Wheel

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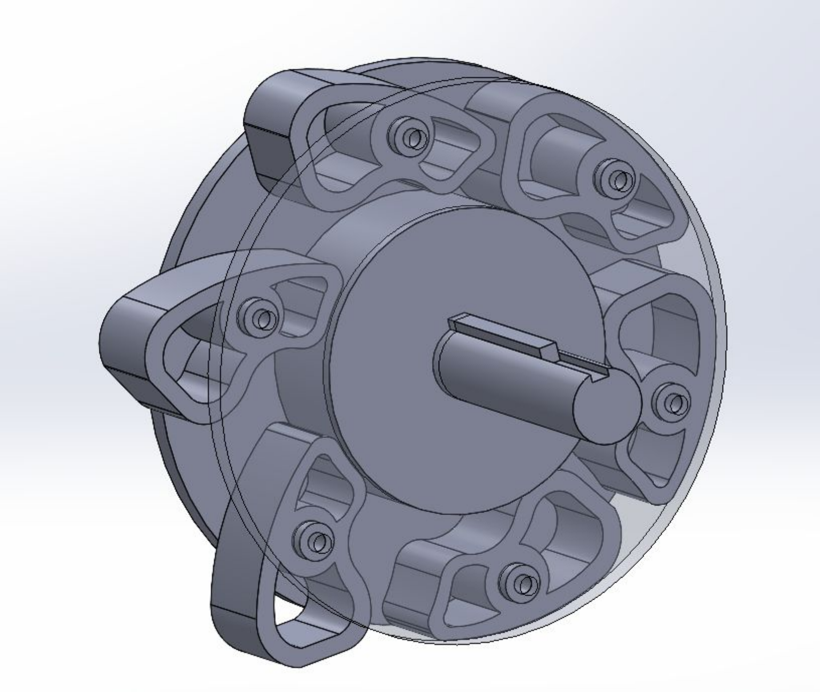
Purpose and Need

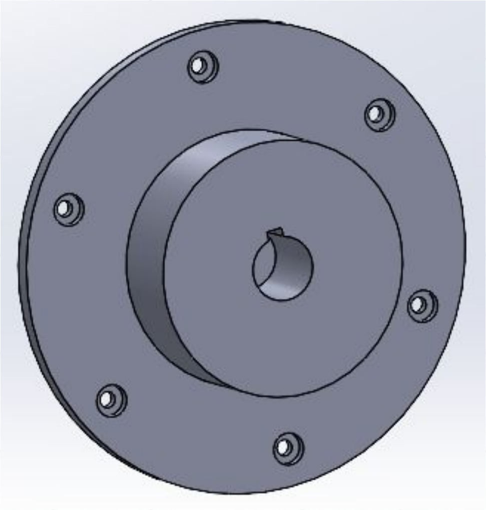
- Convenience
- Improved Mobility
  - Different terrains
  - Can go up stairs

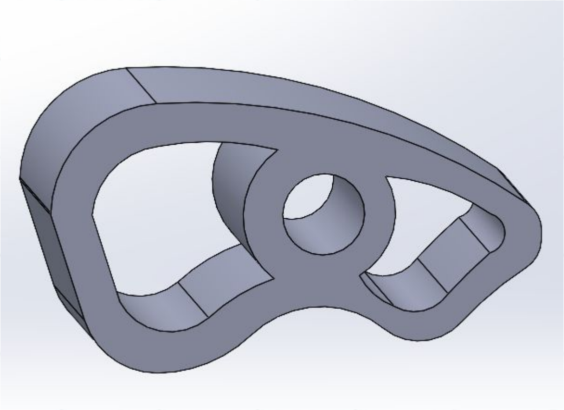


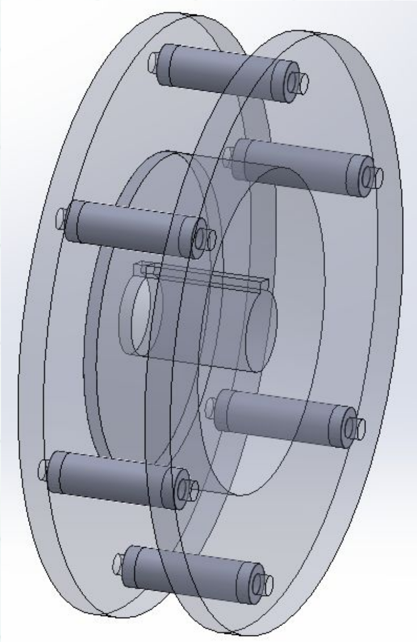
Original Ideas

- We were trying to discover a way to design a wheel that would provide a greater form of grip
- Our design is based around adding hook style grips onto the wheel, allowing for greater form of force and torque to be produced on the surface.
- This enables the wheel to grip onto more unstable surfaces, while providing a smooth feel.
- The gripping mechanism nicknamed “the dogs” went through various designs, and was altered in the final design to be more rounded out so that it would not deform overtime and compromise the wheel’s ability to grip
- The final design also encompassed the intention of allowing the wheel to overcome objects in its path with the main focus being the ability to climb stairs

Components/Parts







<u>Main wheel</u>

- The main support of the wheel

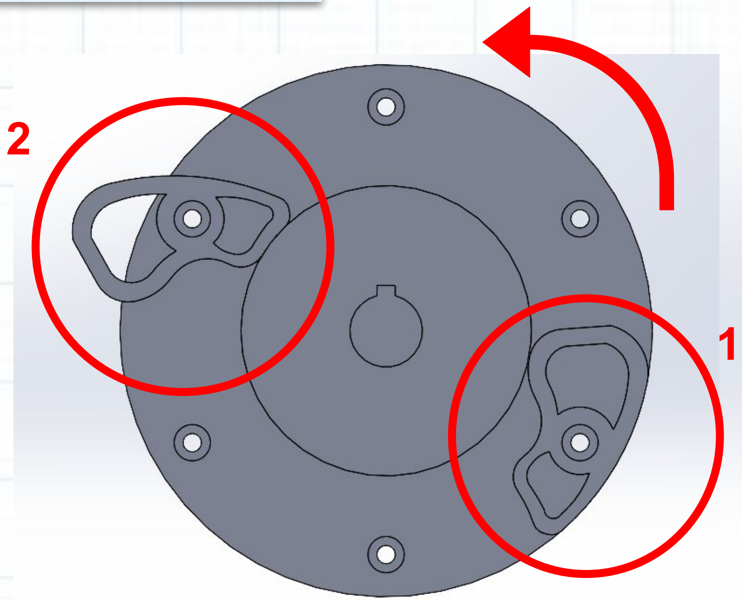
“<u>Dogs</u>”

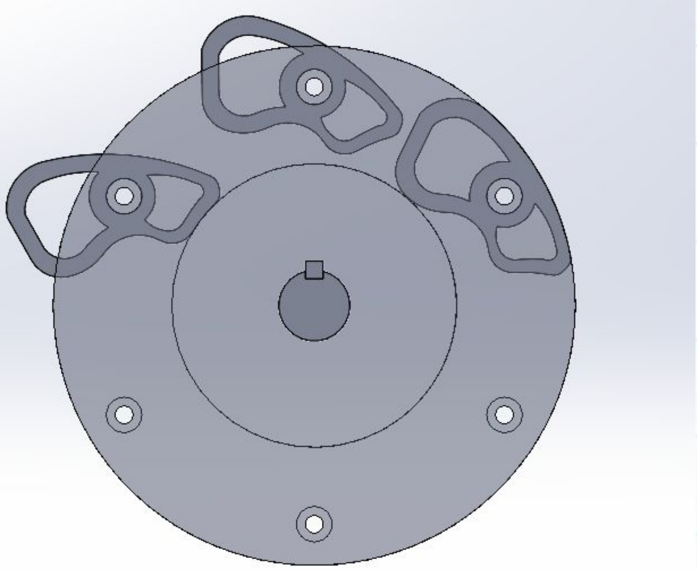
- Provides the wheel more grip to overcome obstacles

<u>Support rods</u>

- The dogs rotate about this rod

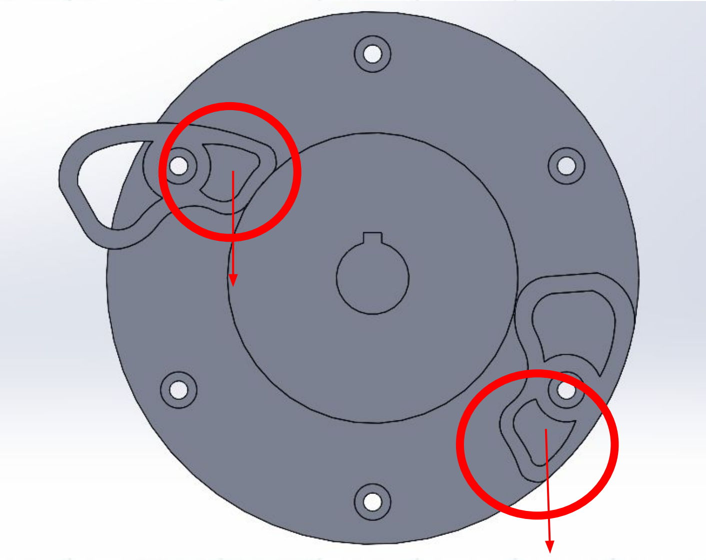
How it works

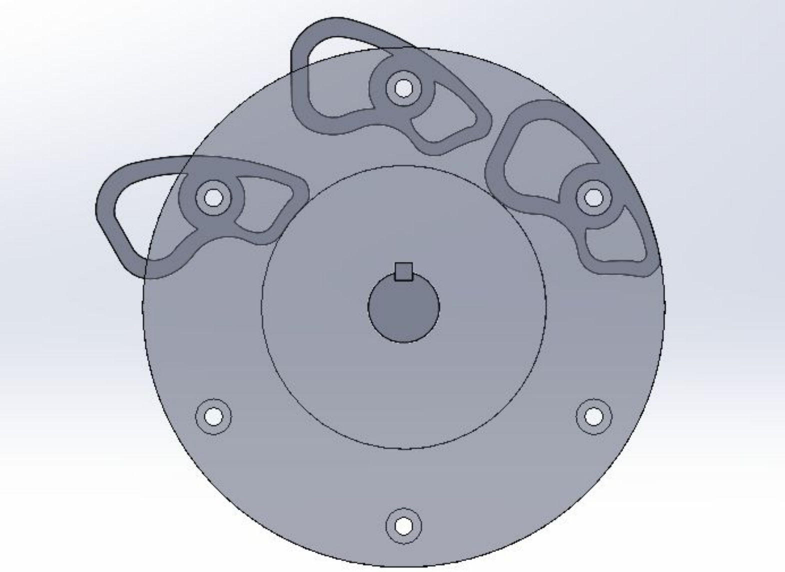




Position 1: dog stays flush with the edge of the wheel because the top has the same radius of curvature
Position 2: dog protrudes out and provides grip as the wheel spins counterclockwise

How it works



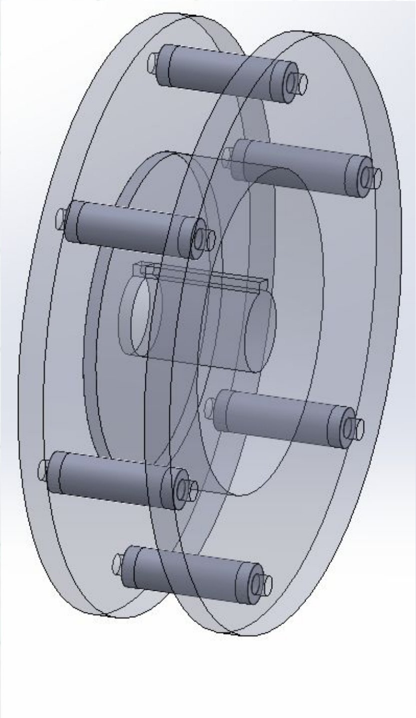


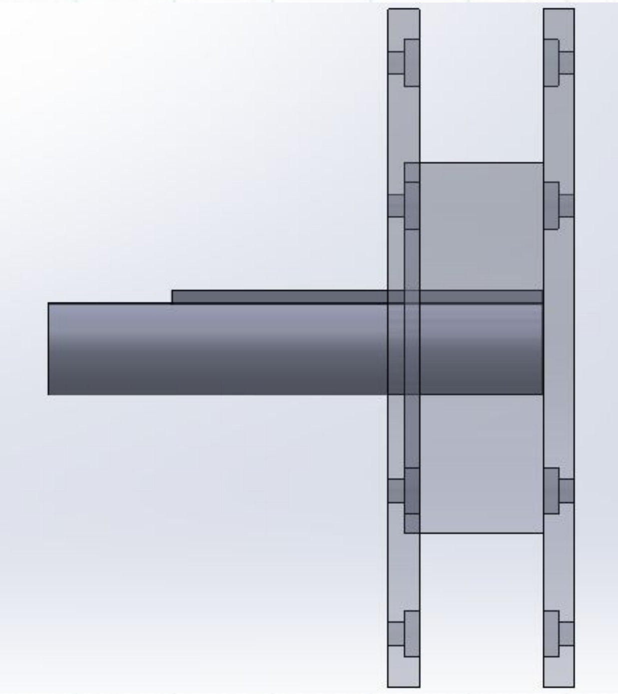
Added weight: weight is added in order to ensure that the dogs stays at its intended position

- Simpler way of letting the dogs fall into place naturally without the need of adding more mechanical components

Additional Support - Screws

- #10 screws
- ¾” shaft
- 3/16” keys
- Countersink
  - Allows for additional support for the rods and less screws to be used





Materials

Dog's Material

Name:**AISI 1020 Steel, Cold Rolled**

Yield strength:**3.5e+08 N/m^2**

Tensile strength:**4.2e+08 N/m^2**

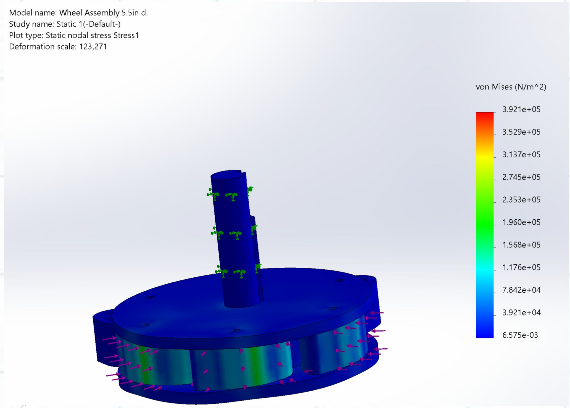
Wheel hub assembly material

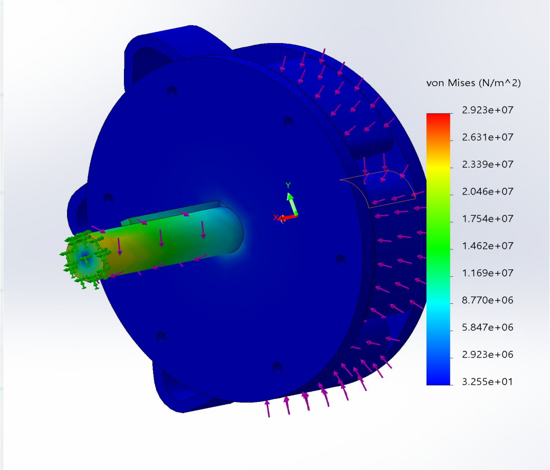
Name:**1060-H12, Cold Drawn**

Yield strength:**7.5e+07 N/m^2**

Tensile strength:**8.5e+07 N/m^2**

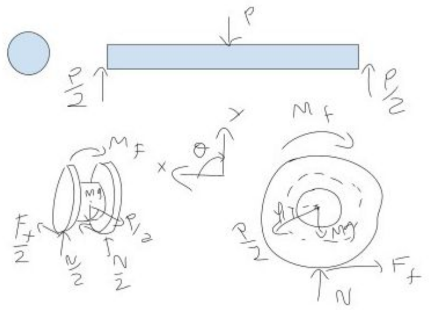
Maximum Stress: Flush:3.921e+05 Extended:2.923e+07





Calculations 1

- Force on main wheel without dogs.



(1) $(P/2)cos(\varphi) - F_f + R_{net,x} + N_{net,x} = M(x/dt^2)$

(2) $N - (P/2)sin(\varphi) - Mg - R_{net,y} - N_{net,y} = 0$

(3) $M_f - r_{wheel} * F_f + r_{react,\perp} * R_{net} = I_{com}(d^2\theta/dt^2)$

$I_{hollow\ cylinder} = (1/2)M(a^2 + b^2)$

a = inner rad. b = outer rad. $I_{cylinder}$ is the same as hollow except there is no inner rad.

The total I_{com} is a superposition of the wheel's components which are just cylinders, and since they already rotate about the same axis each component's I is just additive.

(4) $v = \omega * r_{wheel}$

$$F_f \leq N \cdot \mu_{st,ground}$$

$$M_f \leq n \cdot \left(< r_{dog,i} > x < N_{dog,i} > \right) \cdot \mu_{s,dog}$$

Utilizing index notation, this summation is from i to n=total number of dogs.< > indicate vectors and this is a cross product.

R_{net} & N_{net} are also reaction forces imposed by the dogs on the wheel

$$\frac{I_{com}}{Mr_{wheel}} \left(\frac{P_{max}}{2} \cos \phi - N\mu_{st,ground} \right) = -r_{wheel} N\mu_{st,ground}$$

$$N = \frac{P_{max}}{2} \sin \phi + Mg$$

Calculations 2

- Stress analysis at critical pts.

For stress analysis, the wheels have contact stresses with the ground.

$$b = \sqrt{\frac{2}{\pi L_{one\ wheel}} \cdot \left(\frac{N}{2}\right)\left(1 - v_1^2\right) \cdot \frac{d_{wheel}}{E_1}}$$

E_1 & v_1 *are material properties of the wheel.*

$$b = \sqrt{\frac{P}{\pi \cdot L_{total\ wheel}} \left[\frac{\frac{\left(1 - v_1^2\right)}{E_1} + \frac{\left(1 - v_2^2\right)}{E_2}}{\frac{1}{d_2} - \frac{1}{d_1}}\right]} \quad d_1 > d_2$$

d_1 = *mating diameter of wheel*, d_2 = *shaft diameter*

$$p_{max} = \frac{N}{\pi b L}$$

$$\sigma_x = -2v_1 p_{max}$$

$$\sigma_y = \sigma_z = -p_{max}$$

Calculations 3

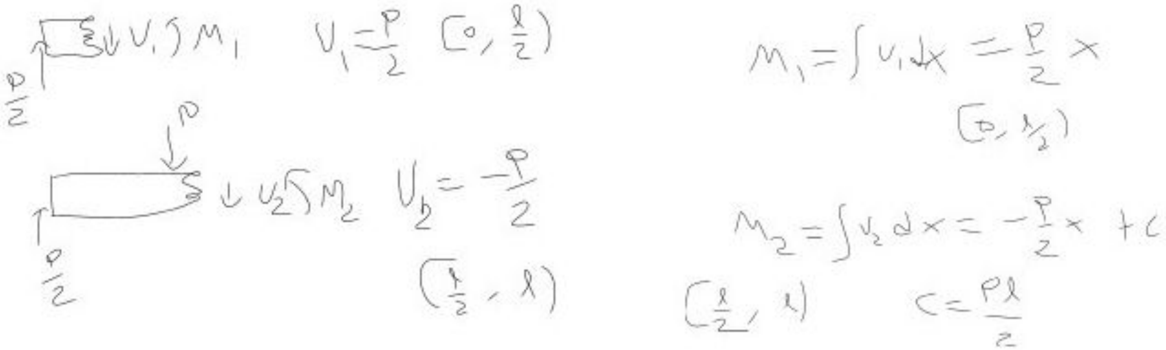
- Max Torque
- The contact stresses are the same except N=Mg in this case whereas in the previous analysis it was N>Mg, therefore to reduce stress we use a pure torque motion. For speed we examine the maximum torque & force P and compare their resultant accelerations. This is not of concern however.

$$\frac{T_{max}}{2} = N\mu_{st,ground}\left(r_{wheel} - \frac{I_{com}}{Mr_{wheel}}\right)$$

Calculations 4

- Shaft Moments/Torques
- Internal torques are just T/2 in magnitude

For the shaft (shaft length / diameter > 10), we neglect transverse shear:



C, the integration constant was obtained via matching the moments, in other words, the total moment function must be continuous, albeit not smooth, since there are no external moments that exist.

Calculations 5

- Static case

$$\sigma_{eq} = \frac{1}{\sqrt{2}} \cdot K_t \cdot 8\,P \cdot \frac{l_{shaft}}{\pi d^3} \leq 350 \cdot 10^6\ \frac{N}{m^2}$$

$$P \leq 5141.59\ N\ (Distortion\ Energy)$$

$$P \leq 3635.65 N\ (MSS)$$

Calculations 6

- Fatigue
- Endurance limit
- Stress concentration

$$K_t = 2.14$$

$$K_{ts} = 3$$

$$r_{notch} = 0.08\ in$$

$$K_f = 1 + 0.7(2.14 - 1) = 1.798$$

$$K_{fs} = 1 + 0.75(3 - 1) = 2.5$$

$$S_{ut} = 420\ MPa$$

$$d = 0.76\ in = 19.3\ mm$$

$$Se' = 0.5 \cdot 420 = 210\ MPa$$

$$k_a = 3.04 \cdot 420^{-0.217} = 0.8197\ (machined\ or\ cold\ drawned)$$

$$k_b = \left(\frac{0.76}{0.3}\right)^{-0.107} = 0.9053$$

$$k_c = 1\ (manage\ by\ DE)$$

$$k_d = 1$$

$$Se = k_a k_b k_c k_d Se' = 155.84$$

Calculations 7

- Failure criterion
- Gives max P

$$\sigma_a' = \frac{32 \cdot K_f \cdot P \cdot 0.127}{4\pi \cdot 0.0193^3} \qquad \sigma_m' = \frac{16\sqrt{3}\,K_{fs} \cdot T_{max}}{2\pi \cdot 0.0193^3}$$

$$DE - GOODMAN \quad \frac{\left(\frac{32 \cdot K_f \cdot P \cdot 0.127}{4\pi \cdot 0.0193^3}\right)}{155.84 \cdot 10^6} + \frac{\left(\frac{16\sqrt{3}\,K_{fs} \cdot T_{max}}{2\pi \cdot 0.0193^3}\right)}{420 \cdot 10^6} = 1$$

Using T-max as stated before. This gives Pmax that's possible for infinite fatigue life.

$$\sigma'_{\max} \approx \sigma'_a + \sigma'_m$$

Fo first cycle yield, conservatively check:

$$n_y = \frac{350 \cdot 10^6}{\sigma_{max}'}$$

Calculations 8

- For shaft critical speed:
- Estimate I = (πd^4)/64
- Assume the value for its mass only.
- Given Pmax chosen depending on the upper limits defined for static yield and fatigue life:

$$\delta_{11} = \frac{\left(\frac{0.127}{2}\right)^2}{6 \cdot 2.05 \cdot 10^{11} \cdot \frac{\pi}{64} 0.0193^4 \cdot 0.127} \left(0.127^2 - \left(\frac{0.127}{2}\right)^2 - \left(\frac{0.127}{2}\right)^2\right)$$

$$m = 7870 \cdot \frac{\pi}{4} \cdot 0.0193^2 \cdot 0.127$$

$$\omega = \sqrt{\frac{1}{0.2924 \cdot 3.056 \cdot 10^{-8}}} = 10578.76 \ \frac{rad}{s}$$

$$\omega = \sqrt{\frac{1}{P_{max} \cdot 3.056 \cdot 10^{-8}}}$$