A Novel Transmission for Motor Vehicles
An Iterative Design Procedure

A Major Qualifying Project Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

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Abstract

Current motorcycle transmissions have extensive room for optimization. This Major Qualifying Project utilizes the engineering design process in order to develop a novel automatic manual motorcycle transmission. The engineering design process is essential throughout the development of the system and was utilized to mimic the design process in a commercial setting. Intended outcomes were to create a smaller transmission system with an internal gear selector system. Gear changes can be set to be computer controlled or manual by the operator, however both will use the automated changing mechanism. This project is a multi-phase project, with this year's intended focus on the gear selector system. A prototype was created in order to analyze and redesign for future development.

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Introduction

Energy efficiency and the drive to create green, renewable technologies are at the forefront of much new research. The automobile industry is a substantial contributor to the problem of pollution and demonstrates the need for further automobile innovation. This project aims to design a transmission which would increase the efficiency of modern automobiles in order to reduce their effect on the environment while potentially lowering costs. The encompassing goal of this research is to develop a new transmission design that will surpass models currently in production in size and weight reduction and efficiency.

Many design methodologies and brainstorming techniques were employed to aid in the design process. Although the general theory for the design has been set by the previous work of our advisor, much of the project focused on refining the preliminary design and implementing improvements. These improvements ranged from technical implementation of the gear selection mechanism to the physical integration which allows for the proper gear ratios. Our team spent the majority of three terms rethinking and redesigning the transmission configuration and its physical integration.

The ultimate goal of this project was to create an automated manual transmission for a small motorcycle which would increase the efficiency while also reducing the size and cost of a modern automatic transmission. The team designed many iterations of the transmission and evaluated the effectiveness of each design and brainstorming technique along the way to determine which methods worked. After creating multiple designs and rough prototypes, the team has compiled both their results of the design process and opinions on design methodologies to demonstrate the requisite knowledge of a senior student of Mechanical

Engineering at Worcester Polytechnic Institute and illustrate the completion of the Major Qualifying Project.

Background

Manual Transmissions

Manual transmissions use three basic components to transmit power from the engine to the wheels: a clutch, a gear selector mechanism, and gears. The clutch allows the operator to provide or remove power from the engine to the transmission. This is typically accomplished through the actuation of pedal, or on a motorcycle, through the actuation of a lever on the handlebars. Gears are selected by the operator using either a stick shift or a shift pedal. Motorcycles use a sequential transmissions which means that the gears can only be shifted in order, from one to another. In a sequential transmission gears cannot be skipped without shifting through the intermediate gears. This is accomplished through the use of a drum which moves a set increment with each actuation of the shifter lever. The shift drum has a groove which runs around the circumference. Selector forks ride inside of this groove to shift the dog-teeth between the multiple gears. The selector forks in turn move the dog-teeth from a neutral position to one of the gear sets and then from one gear set to the next.

The importance of a manual transmission is its high efficiency, because the clutch provides a very good transmission of power when in full engagement, the only losses in power come from the gear-gear interface. Modern transmissions use helical or spline gear patterns which create a very low friction interface with a uniform transmission of power which greatly reduces the losses and makes manual transmission very efficient.

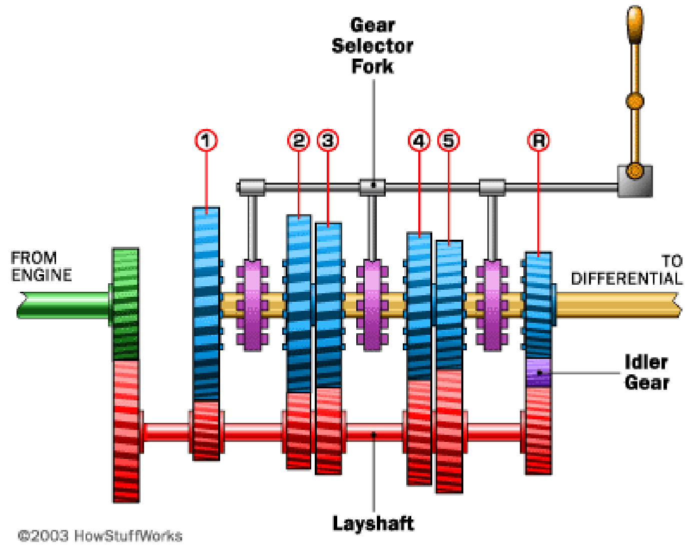

Figure 1: Manual Transmission

http://s.hswstatic.com/gif/transmission-simple.gif

Automatic Transmissions

In an automatic transmission, an electronic computer system installed in the vehicle controls the hydraulically operated transmission. This design does not have a clutch and manual gear selector that is found in the manual transmission. Instead, the vehicle operator can select between a park, reverse, neutral, or drive selection that will control the transmission. In the reverse selection, the single reverse gear will be activated to move the car backwards. In the neutral position, no gears will be selected and therefore the force from the engine will not be transmitted to the drive train. The drive position will allow the driver to operate the vehicle with automatic gear shifting controlled by the throttle and the vehicle's computer system. This system is very common because it allows for smooth and efficient gear changes but does not offer the control of a manual.

Gear Selection: As the throttle is engaged, power from the engine is transmitted to the transmission. Engine management and transmission control systems used transmission fluid to drive sets of planetary gears and clutches. When an engine is accelerating, shift limits are reached that determine when to change gears. In normal driving mode, a vehicle will change gears to maintain optimal fuel efficiency. Some vehicles are outfitted with performance modes that shift at higher gears where there is more power but reduced fuel efficiency.

One of the most important aspects of an automatic transmission is a torque converter. These consist of two freely rotating parts, one connected to the input shaft and the other connected to the engine. These two parts are positioned in very close proximity to each other with a fluid that circulates between them. As rotational energy is applied to the part connected to the engine, the converter connected to the input shaft moves. This is due to the shearing strength of the fluid located within the torque converter.

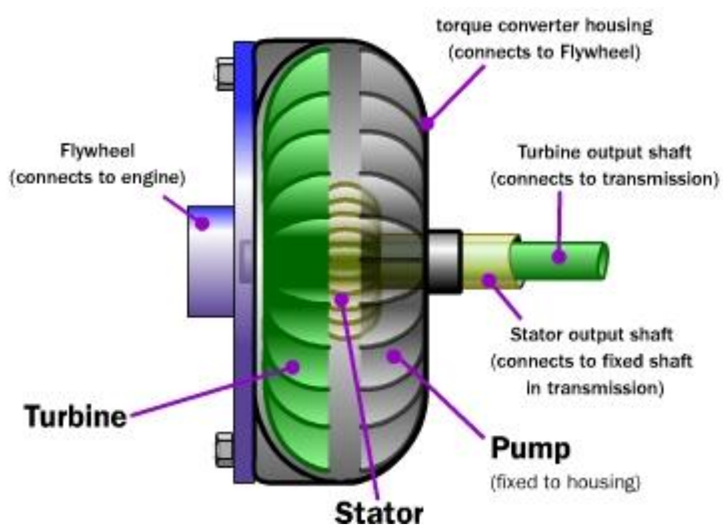

Figure 2: Torque Converter

http://s.hswstatic.com/gif/torque-cutaway.jpg

A torque converter is what sends power to the transmission but from there a compound planetary gears set is used to change gears. This consists of a sun gear which is located in the center, planet gears which rotate around it, and a ring gear that is located on the outside.

From there, hydraulic pressure is used to control which planets and ring gears are allowed to rotate within the planetary system. This style of transmission is very popular in vehicles because it allows for minimal driver engagement while providing a smooth and comfortable transmission of power.

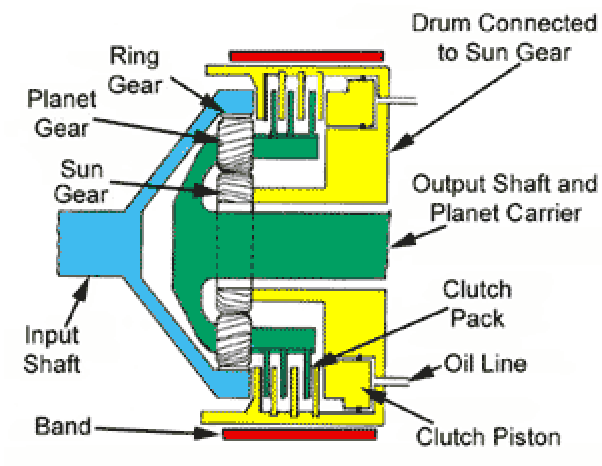

Figure 3: Planetary Gear Set

http://image.cpsimg.com/sites/carparts-mc/assets/classroom/images/trans_planetary2.gif

The downfall of this transmission type, however, is a large drop in efficiency compared to manual transmissions. This is due to both the torque converter which is not nearly as efficient as a clutch in a manual transmission and the complex planetary gear set which has many more gear interfaces than in a standard manual transmission. Similarly, this style of transmission has a higher weight than a manual transmission and with a significantly larger number of components can be more difficult and expensive to repair. The skill required to repair one of these transmissions is also much higher than a manual transmission which makes automatic transmissions not affordable in most regions of the world. All detriments considered, the automatic transmission is a nice luxury, but not very practical for most of the world.

Continuously Variable Transmission

A CVT is very different than the other transmissions discussed because it does not use gears but instead uses a system of rubber or metal belts. These belts are connected to pulley systems that are able to change the diameter of the pulleys. The belts will increase and decrease their effective diameter in order to maintain optimum tension. The use of pulleys instead of gears provides step less ratio changes and a smooth ride. Acceleration is constant because the engine is able to maintain certain rotations per minute without changing gears.

Gear Selection: In a continuous variable transmission, one pulley is connected to the engine and the other is connected to the drive shaft. The pulley system will get closer and further apart, causing the gear ratio to change with it. This allows for an infinite number of gear ratios. The engine is then able to run at the most efficient speed even when a large load is applied. The optimal operating speed is maintained through microprocessor-controlled sensors that can identify what the ideal ratio is for the load.

Automated- Manual Transmission

This type of transmission can be described as a combination of a manual transmission and an automatic transmission. The system is typically completely controlled by the computer, as in an automatic transmission, however the system does not use a planetary gear set. The transmission instead uses a clutch and external gear sets like the manual transmission. This style of transmission is as efficient as the manual transmission and is as user friendly as the automatic transmission. Currently these systems are used largely in the performance car market because the computer can create very accurate fast shifts which increases the clutch life and reduces wear on the transmission.

Motorcycle Transmission

A vast majority of motorcycle transmissions are manual transmissions with a sequential gearbox. This means that the operator selects when to shift from one gear to the next without the ability to skip gears. With this type of transmission, the gears do not move but a shifter fork controlled by a shifter drum is moved to activate different gears. Some gears are fixed to the transmission shaft (driving gears) and other gears, moved by the shifter fork, activate these gears. Power is transmitted through these gears with the use of dog-teeth. These teeth are metal knobs on the side of the gears that fit into holes on the opposing gear and transmit force.

Gear Ratios

Within a transmission, gear ratios are very important to the mechanical advantage of a mechanism. In order to gain the right balance between torque and speed, proper gear ratios are needed. When it comes to gears, torque that is applied to the first gear is transmitted through to teeth to the other gear. The diameter of the gear is very important because small gears driving large gears result in an increase in torque and large gears driving small gears result in a decrease in torque. Speed change is also proportional because smaller gears driving larger gears result in a speed decrease and larger gears driving smaller gears result in a speed increase. In order to determine the gear ratio, the number of teeth on the driven gear is divided by the number of teeth on the driving gear. For example, if the driven gear has 75 teeth and the driving gear has 25 then the ratio is 3:1. This means that for every three rotations of the driving gear, the driven gear rotates once.

In a motorcycle transmission, the gear ratios are largely dependent on the application of the specific bike, however some standard gear ratios exist for small road bikes. These ratios are summarized below in Table 1. The exact ratios of the transmission are not very important, because by changing the sprockets on the output of the transmission and on the rear wheel, the operator has the ability to tune the bike for more speed or more toque. In this case the important factor is the difference between the gear ratios more than the actual ratios themselves because the ratios will change depending on what ratio is used between the transmission and rear wheel.

Table 1: Recommended Motorcycle Gear Ratios

Gear Set Number	Ratio
1	3.2:1
2	2.2:1
3	1.6:1
4	1.2:1
5	0.9:1

Engineering Design Process

Throughout the design of an automated-manual transmission, the engineering design process played a key role. A large goal of this MQP was to gain a better understanding of what it takes to effectively design a component. The first step in the engineering design process is to identify the problem. The automotive industry has extensively focused on increasing engine efficiency while maintaining performance. The problem with current motorcycle transmissions is that they take up a relatively large amount of room within a motorcycle. There is a reduction of fuel efficiency and some performance shortfalls. The second step is to research the problem and determine if there is a need for a solution. From here the focus transitions to the transmission market, determining production and current marketed solutions. Once a need is determined, the third step is developing possible solutions. A large amount of time is spent on generating concepts that possess some, if not all, of the characteristics needed for the solution. Once various designs are generated, the fourth step is to select the best possible solution. There are several methods to use in order to determine what design is best. This is done by creating the criteria for what would be considered a successful design and comparing it to the designs that have been created. Step five is to construct a prototype of the best design. This will nearly always take various iterations because problems will arise that are overlooked in the design phase. Prototypes are also very useful to conceptualize the design and demonstrate the concept. Once a prototype is made, step six is used to test and evaluate the solution. Proper testing will evaluate if the prototype is able to achieve the standards for the design and determine if the design is able to complete is intended tasks consistently. Step seven, communicate the solution, is used once a completed product is developed and can be produced. At this point the design can be used for its intended application. The final step is redesign which can take place at any time during the engineering design process. At times, the original design will not work as intended so there must be a redesign phase.

The Design

This section is broken down into six subsections which outline the design process and the designs that were created as intermediary steps in the design process. At each step of the design, the physical implementation is described as well as the process that was used to get to that point in the design.

Initial Design (From Patent)

The initial form of the design was taken from the patent filed by Christopher Scarpino in which two conical gear trains transfer the power from the input shaft to the outer shell via an eccentric, conical internal gear set. This initial design was drawn as a means for analysis of how the system would function in its currently designed state.

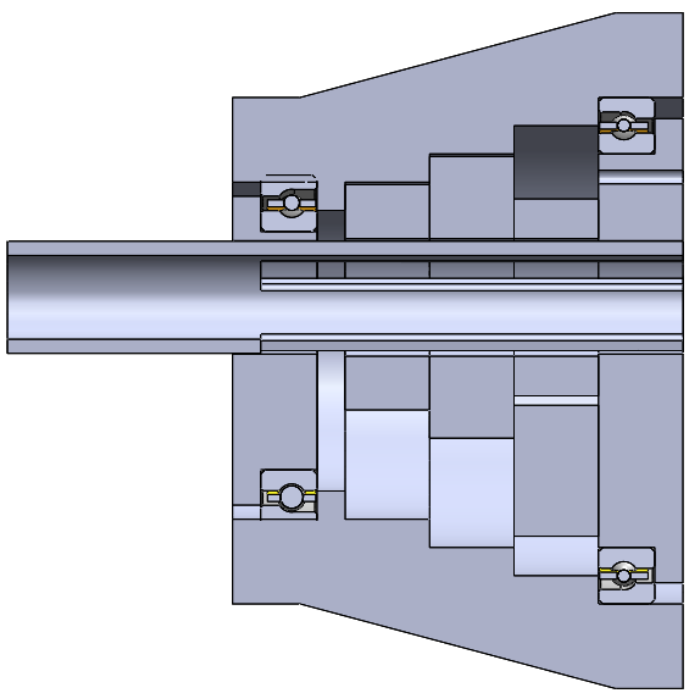

Figure 4: Initial Design Concept

This initial design is a good representation of the direction which the project was moving in, however little information was known about how well this model would function as a transmission. This preliminary model meets the requirements of being both small and simple, which means cost effective to manufacture. This is a seemingly good starting point, however the transmission is not able to produce useful gear ratios for the purpose of power transmission at this point. It was agreed that the next iterations of the design would incorporate a focus on the gear selector and designing with inter-part variables to make modifying the design easier.

Proof of Concept (SolidWorks Design Variables)

During the design process, our group determined that in order to alleviate design restraints we would create each SolidWorks design with variable dimensions. In order to do this, each dimension was given a name for example "Input OD" for the input shaft outer diameter. This would generate an equation in a separate .txt file that was linked to the design. Within that equation file, a number could be associated to the input shaft outer diameter. This can be seen in Figure 5 below. In order for someone to change that diameter they could simply go into the .txt file, change the number, and save it. This would update the design within SolidWorks. Some dimensions would then incorporate two or more individual dimensions. The "Input OD" + "Gear Clearance" would generate the "Gear ID" for example. As the design develops further, nearly every dimension has an equation that correlates to it. The operator can then change a numerical value within the file and it will update every equation using that particular variable and rebuild all associated documents.

```
"Input OD"=1.5
"Input ID"= 1
"Input Length"= 15
"Input Shaft Cut"=11
"Gear 1 OD"=4
"Gear 2 OD"=5
"Gear 3 OD"=6
"Gear 4 OD"=7
"Gear 5 OD"=8
"Gear Thickness"=1.5
"Gear Clearance"=.1
"Gear ID" = "Input OD" + "Gear Clearance"
"Internal Gear 1"=3
"Internal Gear 2"="Internal Gear 1" + ("Gear 2 OD" - "Gear 1 OD") / 2
"Internal Gear 3"="Internal Gear 2" + ("Gear 3 OD" - "Gear 2 OD") / 2
"Internal Gear 4"="Internal Gear 3" + ("Gear 4 OD" - "Gear 3 OD") / 2
"Internal Gear 5"="Internal Gear 4" + ("Gear 5 OD" - "Gear 4 OD") / 2
"Large Journal OD"=8.25
"Journal Clearance"= .02
"Journal ID"= "Journal Clearance" + "Input OD"
"Small Journal OD"=5.5
"Selector ID"= 0.5
"Selector Clearance"=0.05
"Selector OD"="Input ID" - "Selector Clearance"
"Dedendum"=1.2
"Selector Length" = 0.7
"Gear Dog Teeth Input Width"=1
"Gear Dog Tooth Input Radius"=0.8
"Gear Dog Tooth Input Height"=0.3
"Selector Top Land Length"=0.18
"Selector Addendum"=0.15
"Selecor Tooh thickness"=0.34
"Selector Dedendum"=0.17
"Fillet Radius"=0.2
```

Figure 5: Multi-Document Design Variable Sheet

The goal of creating a design with individual design variables is because it allows the designers more freedom to change the initial dimensions and not have to redevelop each part. Redesign is a large part of the engineering design process and using this program would allow far greater freedom in changing the design. The desired goal is to have a single sheet of equations that will contain all the dimension variables for the design. For this process to work as intended, it is extremely important that variables stay consistent. Placement of the variables within the .txt file is also essential for proper functionality. If a variable that is used in an equation is not listed before the equation then the SolidWorks design will become “broken” because it cannot find the intended variable. We believe that the use of this program will provide the ability for anyone working on the design to make changes in order to meet intended design criteria and to understand our original design intent by knowing where each dimension came from.

Focus on Gear Selector

In order to minimize transmission size, the automatic manual transmission design would implement an internal gear selector. In a traditional manual motorcycle transmission there is a main shaft and a counter shaft that contains both fixed and moveable gears. The fixed gears are called constant mesh gears because they stay connected with a gear on the opposite shaft. In order to move these gears they must be engaged using the moveable gears discussed earlier. In order for these moveable gears to be shifted from one gear to the next there are shifter forks that are connected to a shifting drum. The forks, drum and two shafts is something that can be greatly reduced through the implementation of an internal gear selector. The intent was to design a way to select each gear within the shaft. This design will be a sequential transmission meaning that each gear will be selected in order.

Three-Tooth Gear Selector

The preliminary internal gear selector design was to create an interlocking pattern that would use a single three-tooth selector, as seen in Figure 6 below that could move within the shaft. There would be three equally spaced slots running the length of the shaft that would allow lateral movement. These shafts would be enclosed at the ends in order to prevent the selector from traveling past the gears. The shaft would run through the center of each of the gears in sequential order. In order for the selector to drive a gear, each one will have three equally spaced notches, as seen in Figure 7 below, which the selector teeth will be able to move into. As a result, this will cause the shaft, selector, and gear to rotate which will transfer the input power from the shaft to the gear. In order to move to the following gears an actuator will be connected the selector that can provide quick and precise movements.

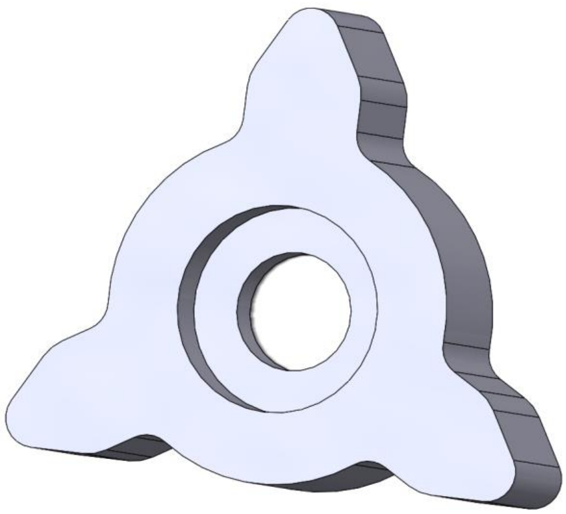

Figure 6: Initial Gear Selector Design

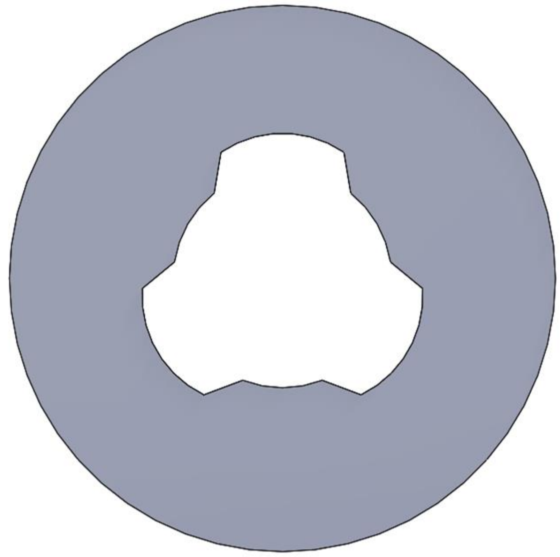

Figure 7: Mating Surface for Initial Gear Selector

In order for there to be efficient and successful transitions between gears, there must be a synchronization mechanism to match the selector teeth with the gear openings. One method that was identified was using an electrical system that identifies the gear locations and determines proper timing to initiate a gear change. This transition period would be when there is an alignment between gear openings and the selector can freely transition from one gear to the next. A synchronizer can be used between gears that would control the rotation and forcibly generate a proper alignment. This design restriction was a substantial factor within the design process and determined the need for a redesign.

Dog-Teeth Gear Selector

The following design was intended to bypass the shortcomings of the three-tooth gear selector design. Similar to a current motorcycle transmission, movable gears containing dog-teeth would be situated between the gears. A selector would be placed between gears one and two, three and four, and five and six. They would be connected with a movable platform located in the shaft that would allow the selector to move laterally in order to select one gear at a time. A selector would be created with three equally spaced dog-teeth on each side. A linear motor within the shaft would then move the selector until the dog-teeth would engage with slots positioned on the gears. Each gear would contain three slots that are approximately double the size of the dog-teeth. This was to ensure proper meshing and reduced wear of the dog-teeth. The motor would then move the selector in the opposite direction, disengaging the first gear and move back into neutral. The motor would continue to move the selector until the teeth on the opposite side would engage the second gear. The selector mechanisms would be identical between all three gear pairs.

In order to move each selector there would have to be a separate control mechanism for each. There would need to be three separate motors that drive each selector individually or a single motor with three outputs that connect to each selector. There was not an identifiable way to connect three outputs to a single motor and therefore was not a practical design. Using three separate motors would cause the main shaft to become excessively large and therefore counteracting the design goal of developing a more compact transmission. At this point the determination was made that the design needed a selector that should efficiently transition between gears while being controlled by a small external shifter.

Actuator Design for Selector Control

When determining a method for controlling the selector two viable options are an electric linear actuator and a hydraulic linear actuator. Each of them had their own advantages and disadvantages in determining their plausibility. The electric linear actuator has the highest precision control. This is very important when transitioning between gears in order to create efficient transitions. Each motion can be completely controlled including velocity, torque, and force. Some disadvantages of the electric liner actuator are its initial cost when compared to other actuators. With the electric motor attached to the actuator, it has a large spacing requirement. With numerous moving parts, electric actuators have a greater chance of a mechanical malfunction. In comparison, the hydraulic linear actuator is better suited for high force applications. They can also change position very quickly ad hold their position under large forces. The number of parts, including fluid reservoir, motors, pumps, and release valves, make it a less viable option compared to an electric linear actuator. There are several other options that can be used but these two are reasonable solutions.

Focus on Gear Ratios

The gear ratio at each gear set is a function of the eccentricity of the input shaft and output shell as well as the diameter of the input gear. This ratio can be determined using the following equation:

$$Output\ Diameter = \left[\frac{1}{2} \times\ Input\ Gear\ Diameter + Eccentricity\right] \times 2$$

$$Gear\ Ratio = \frac{Output\ Diameter}{Input\ Diameter} = \frac{Input\ Diameter + Eccentricity}{Input\ Diameter}$$

Using these two equations, the team was able to create an excel spreadsheet with the values for various uniform increments of eccentricity and uniform increments of input gear diameter. This full spreadsheet can be viewed in Appendix A. A summary of the spreadsheet's results can be viewed below in Figure 8.

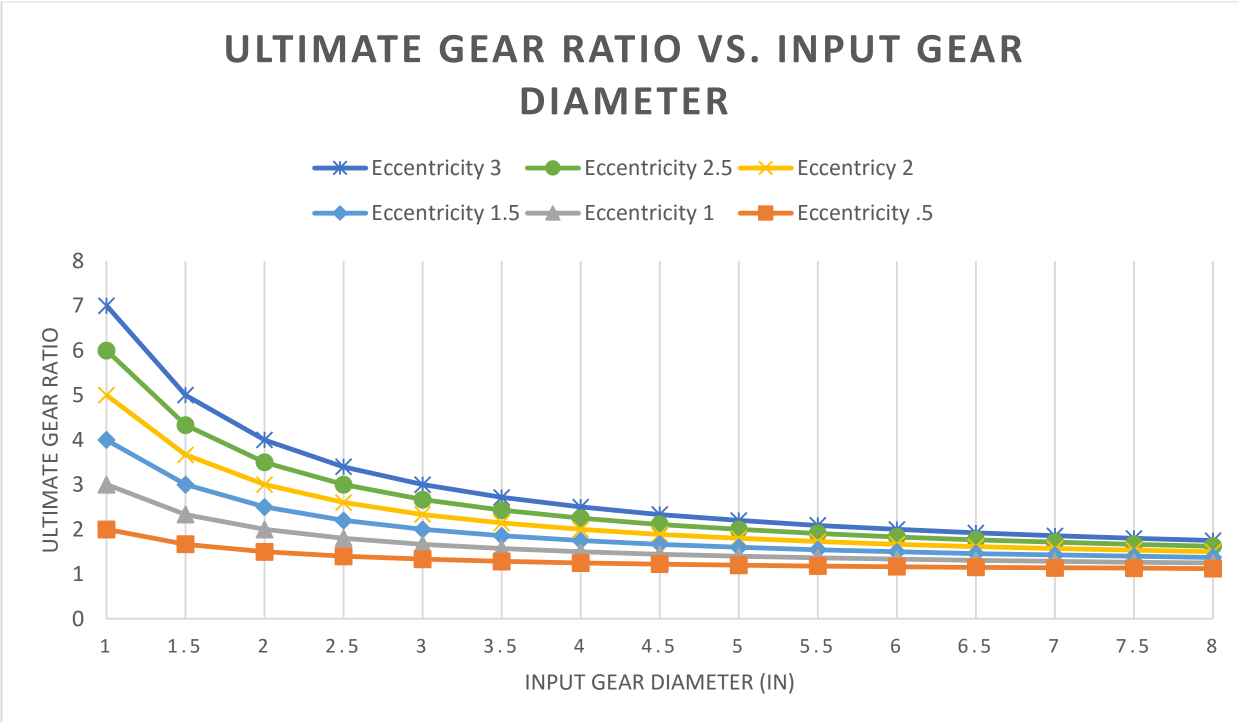

Figure 8: Effect of Eccentricity on Gear Ratio

Figure 8 shows that as input gear diameter decreases, the ultimate gear ratio increases. Inversely, the ultimate gear ratio is positively affected by an increase in eccentricity. Although this would seem like a useful relationship to exploit to create the proper gear ratios, the physical integration needs to be considered and as eccentricity increases, so does the output gear diameter. When operating in the optimal range for gear ratio, the eccentricity and output gear diameters are too large to be feasibly implemented into a compact transmission. At this point the design needed to be reevaluated with a focus on various ways to produce the proper gear ratio.

Many methods were used in articulating the new design ideas. For the greater part of the project up to this point, all design was being drawn up in Solidworks and rough fit and tolerances were created to ensure the proper assembly of the Solidworks model. This, however, proved very time consuming and frustrating because a simple design would require multiple hours to draw up in sufficient detail to explain and evaluate the concept. Some of these designs are illustrated in Appendix A. As an alternative to designing in Solidworks, we sketched possible design solutions on paper and wrote notes to describe interactions which were too hard to draw. This process of ideation was very effective for us, because it allowed us to skip the tedious drawing process that is necessary to show the complexities of a design on Solidworks. Instead of this drawn detail, we decided to use a "magic wand" which would solve make a connection between mechanical linkages which would be hard to draw or explain. This sped up the process significantly, because it allowed us to view the design in enough detail to evaluate it as a team and to sketch notes about the gear ratios which would be produced by the new design.

Final Configuration Design

The final configuration of the design used the original cone gear and internal gear selector which has been utilized throughout the whole process. This design, however, has the addition of a second cone gear with is rigidly attached to the initial cone gear and acts to overdrive the output. This design allowed for switching of two input gear ratios and three output gear ratios to accomplish all of the gear ratios which were decided upon at the beginning of the project. This design was originally drawn using our "magic wand" method and then detailed over the B-C break in Solidworks.

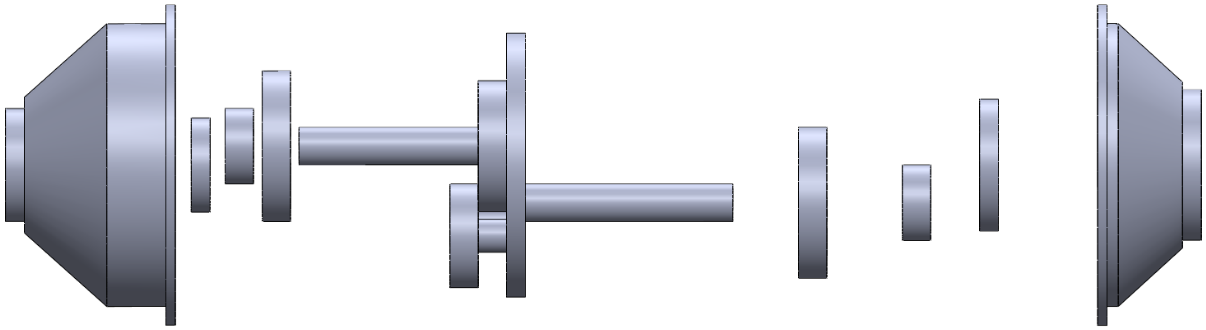

Figure 9: Exploded Assembly View of Final Design

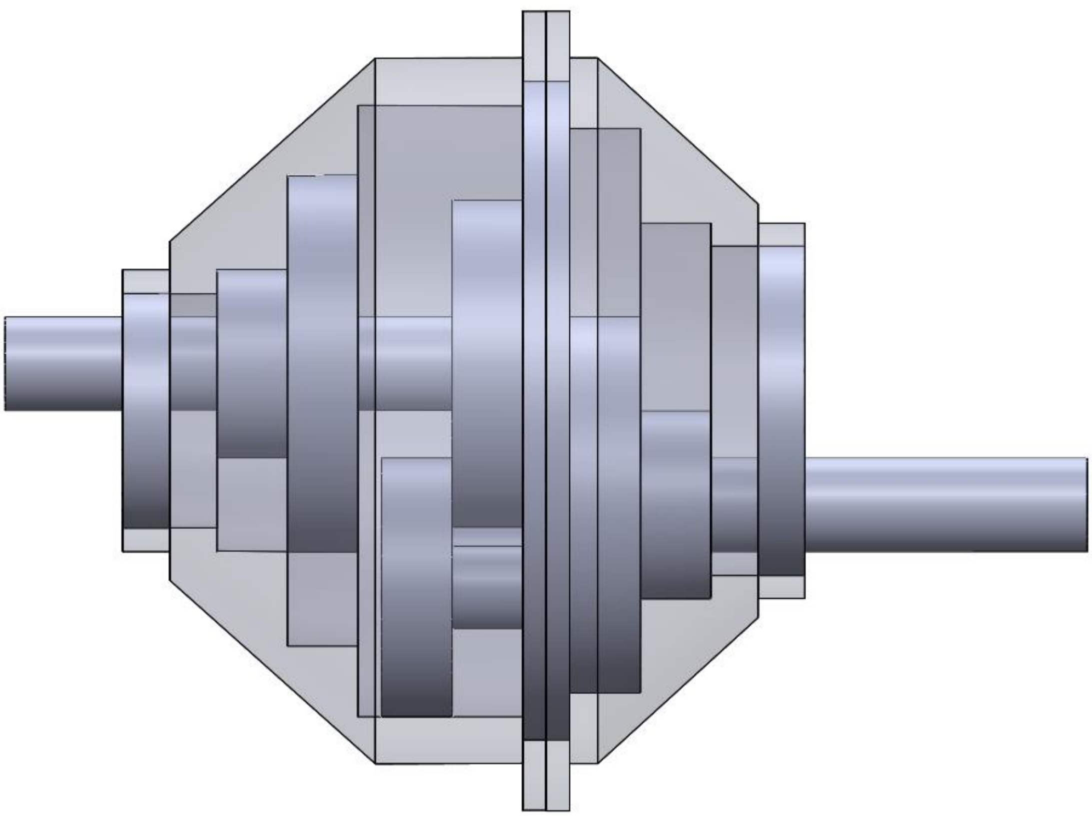

Figure 10: Final Design with Translucent Cone Gears

This design was not fully completed, because the gear selection mechanism had not been narrowed down yet. At this point we set aside the full transmission design to focus on a novel way to transmit power without using a typical dog-teeth-shifter fork transmission like most manual and automated manual transmissions.

Collet Gear Selector

The primary design for this system came through the use of expanding collets that will use friction to select each gear. A typical collet, commonly found in lathes, uses an external collet sleeve around a cylindrical inner surface. When the collet is tightened, there is a strong clamping force put on an object within the collet.

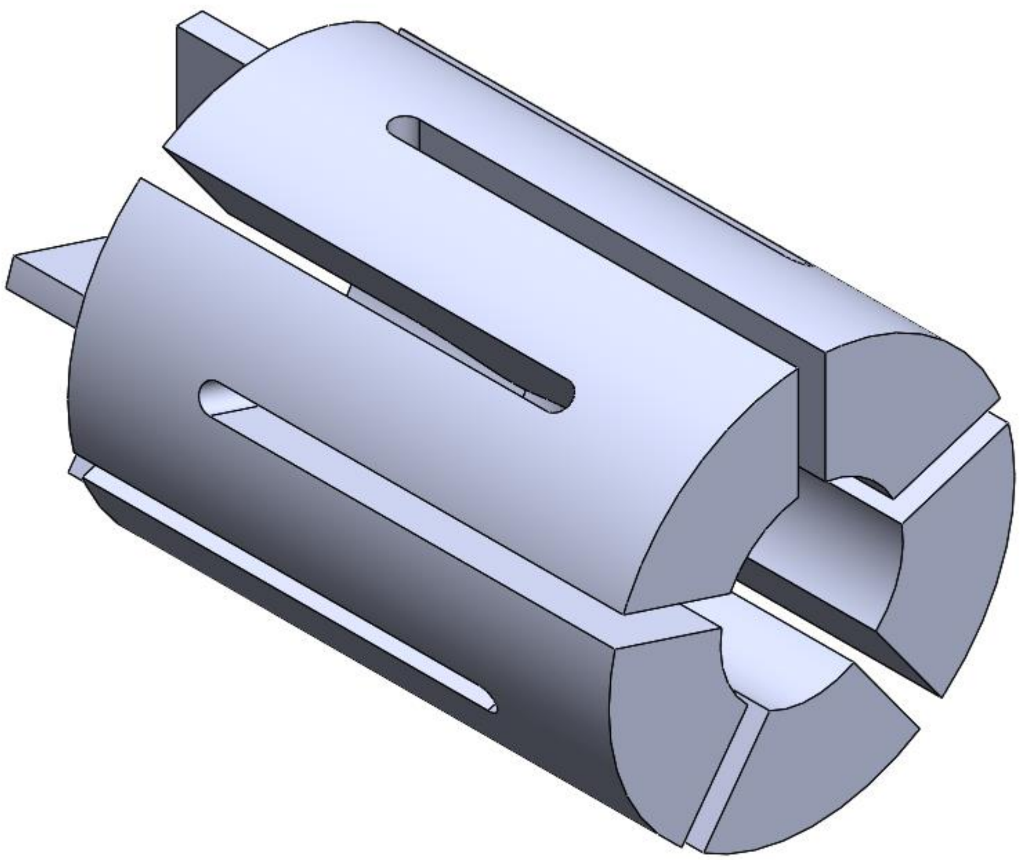

Figure 11: Collet Gear Selector

In an expanding collet, a piece is exerted within the collet that will cause it to increase in diameter in order to engage what is around it. A sketch of the collet design can be seen in

Figure 11 and 12. There a several methods to use that will allow the collet to expand. One method is using a threaded conical feature that when screwed into the collet its increasing diameter would cause the collet to expand. Another method is using a rod with incremental nodules that will cause the collet to expand at specific points.

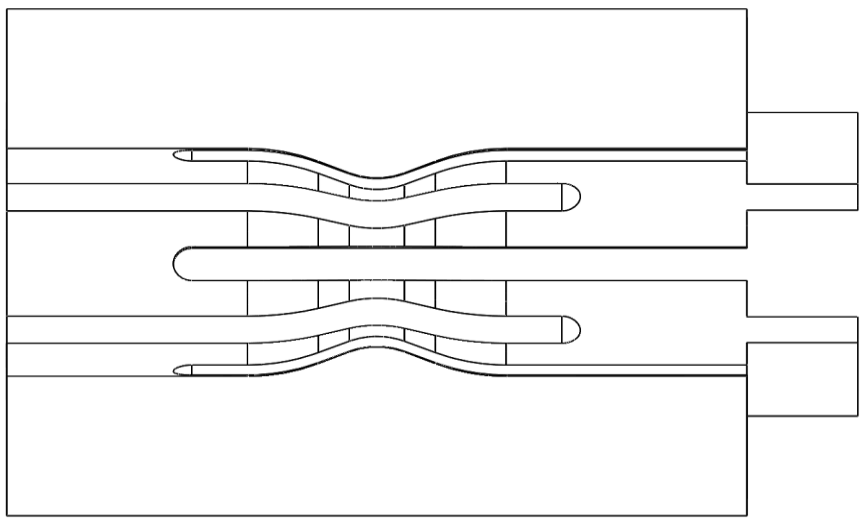

Figure 12: Cross Section of Collet Gear Selector

The expanding collet was designed so that there would be an individual collet for each gear. As the rode moved into different positions within the shaft it would cause a single collet to expand and make contact with the gear surrounding it. Friction would cause the gear to rotate and transfer the input to the output. When the expanding rod moved further, the initial collet would return to its normal position and disengage the gear. Then the next collet would be expanded and engages the following gear. This process would continue for each gear. As the collet expands it will still cause the other collets to rotate through the use of connecting tabs in order to have continuous rotation of the shaft.

The internal shaft would have a separate nodule for each gear that is spaced in increasingly varying increments so that only one collet can be engaged at a time. Using multiple nodules instead of a single nodule allows for a shorter internal shaft that saves valuable space within the design. This can be easily controlled with a linear actuator that can provide precise movements in short distances. It is important to note the potential for wearing of the nodules and implement this factor into the design analysis. Capabilities of slip within a friction controlled force transfer are very high and future designs must determine potential solutions for reducing slip.

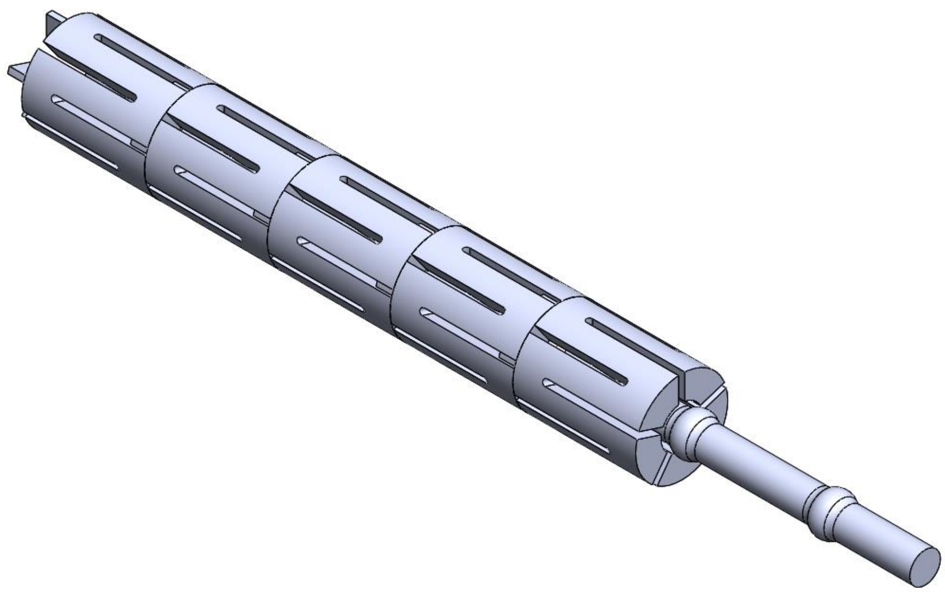

Figure 13: Collet Gear Selector Assembly

The expanding collet design will allow for the entire gear selection process to be located internally within the gears. The operator will have the ability to manually select when they want to shift gears but will not directly operate the selector. A computer system will be needed to determine and create optimum transition speeds between gears. When the operate wants to change gears the computer system will drive the linear actuator to move the selector rod. Each gear change will be sequential because the rod will not allow for gears to be skipped based on the design. This design is highly customizable for a varying number of gears because each gear has its own expandable collet. This can be seen in Figure 13 above. This displays the inner selector system for a five gear transmission. In the design process, we chose to neglect a reversing gear in order to focus simply on the selector system. Several motorcycles in the market do not contain any reversing mechanism, and is simply done manually and physically by the operator. The expanding collet transmission design fits a majority of the criteria for the targeted product. When using this design, an external gear selector is not needed saving room and reducing weight as a result.

Discussion

Throughout the design process for the automatic manual transmission, several design concepts were created and evaluated. At the start of the project there was a focus on creating the entire transmission. Understanding how transmissions worked and what is currently used on the market is absolutely essential in conceptualizing possible design solutions. An automatic manual transmission contains several characteristics found in current designs but no mass produced design contained an internal gear selector. This was the key factor that we determined would be essential in the overall transmission design. This is where the project focus shifted and eventually a prototype of the design was created. The engineering design process splayed a key role in the overall development and success of this project.

Initial designs focused primarily on gaining proper gear ratios and determining how power would be transmitted from the engine, through the transmission, and into the drive shaft. A five gear transmission was used as the base model and features were added to meet the desired product. In this design, the three-toothed gear selector and the dog-teeth gear selector designs were used to determine methods for proper gear selection. The gears were then connected to a cone that enclosed the entire transmission and serves as the output gear set. In this design, all the gears would transmit force directly to the cone gear which would then transmit force to the wheels. This design can be seen in Figure 14 below. A bearing is located at both ends of the transmission to allow the cone gear and the selector shaft to rotate freely while still being supported by the transmission housing, not pictured.

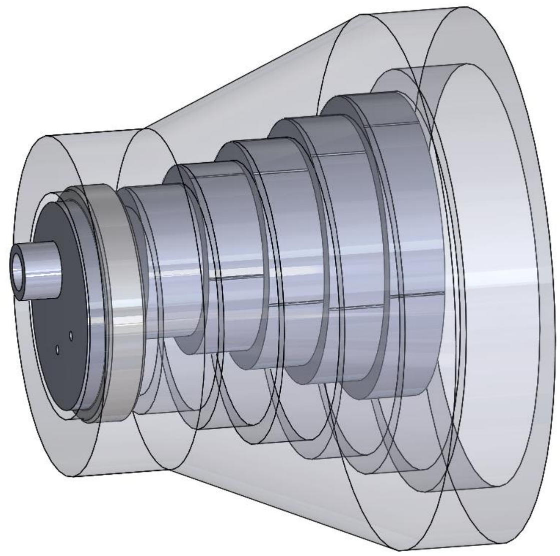

Figure 14: Initial Transmission Design

A problem with the initial design arose when we could not get the proper gear ratios. Our solution was to then use two separate transmissions that contained fewer gears. One design, seen in Figure 15 below, uses a two gear transmission and a three gear transmission. This would allow several different gear ratio options based on which gear was selected in each transmission. There would need to be a way to transmit the power from one cone gear to the next. Another issue was controlling each gear selector and aligning them so that they would shift in unison. Upon evaluation of this design it was easy to determine that it had several features that were too complex to make it work. Another issue is that using two separate transmissions would increase the size of the overall product which defeats our intended purpose.

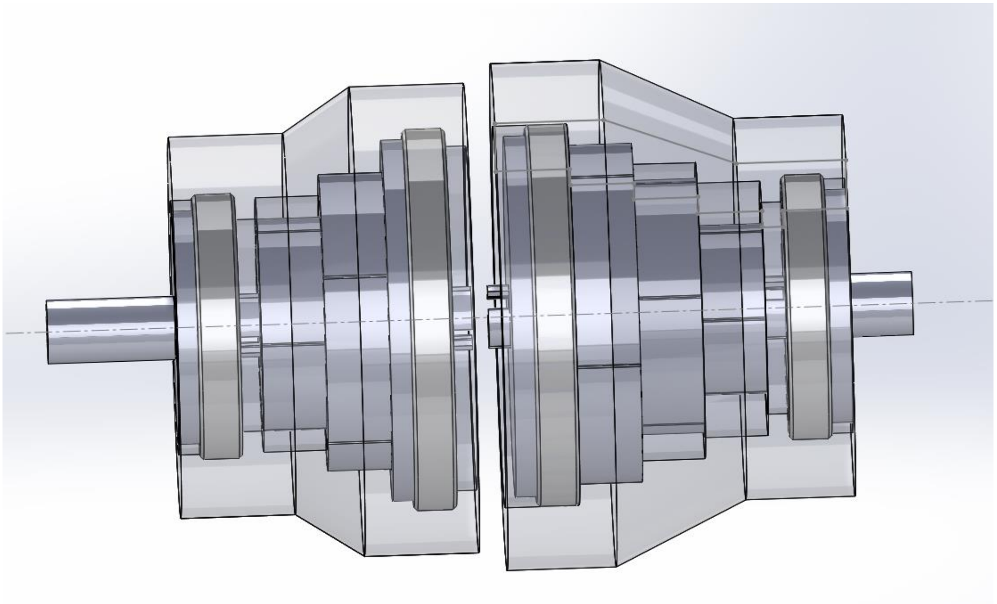

Figure 15: Dual Cone Gear Transmission Design

From this point on, we decided to put greater focus into the gear selector because we believe it was essential for the larger design. We decided to start developing several different approaches that could possibly generate a solution. Examples of these designs can be found in Appendix A. Eventually we directed our attention to collets, specifically expanding collets, in an attempt to find a new idea. To start, it is important to analyze how an expanding collet works. There are several machined openings within the collet that allow it to expand outward when an object is either inserted or screwed into the collet. This would then apply a force onto whatever may be surrounding the collet. In our specific design, the expanding collet would activate the gear located around it. We assumed that the interface between the gear and the collet could act similarly to a clutch and therefore reduce the slip in the interface.

Conclusion

Overall, the project was a success in its ability to further the design work of this particular style of automated manual transmission. Although we were not able to complete a design which achieved all of our functional requirements, we have established a sufficient design that can continue to be developed. Our work will serve future MQP students as a guide on what design and methodologies do and do not work for this transmission. Our team was also able gain extensive experience with the engineering design process as individual engineers and as a team. The purpose of an MQP is not to create a project, but to put forth the cumulative knowledge of education to earn valuable experience about design and how engineering projects are conducted in real life. In conclusion, we were able to create a completely unique transmission design that, with further design and analysis, can be developed into a more compact and efficient motorcycle transmission.

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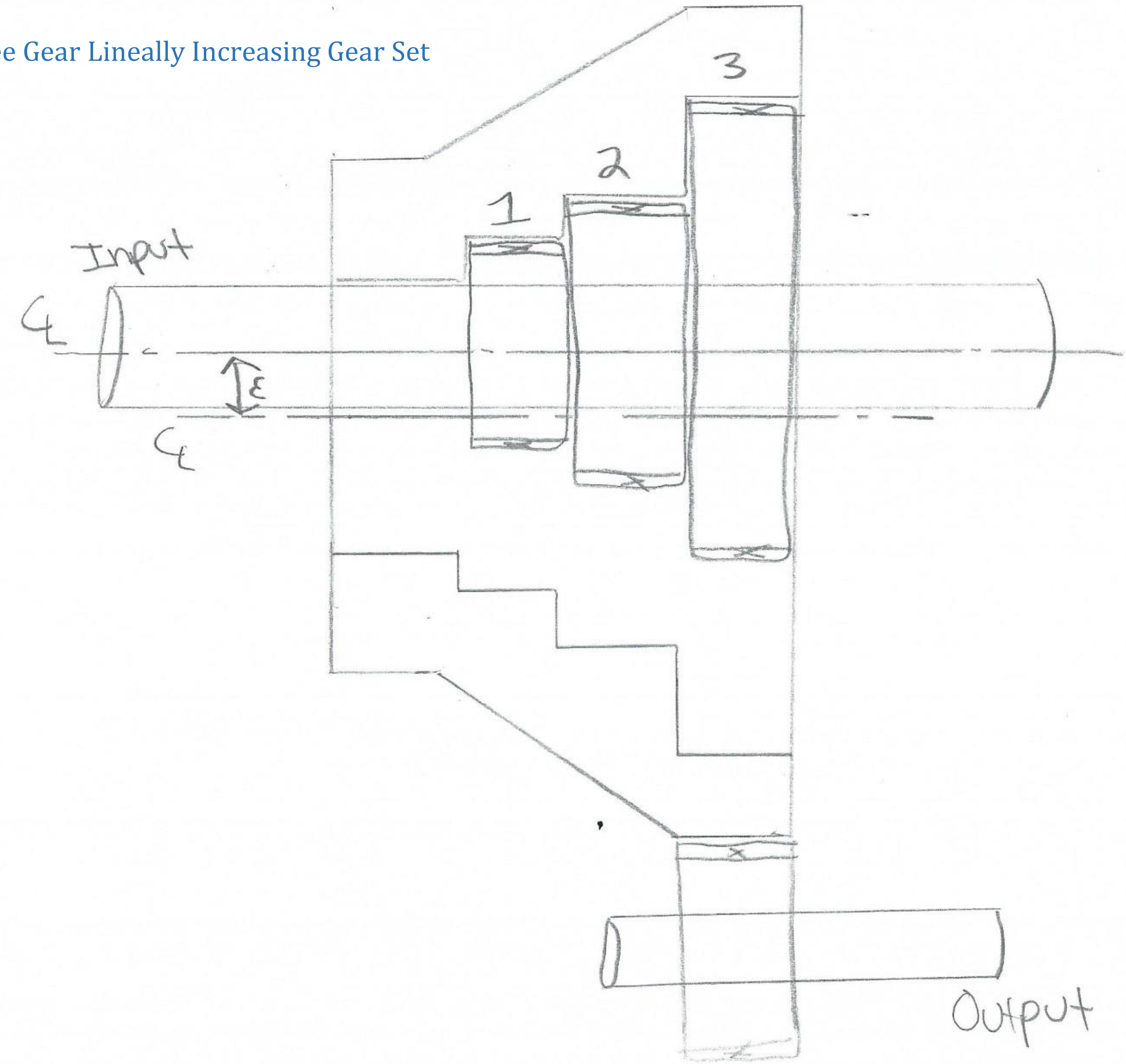
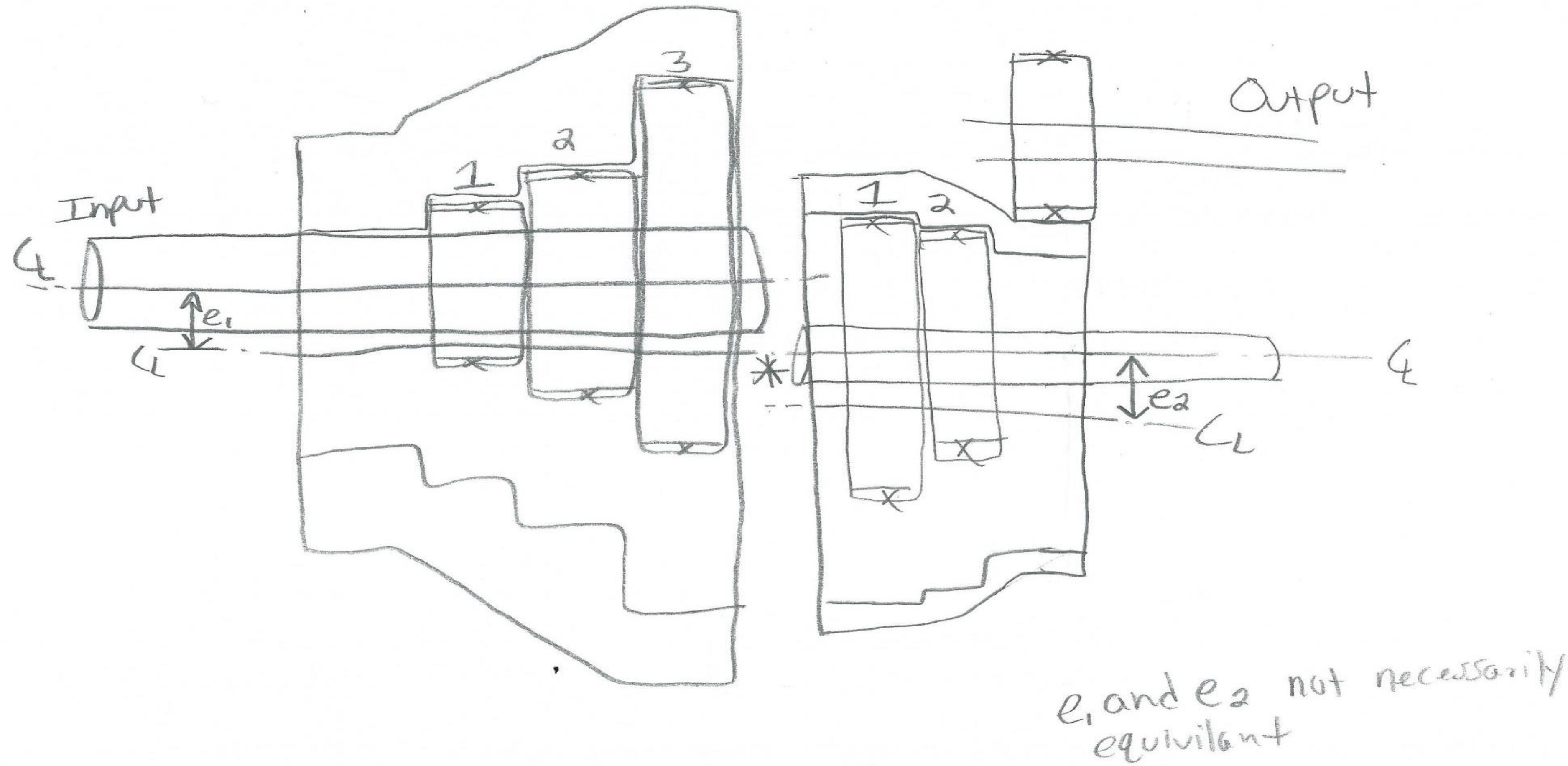
Appendix A: Design Drawings

Three Gear Lineally Increasing Gear Set

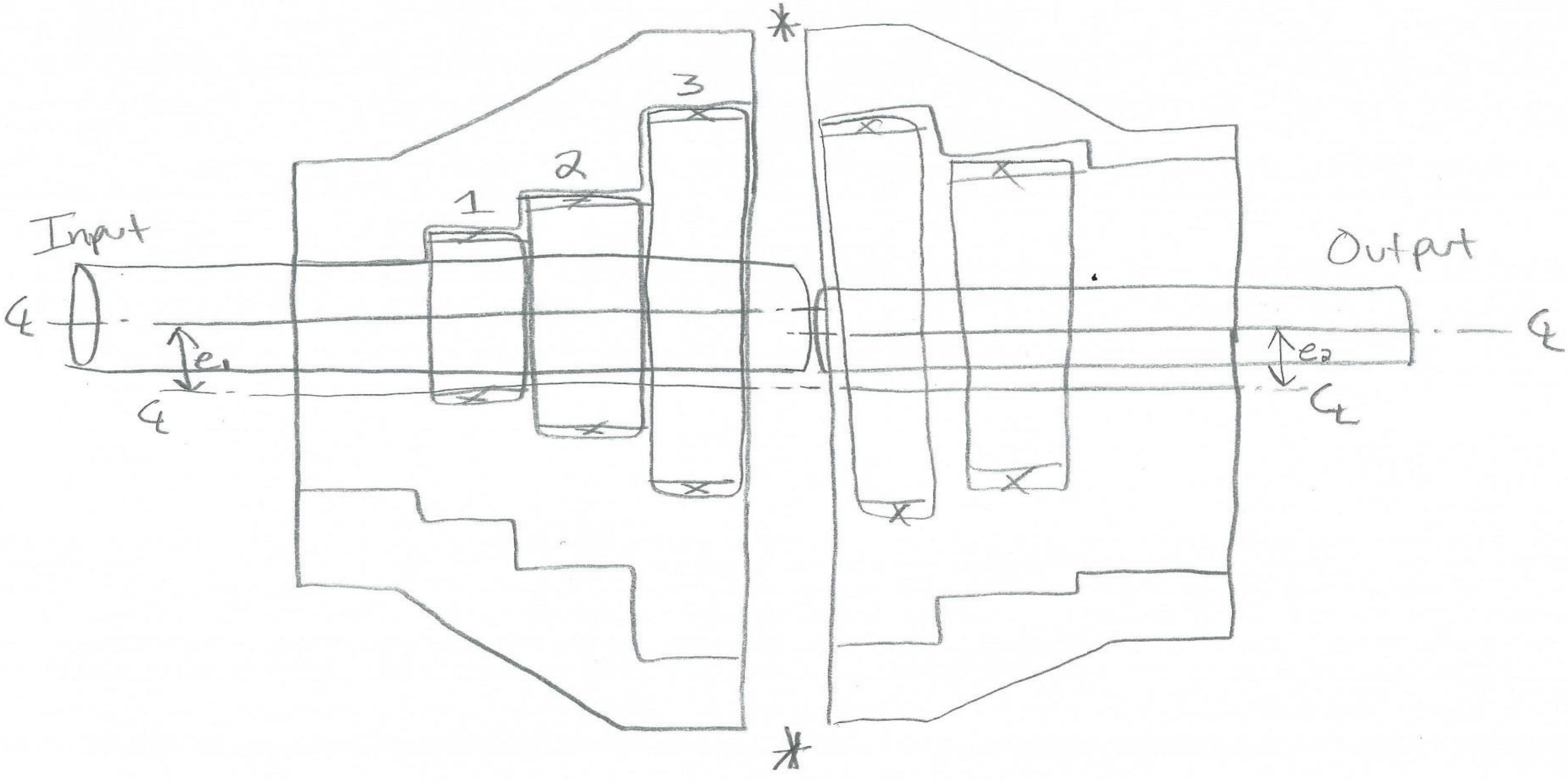


Five Gear Dual Cone Design



* Cone gear (input) is connected to center shaft on cone gear (output)

Five Gear Equal Size Cone Design



e_1 and e_2 are not necessarily equivilant

* Connection between two cone gears