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Elecycle

Project 2 Report: Group 11

Simon Fraser University

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Executive summary

This proposal brought forth by EleCycle discusses the transmission design of the motorcycle. It highlights how EleCycle's design process for the transmission begins. Furthermore, it reveals how we conclude the final component and material selection. EleCycle has designed a transmission that will fit and function as per our bike design. The selection of this involved reflecting back to our design goals from part one and creating concepts to establish the most viable design for the transmission. Following the selection of a concept we began the calculations to get the correct gears, chains and material. The iterative process was done to establish the correct components to use in the design of the transmission. This process lead us to have a motor connected to a pinion of 24 teeth which was then connected to a meshing gear of 100 teeth. The bigger gear was then connected to one end of an intermediate shaft. The other end was then connected to a sprocket of 22 teeth. The sprocket was then connected to another 28 teeth sprocket using a # 60 chain, producing an overall transmission gear ratio of 5.3:1. This design allowed EleCycle to produce 32.16 Hp at 1200rpm. The material that was selected was 4140 OQT 1300 steel, this was verified as research shows that this is the material manufacturers use to produce gears for this applications. Overall this design theoretically will be more than sufficient to carry out the design goals set out in the first part of the project.

Introduction

As the world transitions from fossil fuels to green energy, electricity is the first thing that comes to mind. There has been a huge surge in electrical transportation production and design over the last few years. It has become apparent that manufacturers are trying to design more fuel economic and zero emission transportation. There are huge industrial uses of electric transportation such as vehicles, bikes, buses and all sorts of transportation. When it comes to motorcycle there hasn't been much of a push to standardize electrical methods of application. Therefore, EleCycle aims to create a two-wheeled electric motorcycle which will be capable of traversing through an urban environment. The key design aspects we focused on in part 1 are to create a motorcycle that would give you a days' worth of drivability using rechargeable batteries and an electric motor, whilst still being able to carry a maximum of two passengers. Providing all this in an affordable package with no hidden fees is what we have strived for. Furthermore, we aim for EleCycle to be able to withstand various cyclic and impulsive forces. In part two, EleCycle aims to complete the power transmission design to be able to withstand all our goals set out in part 1. This will allow EleCycle to be further developed and prepared for real world usage.

Description and Analysis of Transmission Layout Alternatives

Transmission Designs

Design 1

The initial design our team came up with required a worm gear reducer to control the high-speed motor being employed in our final product. The worm gear reducer was connected to the rear wheel via a V-belt. Though this design ensured low cost and maintenance, a chain would last longer than a V-belt.

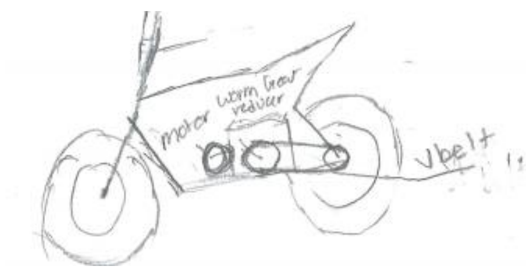

Figure 1: Design 1 sketch

Design 2

The second design our team came up with required a spur gear train to increase torque from the motor, followed by a sprocket-chain design to drive the rear wheel. This design is more reliable than our initial design, mainly due to chain's longer service life as compared to belt. Moreover, spur-gears give a larger variety and are cheaper as compared to worm-gear drive. It was noted that the use of spur-gears and chain drive would result in an increase in the weight and space required to hold the system.

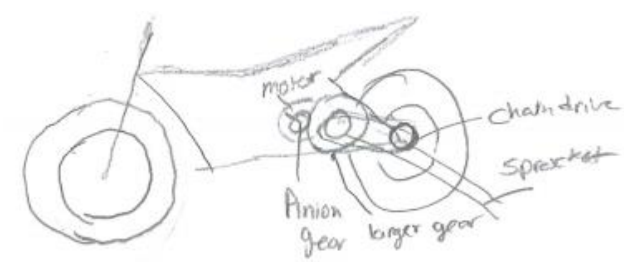

Figure 2: Design 2 sketch

Selection of Transmission for further development

In order to select a design for further development we will employ the use of a decision matrix which will allow us to numerically represent our design criteria based on importance. This matrix will show that we weight safety the highest followed by cost, longevity, reliability, maintenance and size.

	Weight	Design 1	Design 2
Safety	40%	9	9
Cost	30%	9	8
Longevity	10%	7	9
Reliability	10%	8	10
Maintenance	5%	9	7
Size	5%	8	8
Total		**8.3**	**8.5**

Table 1: Decision Matrix

The decision matrix shows us that both these designs are graded closely but we shall proceed with design 2. This design does cost a little more, but we are willing to pay the costs as it is more reliable and will last a lot longer than design 1.

Detail transmission system design

The following text provides the details regarding the procedures and assumptions employed in the design of our final transmission system. Figure 3 below provides a sketch of the transmission system employed by EleCycle.

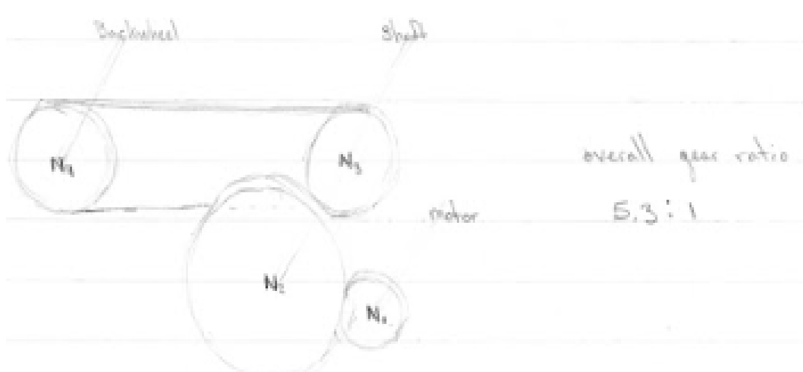

Figure 3: Transmission Sketch

EleCycle's transmission system contains one gear-train with a gear ratio of 4.167:1, which connects the motor shaft to an intermediary shaft as shown in Figure 4.

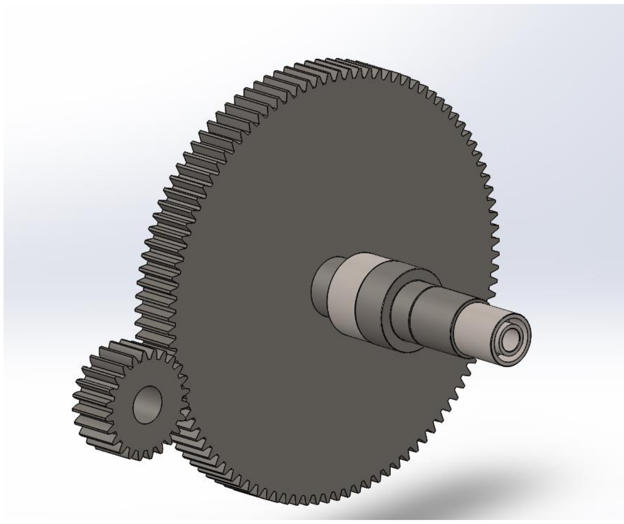

Figure 4: Gear Train

Following the gear-train, the transmission system utilizes a chain-drive at a gear ratio of 1.3:1, which connects the intermediary shaft to the back-wheel axel. Hence, the overall transmission system of EleCycle gives our bike a speed ratio of 5.3:1. Figure 5 shows the complete transmission system used by EleCycle.

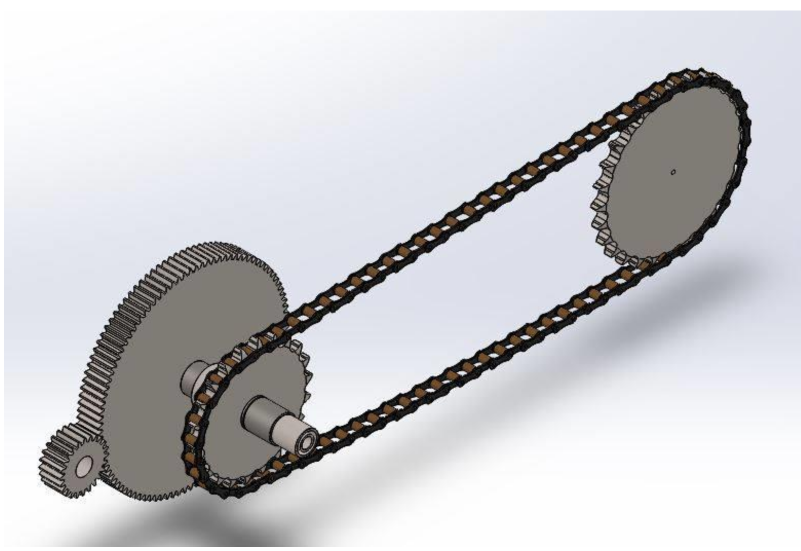

Figure 5: Chain Drive

<u>Initial Condition:</u> The motor employed by EleCycle provides a power of 33.5Hp at 5000 rpm. Therefore, all transmission system calculations are based on these conditions

From the known input speed, after several iterations a 24-tooth pinion was selected as the pinion gear in our gear-train. Following the calculations attached in Appendix A, with a 24-tooth pinion gear it was established that the meshing gear will have a size of 100-teeth. Both pinion and the gear have a standard 20^o pitch. In addition, following the calculations attached under Appendix A. It was concluded that our gear-train transmission would be satisfied, provided our pinion and gear are made of 4140 OQT 1300 steel. Figure 6 is the final gear train employed by EleCycle in its transmission cycle.

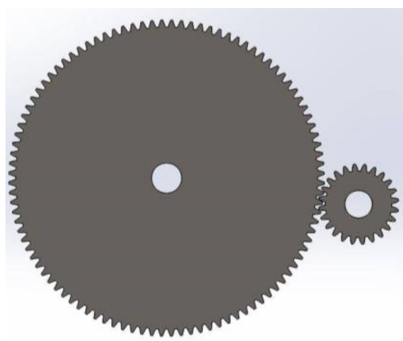

Figure 6: Final Gear Train

Moving to the second half of our transmission, i.e. power transmission from the output of the gear-train to the chain, EleCycle assumed a 96% efficiency between the gear-train and chain-drive which is based off the standard transmission efficiency. Hence, it was established that the intermediary shaft connecting the gear of our gear-train to the smaller sprocket of the chain-drive is to rotate with 32.16 Hp at 1200rpm as shown in Appendix B. Based on these results, EleCycle employed a #60 chain with a smaller-sprocket of 22 teeth, to deliver the desired power of $32.16\ Hp$. To satisfy our designed gear ratio of 1.3:1, we employed a 28-teeth larger-sprocket. Figure 7 is the final gear train employed by EleCycle in its transmission cycle.

Figure 7: Final Gear Train

At the end of our gear and chain design, we ensured our transmission system was going to fit within our current bike configuration. With the gear and sprocket diameters, and center distances we were able to confirm that our transmission design would not require any further modification to the bike chassis design established in part 1.

Following our successful gear-train and chain-drive transmission component placement within our chassis design, we started the design of the intermediary shaft, which is to contain the output gear and input sprocket as well as two bearings for support. Figure 8 provides a sketch of the intermediary shaft that connects the gear of our gear-train and the small/input sprocket of our chain-drive.

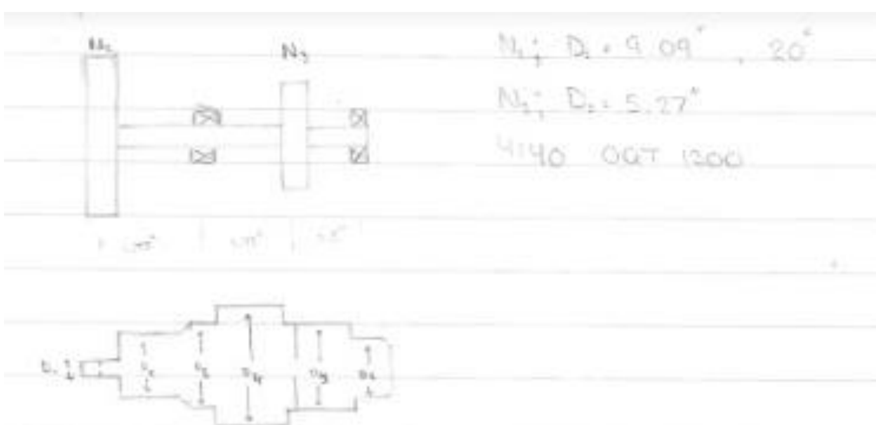

Figure 8: Intermediary shaft sketch

After some research it was determined that 4140 OQT 1300 was a standard material employed in shaft design of a transmission system. Hence, verifying EleCycle's transmission system is within standards of a transmission system, 4140 OQT 1300 was used as our shaft material.

From the chose material and an assumption of a max diameter of 3", we were able to determine all shear force and bending moment calculations, these calculations are included in Appendix C. Moreover, with all forces we were able to determine all the required diameters shown in Figure 9.

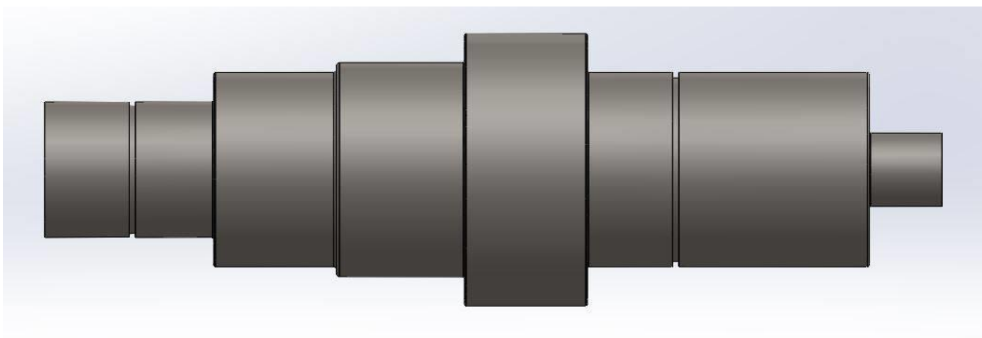

Figure 9: Final Shaft Design

It is to be noted that all parameters confirmed our transmission system falls within the standards of gear, chain and shaft designs. Following the calculations of all the required diameters, standard tables for diameter and shaft sizes were used to select a standard diameter and shaft size for EleCycle's transmission system.

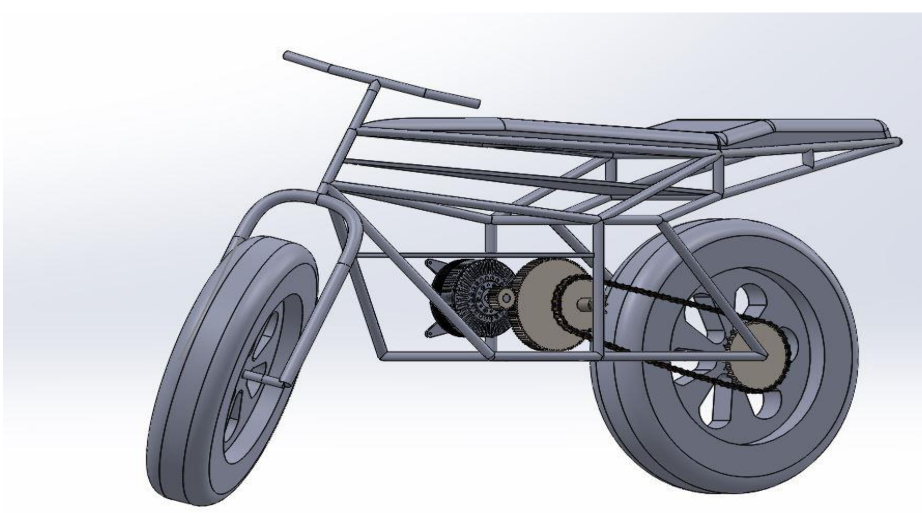

Figure 10: Final Model

Overall Design

Machine Safety

Canadian Motor Vehicle Safety Standard (CMVSS) classifies EleCycle as an Open Motor-cycle [1]. Using this information, we must follow strict guidelines as listed below to allow the motorcycle to be street legal. These guidelines will ensure our motorcycles safety and reliability.

106-Brake Hoses: The cycle will be using steel braided brake lines to ensure longevity

108-Lighting System and Retroreflective Devices: The cycle will have a series of LED light

108.1-Alternative Requirements for Headlamps: Daytime running light will be installed.

111-Mirrors: Two mirrors will be placed adjacent to each other to ensure blind spot view

115-Vehicle Identification Number: Special Identification number will be on every bike

116-Motor Vehicle Brake Fluids: We will use Dot 3 brake fluid for its robust, cyclic uses

122-Motorcycle Brake Systems: Motorcycle will have 2 disk brakes one for the front and one for the rear

123-Motorcycle Controls and Displays: Motorcycle will have a touch display complying with all symbols and regulations

205-Glazing Materials: glass will be coated with ANSI/SAE Z26.1

These safety regulations will ensure that the user is safe and that the bike will be able to withstand a lot of cyclic uses. This will allow the bike to be reliable as failure points for material will be high.

Cost analysis

In order to calculate the costs involved with our transmission we must first assess whether these parts are available on the market or must they be machined. The research revealed that majority of the parts are available on the market and if they aren't we can get them made by the manufacturers [1]. The prices where then found on the website where all gears were listed, these prices are based on buying a batch of 100. The only part that must be machined is our shaft as it is unique and unavailable online. However, the manufacturers offer a CNC milling option which is fairly inexpensive when buying in bulk.

Part	Cost ($)
24 tooth pinion	38.26
100 tooth gear	42.36
28 tooth sprocket	38.25
22 tooth sprocket	31.26
# 60 Chain	48
Final Shaft Design	98.13
Total	**296.26**

Table 2: Transmission cost

When assessing the cost of the internals of the bike we decided to go with an EMRAX 118 motor as it has a built-in motor controller for variable speed. It also can produce 32kW of continuous power with a peak torque of 90Nm. This motor has a range of up to 6000 RPM, so it can achieve our goal speed and maintain it. The battery to couple with this motor is 1100, 18650 cells which have been proven in various similar projects. These batteries and the motor will be able to provide our goal speed and range. The suspension will be a Penske unit that is a shock and spring combo. It will be able to withstand impulse forces with a quick rebound as well as being able to adjust the dampening and spring length.

	Battery 18650 cells (1100 pcs)	Motor-EMRAX 188	Tires and rims	Suspension	Frame	Assembly	Misc	Total
Cost (USD)	1200	1100	400	200	169.36	200	500	**3769.36**

Table 3: Bike Internal Cost analysis

We have established the cost for both the externals and internals of the bike. The final cost of our bike (Table 4) is still much lower than our competitors for the amount of battery capacity and speed we offer.

Components	**Cost**
Transmission	296.26
Internals	3769.36
Total	4065.62

Table 4 Final Bike Cost

When considering the Life cycle costs of the bike we believe that the gears will last the life of the bike, as we will not hit any high speeds which will create stress on the gears but there will be a lot of stop and go. This will wear down the gears and the chain, but the research shows that a chain and sprocket will fail before a gear fails. This indicates our only life cycle cost would be the chain and sprocket. However, they are very easily accessible making it easy to change. When considering the bike as a whole, we believe after cyclic usage the batteries may begin to lose charge capacity based on usage. This may also be a life cycle cost.

Conclusion

When considering how our team set out with a goal to design and build a motorcycle to meet our design goals, it seems we have surpassed expectations to the design of EleCycle's first ever electric motorcycle, Streamliner. This final design has gone through many iterations in order for it to be a viable option and live up to the daily wear and tear which ultimately result in various cyclic and impulse forces. The key design aspects we focused on are to create a motorcycle that would give you a days' worth of drivability using rechargeable batteries and an electric motor, whilst still being able to carry a maximum of two passengers. Providing all this in an affordable package with no hidden fees is what we have strived for.

When considering how well EleCycle has designed, there aren't many recommendations that can be given to its design. Thinking of general recommendation, we believe for our next iteration of streamliner we would like for it to be a highway capable motorcycle. Otherwise we believe EleCycle has presented its best design for an electric motorcycle.

References

[1]"Spur Gears | KHK Gears", KHK Gears, 2018. [Online]. Available: https://khkgears.net/new/spur_gears.html . [Accessed: 03- Dec- 2018].

[2]"Motorcycle Suspension by Penske Shocks - GP Suspension", Gpsuspension.com, 2018. [Online]. Available: http://www.gpsuspension.com/penske_c_5557.html . [Accessed: 03- Dec- 2018].

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[6] Vectors, Royalty, Logo Vectors, and Lightning Image. "Lightning thunderbolt electricity logo design vector image on VectorStock". *VectorStock*, 2018. Online. Internet. 13 Nov. 2018. Available: https://www.vectorstock.com/royalty-free-vector/lightning-thunderbolt-electricity-logo-design-vector-21524147 .

Appendix A – Motor Selection and Gear Design

Motor selection

Emrax 188 33.5 Hp @ 5000 *(from data sheet)

Gear Design

$\frac{n_1}{n_2} = \frac{5000}{1200} = 4.167$ assume $N_1 = 24$ teeth

$N_2 = N_1 \cdot SR = 24 \cdot 4.167 = 100$ teeth

$k_o = 1.4$, $P_{design} = 1.4 \times 33.5 = 46.9$ Hp [table 9-1]

$P_d = 11$, $A_v = 6$ [figure 9-11 , table 9-5]

$C = \frac{N_1 + N_2}{2 P_d} = \frac{24 + 100}{22} = 5.64''$

$F = \frac{12}{P_d} = \frac{12}{11} = 1.09$

$k_s = 1$, $K_B = 1$, $K_R = 1$, $SF = 1$ [table 9-2, figure 9-14, table 9-11]

$D_1 = \frac{N_1}{P_d} = \frac{24}{11} = 2.18$, $\frac{F}{D_1} = \frac{1.09}{2.18} = 0.5$

$C_{pf} = 0.01$, $C_{ma} = 0.27$ [figure 9-12 , figure 9-13]

$K_m = 1 + C_{pf} + C_{ma} = 1 + 0.01 + 0.27 = 1.28$

$V_t = \frac{\pi D_1 n_1}{12} = \frac{\pi (2.18)(5000)}{12} = 2853.6$

$k_v = 1.13$ [figure 9-16]

$L = 1500 \rightarrow 5000 \approx 3500$ hrs [table 9-12]

$N_c = L n q = (3500)(5000)(1) = 1.75 \times 10^7$ cycles

$W_T = \frac{126000\, P}{n_1 D_1} = \frac{(126000)(33.5)}{(5000)(2.18)} = 387.25$

$Y_N = 1$, $Z_N = 0.98$ [figure 9-21 , figure 9-22]

$I = 0.115$, $J = 0.36$ [figure 9-17 , figure 9-10]

$S_{at} = \frac{SF \cdot K_R}{Y_N} \times \frac{W_t P_d}{FJ} (k_o k_s k_B k_m k_v) = 1 \cdot \frac{(387.25)(11)}{(1.09)(0.36)} \left((1.4)(1.28)(1.13)\right) = 21982$ psi

$S_{ac} = \frac{SF \cdot K_R}{Z_N} \times C_p \sqrt{\frac{W_t (k_o k_s k_B k_m k_v)}{F D_1 I}} = \frac{1}{0.98} (2300) \sqrt{\frac{(387.25)(1.4)(1.28)(1.13)}{(1.09)(2.18)(0.115)}} = 125723$ psi

$S_{at} \Rightarrow$ HB 118 , $S_{ac} \Rightarrow$ HB 300

4140 OQT 1300 is a sufficient material for the gears (HB 235)

*All parameters can be found in the textbook

Appendix B- Chain Design

Chain Design

assuming 96% efficiency

32.16 Hp @ 1200 rpm

$N_3 = 22$ teeth # 60 chain type B lube

$SR = 1.3 = \frac{N_4}{N_3} \Rightarrow N_4 = 22 \times 1.3 = 28$ teeth

$C = 19.685 \Rightarrow 26.25$ pitches

$$L = 2C + \frac{N_4 + N_3}{2} + \frac{(N_4 - N_3)^2}{4\pi^2 C} = 2(26.25) + \frac{50}{2} + \frac{6^2}{4\pi^2(26.25)} = 77.5 \Rightarrow 78 \text{ links}$$

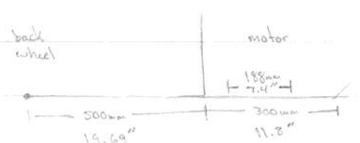
$$C = \frac{1}{4}\left[L - \frac{N_4 + N_3}{2} + \sqrt{\left(L - \frac{N_4 + N_3}{2}\right)^2 - \left(\frac{2(N_4 - N_3)^2}{\pi^2}\right)}\right]$$

$$= \frac{1}{4}\left[78 - \frac{50}{2} + \sqrt{\left(78 - \frac{50}{2}\right)^2 - \left(\frac{2(6)^2}{\pi^2}\right)}\right] = 26.5 \text{ pitch} \Rightarrow 19.86''$$

$$D_1 = \frac{P}{\sin\left(\frac{180}{N_1}\right)} = \frac{0.75}{\sin\left(\frac{180}{22}\right)} = 5.27'' \quad , \quad D_2 = \frac{P}{\sin\left(\frac{180}{N_2}\right)} = \frac{0.75}{\sin\left(\frac{180}{28}\right)} = 6.70''$$

$$\theta_1 = 180 - 2\sin^{-1}\left(\frac{D_2 - D_1}{2C}\right) = 180 - 2\sin^{-1}\left(\frac{1.43}{2(19.86)}\right) = 175.9^\circ$$

Placement



axial to motor shaft distance

min : $19.69 + 3.7 = 23.39''$

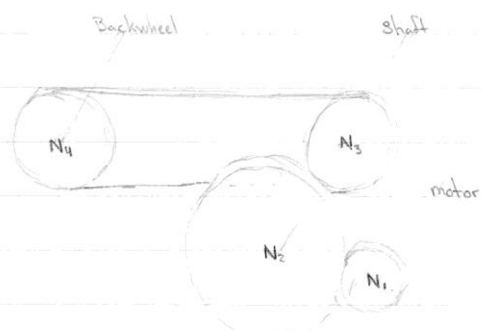
max : $19.69 + 11.8 - 3.7 = 27.79''$

from gear and chain design

$C_1 = 5.64''$, $C_2 = 19.86''$

$5.64 + 19.86 = 25.5''$

$23.39 < 25.5 < 27.79$ ✓ (fits in current enclosure)



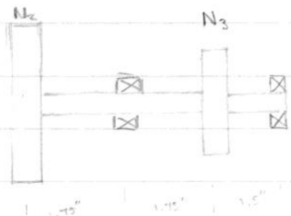
overall gear ratio

5.3 : 1

* All parameters can be found in the textbook

Appendix C- Shaft Design

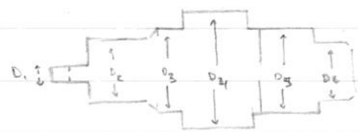
Shaft Design



N_2; $D_2 = 9.09''$, $20°$

N_3; $D_3 = 5.27''$

4140 OQT 1300



$S_y = 100$ ksi , $S_u = 117$ ksi , $S_n = 44$ ksi (assuming machined)

$C_m = 1$, $C_{st} = 1$, $C_R = 0.81$, $C_s = 0.78$ (assuming 2" max diameter)

$S_n' = S_n C_m C_{st} C_R C_s = (44)(1)(1)(0.81)(0.78) = 27.8$ ksi

$T = \frac{63000\,P}{n} = \frac{(63000)(32.16)}{1200} = 1688.4$ lb·in

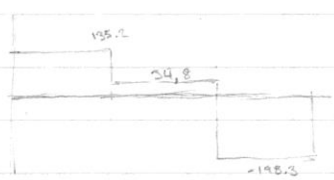
$W_t = \frac{126000\,P}{nD} = \frac{T}{D/2}$

$N_2 = \frac{1688.4\,(2)}{9.09} = 371.49$ lb , $N_3 = \frac{1688.4\,(2)}{5.27} = 640.76$ lb

$W_r = W_t \tan(\phi)$

$N_2 = 371.49 \tan(20) = 135.21$ lb , $N_3 = 640.76 \tan(20) = 233.21$ lb

V_{xz}



$D - B = 98$

$M_A = -B(1.75) - 233.21(3.5$

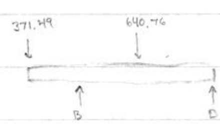
$D = 163.25 + 0.35($

M_{xz}

$M_B = 236.62$ $B = 100.38$

$M_C = 297.57$ $D = 198.38$

V_{yz}



$B + D = 1012.25$

$M_A = B(1.75) - 640.76(3.5) +$

$D = 448.53 - 0.35B$

M_{yz}

$M_B = 650.11$ $B = 867.26$

$M_C = 217.49$ $D = 144.99$

$$V_A = \sqrt{V_{AXZ}^2 + V_{AYZ}^2}$$

$$= \sqrt{135.21^2 + 371.49^2} = 395.33$$

$$V_D = \sqrt{V_{DXZ}^2 + V_{DYZ}^2}$$

$$= \sqrt{198.38^2 + 144.99^2} = 245.72$$

$$M_B = \sqrt{M_{BXZ}^2 + M_{BYZ}^2}$$

$$= \sqrt{236.62^2 + 650.11^2} = 691.83$$

$$M_C = \sqrt{M_{CXZ}^2 + M_{CYZ}^2}$$

$$= \sqrt{297.57^2 + 217.49^2} = 368.58$$

Assuming Safety Factor $N = 3$

$$D_1 = \sqrt[3]{\frac{32N}{\pi}\sqrt{\frac{3}{4}\left(\frac{T}{S_y}\right)^2}}$$

$$= \sqrt[3]{\frac{96}{\pi}\sqrt{\frac{3}{4}\left(\frac{1.688}{100}\right)^2}} = 0.76''$$

$$D_2 = \sqrt[3]{\frac{32N}{\pi}\sqrt{\left(\frac{K_t M}{S_n'}\right)^2 + \frac{3}{4}\left(\frac{T}{S_y}\right)^2}}$$

$$= \sqrt[3]{\frac{96}{\pi}\sqrt{\left(\frac{(1.5)(691.8)}{27.8k}\right)^2 + \frac{3}{4}\left(\frac{1.688}{100}\right)^2}} = 1.07''$$

$$D_3 = \sqrt[3]{\frac{32N}{\pi}\sqrt{\left(\frac{K_t M}{S_n'}\right)^2 + \frac{3}{4}\left(\frac{T}{S_y}\right)^2}}$$

$$= \sqrt[3]{\frac{96}{\pi}\sqrt{\left(\frac{(2.5)(691.8)}{27.8k}\right)^2 + \frac{3}{4}\left(\frac{1.688}{100}\right)^2}} = 1.25''$$

$$D_4 > D_3, D_5$$

$$D_{5A} = \sqrt[3]{\frac{32N}{\pi}\sqrt{\left(\frac{K_t M}{S_n'}\right)^2 + \frac{3}{4}\left(\frac{T}{S_y}\right)^2}}$$

$$= \sqrt[3]{\frac{96}{\pi}\sqrt{\left(\frac{(2.5)(368.6)}{27.8k}\right)^2 + \frac{3}{4}\left(\frac{1.688}{100}\right)^2}} = 0.88''$$

$$D_{5B} = 1.06 \times \sqrt[3]{\frac{32N}{\pi}\left(\frac{K_t M}{S_n'}\right)}$$

$$= 1.06 \times \sqrt[3]{\frac{96}{\pi}\left(\frac{(3)(368.6)}{27.8k}\right)} = 1.13''$$

$$D_6 = \sqrt{\frac{2.94 K_t V N}{S_n'}}$$

$$= \sqrt{\frac{(2.94)(2.5)(245.7)(3)}{27.8k}} = 0.44''$$

calculated		from standards	
$D_1 \geq 0.76''$	$\Rightarrow$	$0.875''$	[table A2-1]
$D_2 \geq 1.07''$	$\Rightarrow$	$1.25''$	[table A2-1]
$D_3 \geq 1.25''$	$\Rightarrow$	$1.378''$	[from table 14-3 [bearings]]
$D_4 > D_3, D_5$	$\Rightarrow$	$1.75''$	[table A2-1]
$D_5 \geq 1.13$	$\Rightarrow$	$1.25''$	[table A2-1].
$D_6 \geq 0.44$	$\Rightarrow$	$0.4724''$	[from table 14-3 [bearings]]