	0.040
	35	10	0.3	0.15	6 600	3 800	675	390	14.5	32 000	43 000	8.5	19.5	32.5	0.3	0.044
	40	12	0.6	0.3	10 800	6 000	1 100	610	—	20 000	28 000	14.2	22	35	0.6	0.067
	40	12	0.6	0.3	9 950	5 500	1 010	565	—	14 000	19 000	18.0	22	35	0.6	0.068
	40	12	0.6	0.3	11 600	6 100	1 180	625	—	16 000	22 000	18.2	22	35	0.6	0.065
	40	12	0.6	0.3	10 900	5 850	1 110	595	13.3	28 000	38 000	9.8	22	35	0.6	0.075
	47	14	1	0.6	15 900	8 650	1 630	880	—	14 000	19 000	16.2	23	41	1	0.116
	47	14	1	0.6	14 800	8 000	1 510	820	—	13 000	17 000	20.4	23	41	1	0.118
	47	14	1	0.6	16 800	8 300	1 720	850	—	14 000	20 000	20.4	23	41	1	0.113
20	37	9	0.3	0.15	6 600	4 050	675	410	—	24 000	32 000	11.1	22.5	34.5	0.3	0.036
	37	9	0.3	0.15	6 950	4 250	710	430	14.9	28 000	38 000	8.3	22.5	34.5	0.3	0.036
	42	12	0.6	0.3	10 800	6 600	1 110	670	—	18 000	24 000	14.9	25	37	0.6	0.068
	42	12	0.6	0.3	11 100	6 550	1 130	665	14.0	26 000	36 000	10.1	25	37	0.6	0.076
	47	14	1	0.6	14 500	8 300	1 480	845	—	17 000	22 000	16.7	26	41	1	0.106
	47	14	1	0.6	13 300	7 650	1 360	780	—	12 000	16 000	21.1	26	41	1	0.109

Bearing Numbers (²) Single	Duplex			Basic Load Ratings (Matched) (N) C_r	C_{0r}	(kgf) C_r	C_{0r}	Limiting Speeds (¹) (Matched) (min⁻¹) Grease	Oil	Load Center Spacings (mm) a_0 DB	DF	Abutment and Fillet Dimensions (mm) d_b (³) min.	D_b max.
7903 A5	DB	DF	DT	7 750	5 600	790	570	24 000	32 000	18.0	4.0	—	28.8
7903 C	DB	DF	DT	8 150	5 850	830	600	28 000	38 000	13.3	0.7	—	28.8
7003 A	DB	DF	DT	10 400	7 650	1 060	780	17 000	24 000	25.0	5.0	18.2	33.8
7003 C	DB	DF	DT	10 700	7 600	1 100	775	26 000	34 000	17.0	3.0	—	33.8
7203 A	DB	DF	DT	17 600	12 000	1 790	1 220	16 000	22 000	28.5	4.5	19.5	37.5
7203 B	DB	DF	DT	16 100	11 000	1 650	1 130	11 000	15 000	35.9	11.9	19.5	37.5
*7203 BEA				—	—	—	—	13 000	18 000	36.3	12.3	19.5	37.5
7203 C	DB	DF	DT	17 600	11 700	1 800	1 190	22 000	32 000	19.6	4.4	—	37.5
7303 A	DB	DF	DT	25 900	17 300	2 640	1 760	11 000	15 000	32.5	4.5	22	42
7303 B	DB	DF	DT	24 000	16 000	2 450	1 640	10 000	14 000	40.9	12.9	22	42
*7303 BEA				—	—	—	—	11 000	16 000	40.9	12.9	22	42
7904 A5	DB	DF	DT	10 700	8 100	1 090	825	19 000	26 000	22.3	4.3	—	35.8
7904 C	DB	DF	DT	11 300	8 500	1 150	865	22 000	32 000	16.6	1.4	—	35.8
7004 A	DB	DF	DT	17 600	13 200	1 800	1 340	15 000	20 000	29.9	5.9	22.5	39.5
7004 C	DB	DF	DT	18 000	13 100	1 840	1 330	20 000	30 000	20.3	3.7	—	39.5
7204 A	DB	DF	DT	23 500	16 600	2 400	1 690	13 000	19 000	33.3	5.3	25	42
7204 B	DB	DF	DT	21 600	15 300	2 210	1 560	9 500	13 000	42.1	14.1	25	42

Regards,

Frank Mayer
Power Transmission Sales

Statewide Bearings
67 Kewdale Road
Kewdale WA 6105
T (08) 9352 2200
F (08) 9352 2244

FIGURE T

NAISMITH

Power Transmission is all we do

Sales Quote

Naismith Engineering & Manufacturing Co. Pty Ltd 149 Heidelberg Rd, Northcote VIC 3070 Australia PO Box 261, Northcote VIC 3070 Australia
Ph: 03 9489 9811 Fax: 03 9482 1474
www.naismith.com.au A.B.N. 25 004 284 388

To:	**Cash Sale Account** Cust Phone No: Cust Fax No: Australia	Date: 27/04/18 Account Code: CASHSALE Quote No: Q108624 Page No: 1 of 1
Attention: From:	Cyprian Sino Pinal	

10% G.S.T. MUST BE ADDED TO THESE PRICES

Item Description Quantity Unit Price Disc% Extension **A$ List**

16 X T5-340 T5-340 Metric Timing Belt (68)

`

25-T5-16	25-T5-16F Timing Pulley Pilot Bore 27T5/25	2.00	EACH	13.60
REBORE	Bore 14mm H7 with 5mm x 2.3mm Key-way + G/S	1.00	EACH	41.90
REBORE	Bore12mm H7 with 4mm x 1.8mm Key-Way + G/S	1.00	EACH	41.90
-340-T5-16	340-T5-16 Metric Timing Belt (68) This belt is cut from a sleeve and is not returnable.	1.00	EACH	36.10

All above Ex-Stock Melbourne.

Allow approx. 2-3 working days for Machining.

Bank Details

IMPORTANT NOTICE

All prices are subject to change without notice. Prices for goods imported against orders are subject to change due to exchange rate variations

Sub Total Exc. G.S.T.	$147.10
10% G.S.T.	$14.71
Quotation	**AUD**

For Direct deposits and electronic transfer
Westpac
BSB - 033048
Account No. - 612285

Terms: Cash

This Quote will automatically expire 30 days from the date issued.
This quotation must be read in conjunction with our General Terms and Conditions of Sale

FIGURE U

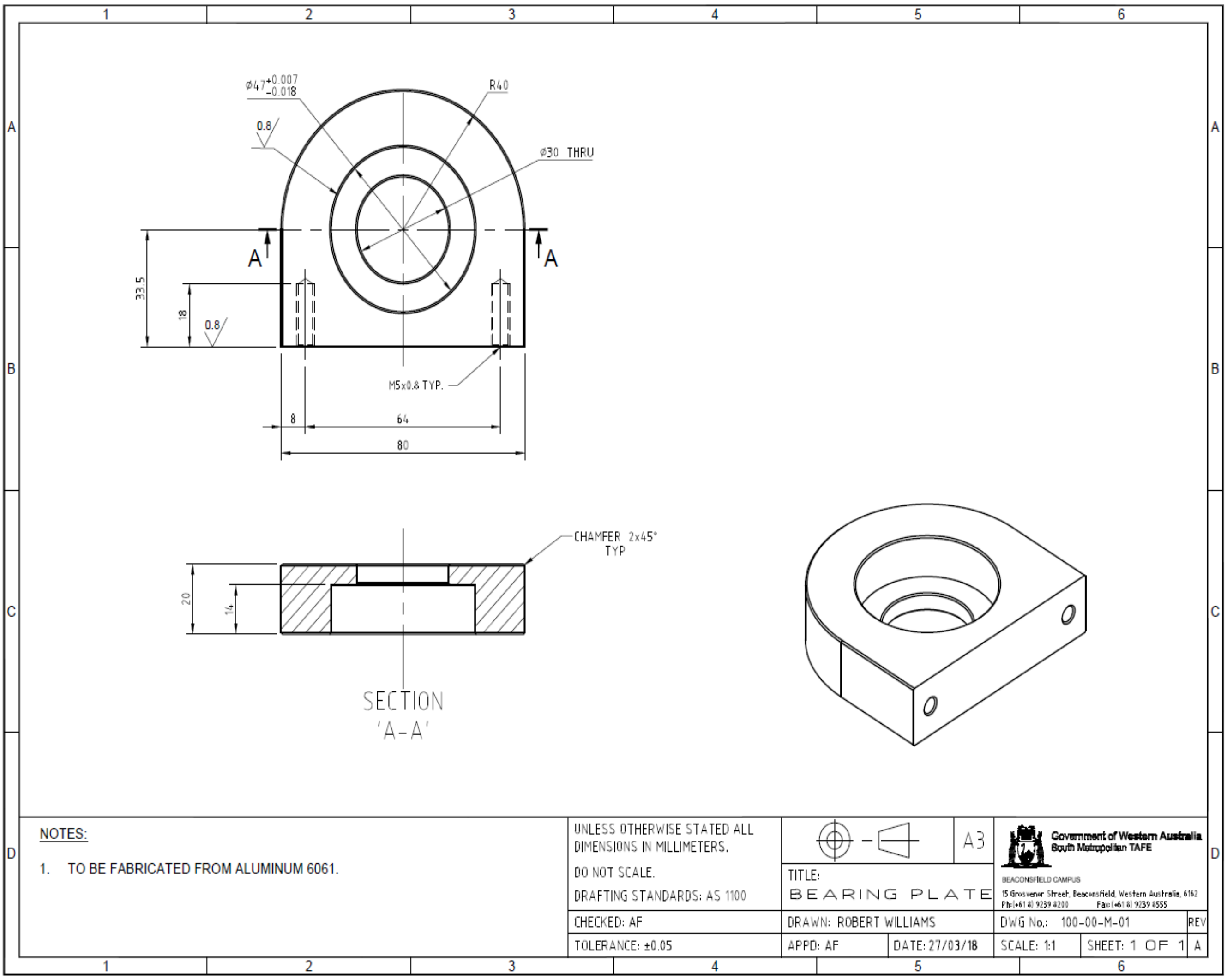


FIGURE V

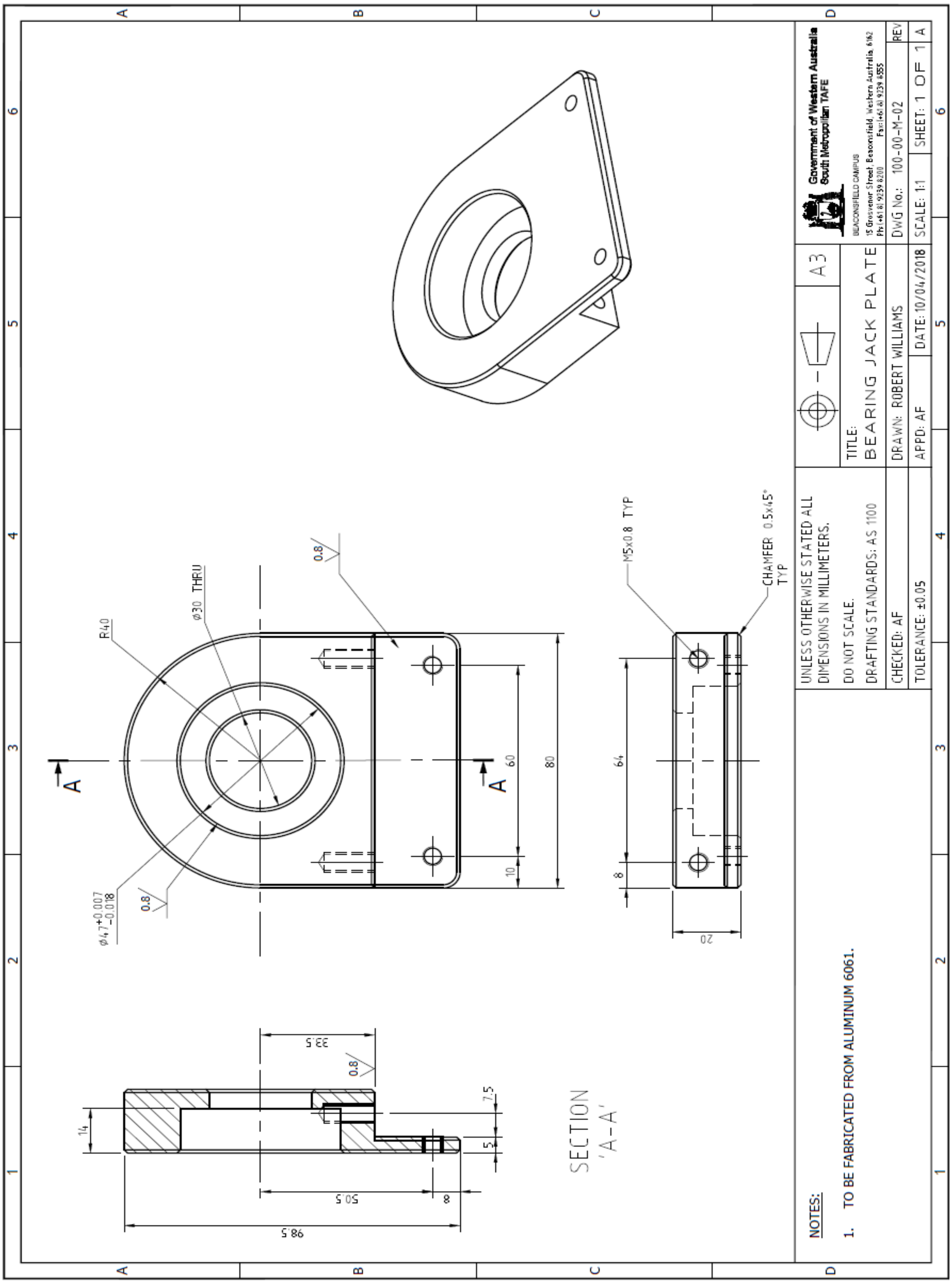
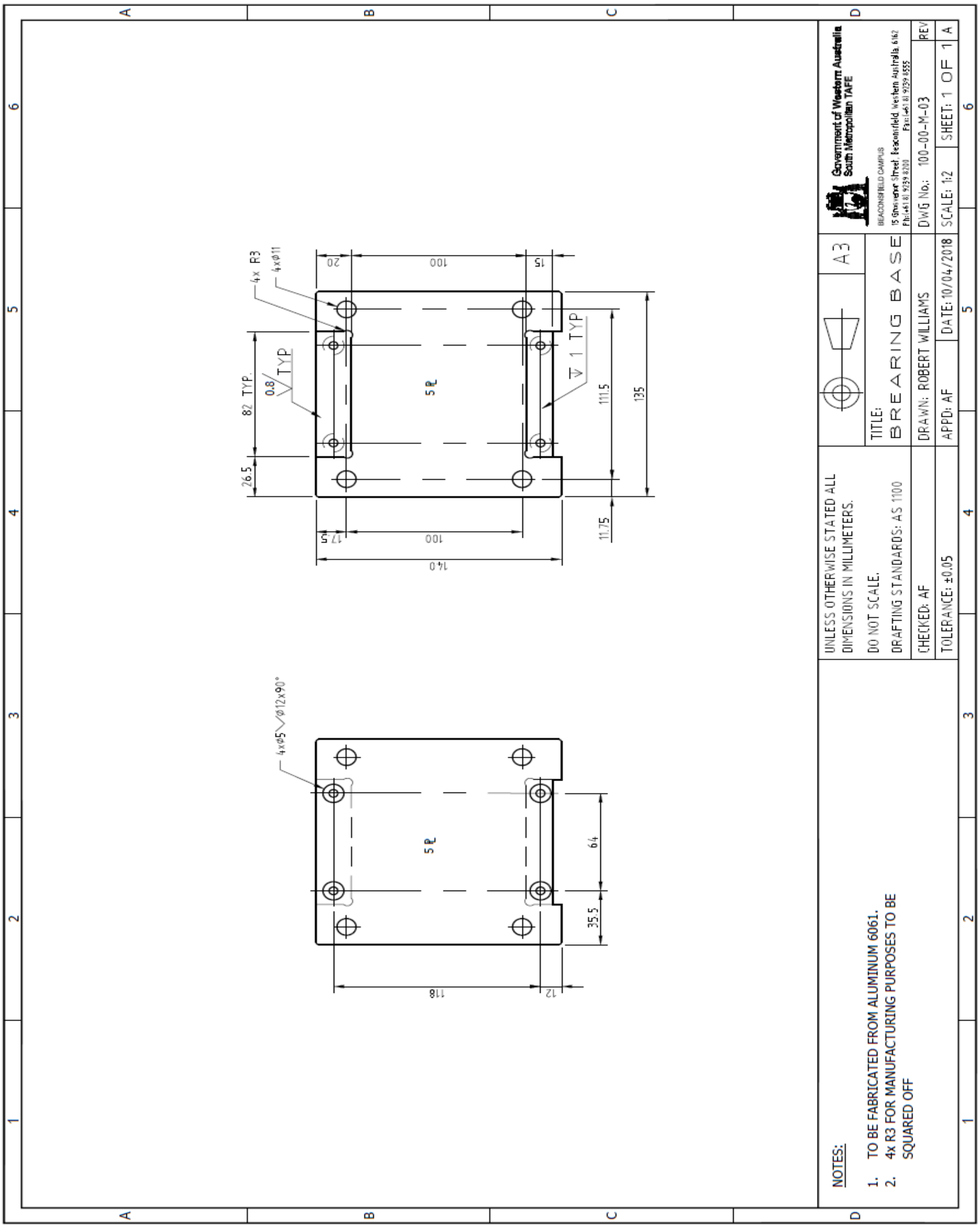

SECTION 'A-A'
NOTES:
1. TO BE FABRICATED FROM ALUMINUM 6061.
UNLESS OTHERWISE STATED ALL DIMENSIONS IN MILLIMETERS.
DO NOT SCALE.
DRAFTING STANDARDS: AS 1100
CHECKED: AF
TOLERANCE: ±0.05
TITLE:
BEARING JACK PLATE
A3
DRAWN: ROBERT WILLIAMS
APPD: AF
DATE: 10/04/2018
DWG No.: 100-00-M-02
SCALE: 1:1
SHEET: 1 OF 1
REV A
Government of Western Australia
South Metropolitan TAFE
BEACONSFIELD CAMPUS
15 Grosvenor Street, Beaconsfield, Western Australia, 6162
Ph: (+61 8) 9239 8200 Fax: (+61 8) 9239 8555
R40
Ø30 THRU
M5x0.8 TYP
CHAMFER 0.5x45° TYP
Ø47 +0.007 -0.018

FIGURE W


NOTES:
1. TO BE FABRICATED FROM ALUMINUM 6061.
2. 4x R3 FOR MANUFACTURING PURPOSES TO BE SQUARED OFF
UNLESS OTHERWISE STATED ALL DIMENSIONS IN MILLIMETERS.
DO NOT SCALE.
DRAFTING STANDARDS: AS 1100
CHECKED: AF
TOLERANCE: ±0.05
TITLE:
BREARING BASE
DRAWN: ROBERT WILLIAMS
APPD: AF
DATE: 10/04/2018
A3
Government of Western Australia
South Metropolitan TAFE
BEACONSFIELD CAMPUS
DWG No.: 100-00-M-03
SCALE: 1:2
SHEET: 1 OF 1
REV
A

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