Method of transportation

Since Butler is to execute a go and grasp with a stiff arm the whole sequence will be dependent on the effectiveness and the accuracy of the robots movement. A holonomic drive was deemed necessary to control the smaller movements when aligning the arm to the target. With Ackerman steering or 4 wheel direct drive a situation where the robot is off target might result in multistep process of turning or driving in reverse, when using a holonomic driving solution the robot can simply ”translate” towards the target.

Multiple wheel and driving solutions where reviewed for the holonomic drive control the robot with Omni wheels or Swedish wheels would give the robot holonomic movement. Since Omni wheels optimal operating environment is on smooth surfaces possible obstacle such as cables, doorways or slippery floors will limit the effectiveness of the wheels. To avoid these problems the robot uses two motors per wheel, one motor to control the wheel yaw and the other motor to control roll. This driving method is called swerve drive. Both the roll and yaw motors are stepper motors and was chosen over DC motors to avoid the fragility and size of the planetary gear required for a DC motor to drive the robot.

Mechanical design

Each wheel is designed as a separate module. The four wheel modules are completely identical and designed to be removed from the main body if upgrades or changes are required.

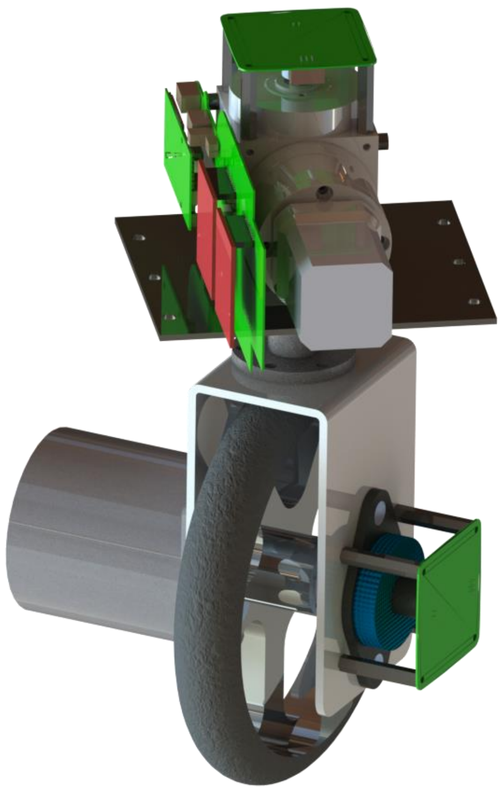

Figure 1: A complete wheel module

The roll motor is mounted on a wheel fork together with the wheel, which it turns directly. The yaw motor is mounted inside the body and turns the whole wheel fork via a beveled gearbox.

The beveled gear box has a 1:5 ratio gearing which limits the required size and strength of the yaw motor. The gearbox also has the benefit of adding increased resolution to the angle of the wheel fork without having the motor rely on micro or half stepping, which would limit the torque output. Since the gear box is not 1:1 a problem occurs when estimating the angle of the wheel fork: it is impossible to estimate the angle of the wheel fork by an encoder onboard the yaw motor, instead the rotary encoder must be placed on the outgoing shaft from the gear box. The selected gearbox has two outgoing shafts where one is connected to the wheel fork and the other is dedicated for the rotary encoder PCB.

The wheel fork has a bearing housing mounted opposite to the motor and a rotary encoder to avoid an open loop system.

Another bearing housing is mounted between the body of the robot and the wheel fork. The bearing will sustain the weight from the robots body leaving torque to be the only remaining force that is applied to shaft connected to the beveled gearbox. Since the bearing will be effected by both radial and axial forces an angular contact bearing was selected and a custom made housing was constructed for it.

The wheel in question is a kick bike wheel and was selected over a standard robot wheel due to its smoother profile and smaller contact area compared to the flatter profile of the robot wheel. This means that the kick bike wheel has the ability to turn on the spot with ease while still maintaining sufficient friction for forward driving.

A custom design for the wheel hub was needed due to the lack of an intuitive way to connect the roll motor to the wheel while still having the ability to attach the bearing housing and rotary encoder on the motor shaft. The wheel is kept in place in place by a nut.

The rotary encoders operating distance from the magnet is between 0.5 and 1.5 mm. The spacers and the length of the wheel hub where selected and constructed to full fill this requirement.

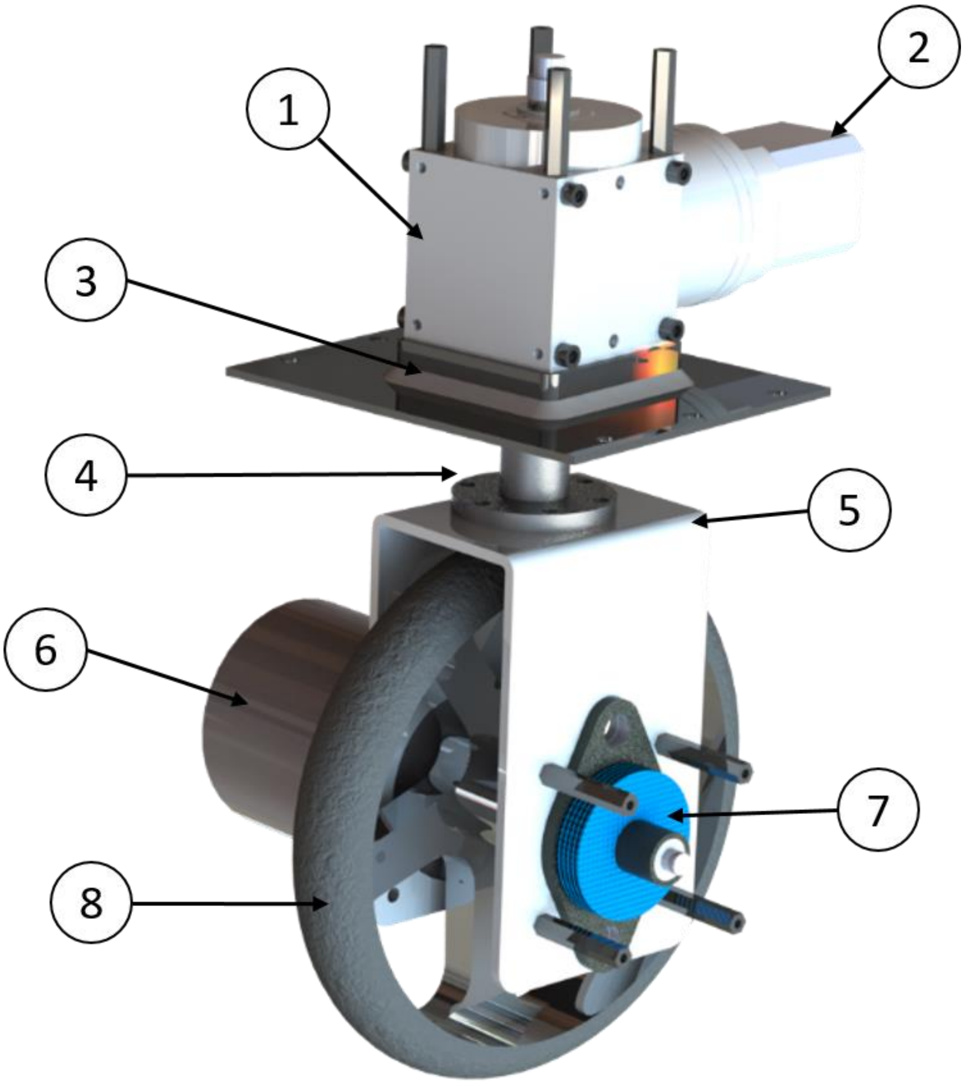

Figure 2: The Components of a wheel module. (1) Beveled Gearbox, (2) Yaw Motor, (3) Angular Contract Bearing Housing, (4) Outgoing Shaft, (5) Wheel Fork, (6) Roll Motor, (7) bearing Housing, (8) Wheel

Stress Test Simulations

The wheel modules where stress tested, before their construction began, with the simulation tools provided by solid works. Since the wheel modules are symmetrical it is assumed that all modules carries an equal amount of the robots weight which allows the modules to be simulated individually. Simulations was performed on the two of the most critical areas: the wheel fork and the wheel hub.

All of the components that are not part of the simulations are considered to be ridged and not effected by the robots weight. This allows the two components to be simulated individually, which both speed up the simulation and provides a clearer result.

During simulations the weight of the robot was exaggerate to ensure that the wheel module would hold for future constructions. For both simulations the weight of the robot is estimated to be 160 Kg and the gravitation constant is rounded to 10. It is assumed that each module carries a fourth of the total weight of the butler robot, which means that a simulated force of 400 N is used to represent the weight of the robot. Both components is simulated with a generic alloy steel material.

Only bearings, bolts and the beveled gearbox with a payload greater than the targeted weight of the butler robot were selected, so no simulations were made on these components.

The Wheel Fork

The simulated force is applied on top of the wheel fork, where the hub which connects the beveled gearbox to the wheel for is mounted.

It is assumed that the wheel hub, roll motor and bearing housing is unaffected by the force applied to the wheel hubs and thus the bolt holes for both the roll motor and bearing housings are treated as being completely rigid.

The Wheel Hub

The rubber wheel is assumed to be unaffected by the robots weight thus the surface area on the wheel hub that is in direct contact with the wheel is considered rigid, with an exception of the upper half of surface area which provides no lifting support for the wheel hub.

The weight of the robot is spread out on two section of the wheel hub. The first is the area around the bearing housing and the second is the inside of the wheel hub where the motor shaft is fitted. The bearing housing provides a downward force on the upper part of the surface where the two components are connected. The second area has a downward force on the lower half of the hole for the roll motors shaft. The total force is spread evenly on these two surfaces.

Simulation Results

The displacement of the components are exaggerate.

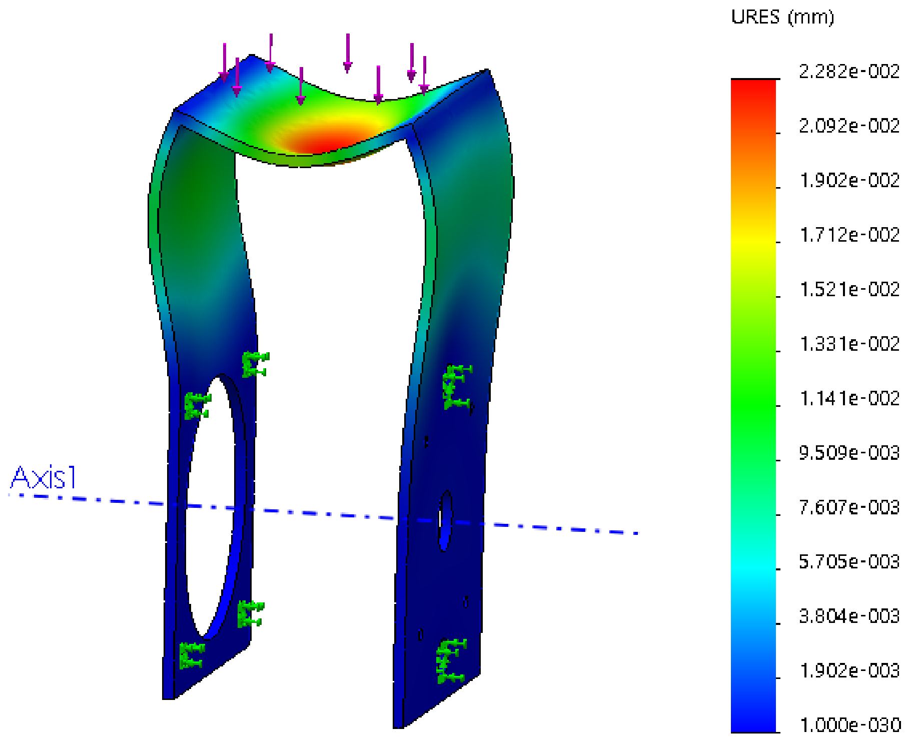

Figure 3: Wheel fork displacement in mm. Green arrows represents rigid surfaces, purple arrows represent the simulated force of 400N.

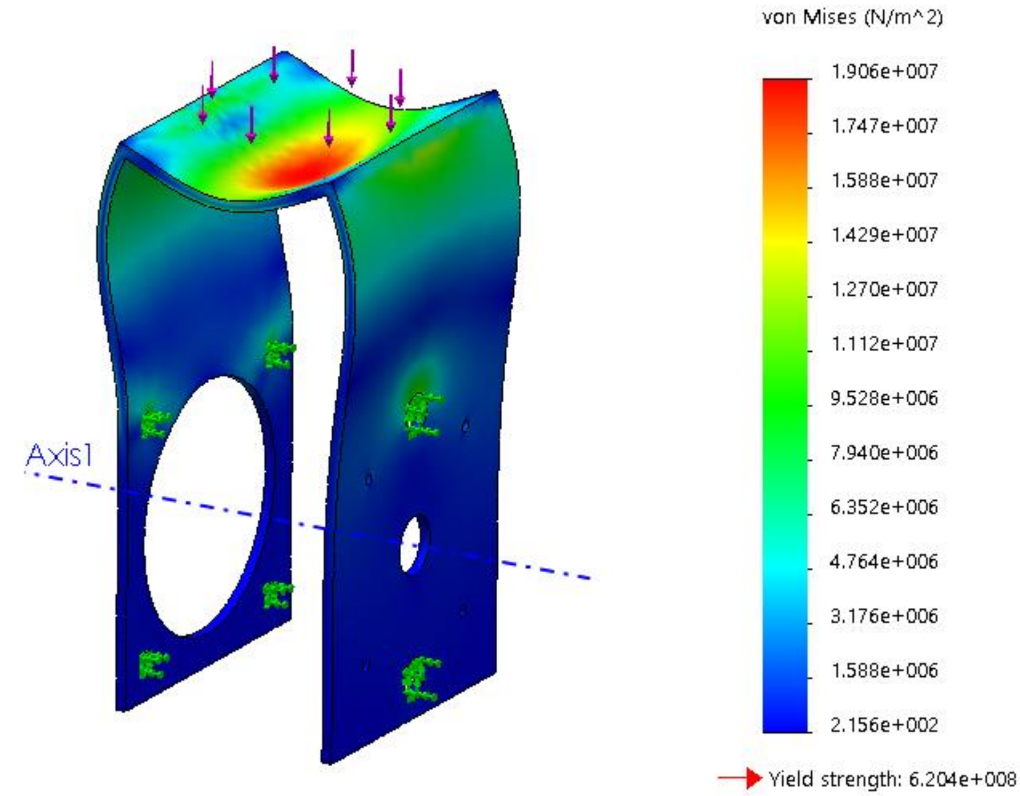

Figure 4: Wheel fork stress test using the Von Mises criterion. Green arrows represents rigid surfaces, purple arrows represent the simulated force of 400N.

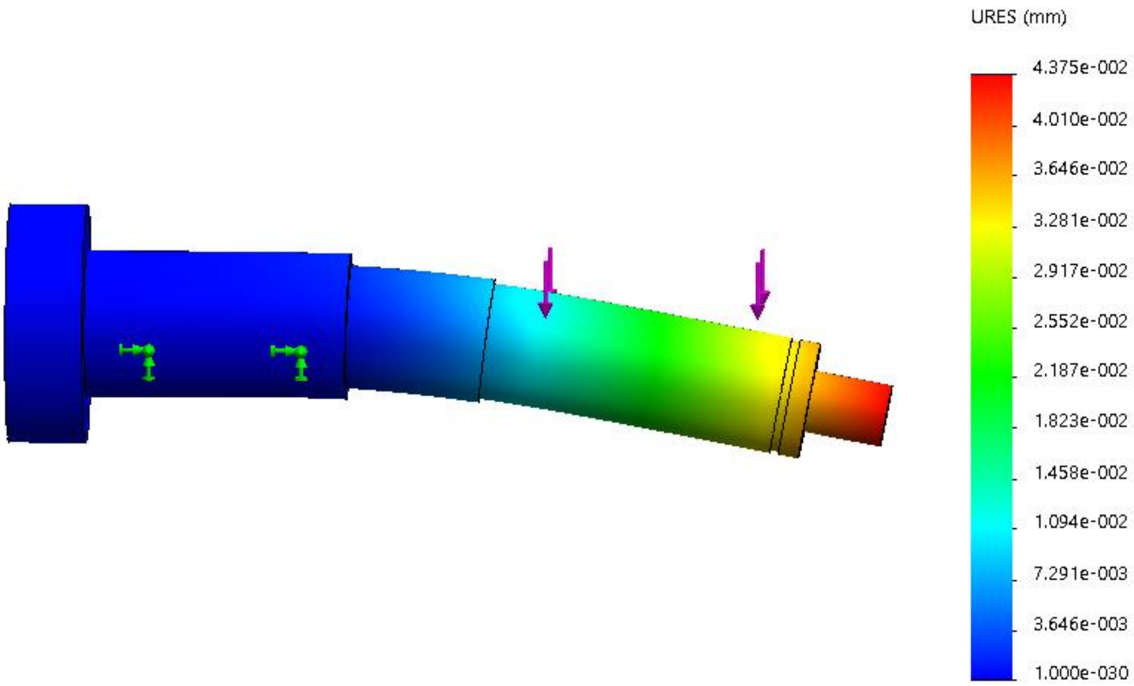

Figure 5: Wheel hub displacement in mm. Green arrows represents rigid surfaces, purple arrows represent the simulated force of 400N.

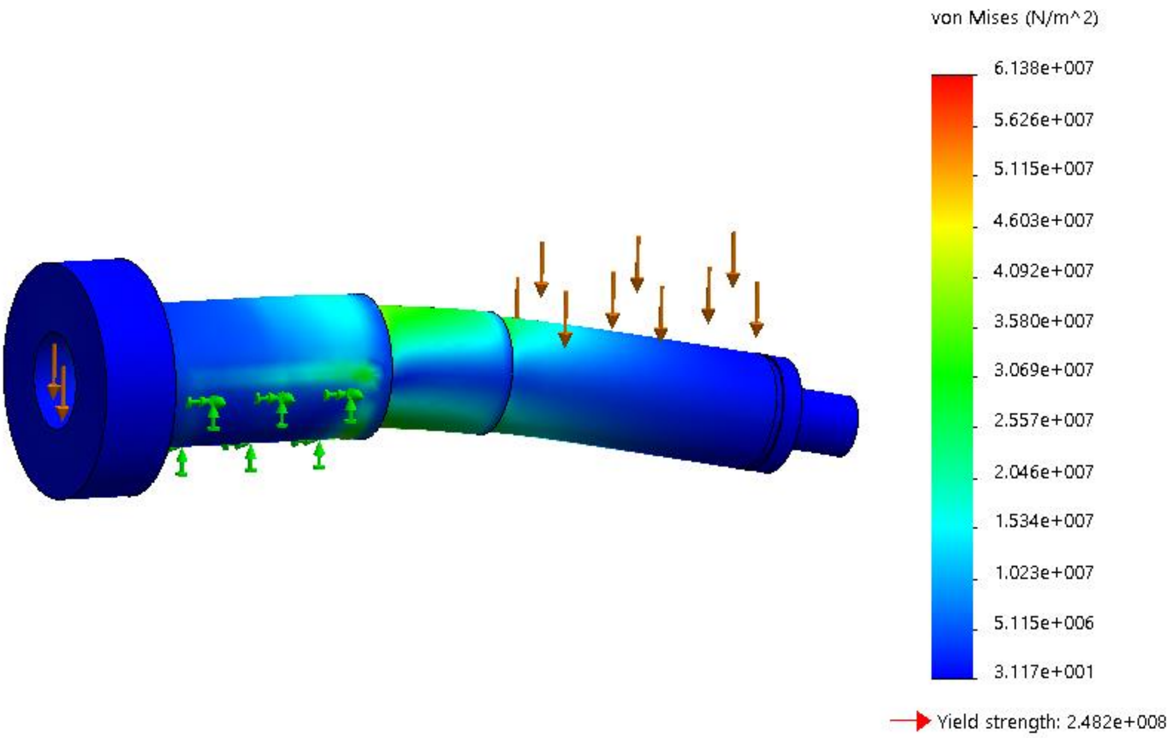

Figure 6: Wheel hub stress test using Von Mises criterion. Green arrows represents rigid surfaces, orange arrows represent the simulated force of 400N.

Conclusions

No component provides a displacement significant displacement (the maximum displacement of both components is under a tenth of an mm) and both components fulfill the von Mises criterion. With these results it can be assumed that the wheel module will hold for the robot butler as it is (now of writing) and for future expansions.