Mechanical Engineering with a Remote Control Car

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Abstract

The goal of this project was to design and build a remote controlled car. The idea was to first design the car on paper, including the parts, their locations, and their overall purposes. Using our own previous knowledge of cars in general combined with the teachings of ProEngineer, computer software specifically designed for three-dimensional CAD drawings, it was possible to research different aspects of cars and create as well as buy the various parts compatible for an R/C car. We were motivated by our passion for engineering and the overall satisfaction of driving our end product.

Using the ProEngineer software, we were able to design and replicate the components of our very own miniature car. Using nothing but two sets of calipers, we were able to get dimensions for each part of the car and replicate the pieces into the program. Calipers are measuring tools which can make precise distance measurements down to a thousandth of a millimeter. Using our intricate drawings on the program, we used a "3-D Printer" to convert our 2-D drawings into 3-D plastic parts.

Introduction

A remote controlled car is a car that uses radio frequencies as a source of control. The first R/C model was a Ferrari 250LM built in a 1:12 scale. This model was then followed by the company's (El-Gi) next R/C Ferrari P4 built in a 1:10 scale. R/C cars started off reasonably primitive back then, having the bare minimum of parts and being shaped as dune buggies, then later evolving into monster trucks [5].

It wasn't until the mid 1980s that the United States got actively involved in the remote controlled car industry and the structures became more and more involved. They went from just a simple motor and axes, to a fully functional miniature car. Manufacturers began to give them complex systems including ball bearings, transmissions, shock absorbers, and disc brakes. The transformation happened rather rapidly and is still evolving today.

Thus began the basis for our project, to design and construct our own remote controlled car. The only thing we had to use was a set of calipers and a totally new program. These circumstances were not exactly in our favor, but we believe that we carried out the planning, designing, drawing, and engineering phases of the task to the best of our abilities.

Background Information/Related Work

The first few days were devoted to mastering the basics of a single, vital program. "Pro-Engineer," as it was called, would be used primarily to execute the CAD and CAM functions. Rapid prototyping is an additive fabrication technology used for building physical models and prototype parts from 3D computer-aided design (CAD) and medical scan data.

Unlike CNC machines tools, which are subtractive in nature, these systems join together liquid, powder, and sheet materials to form complex parts. Layer by layer, they fabricate plastic, wood, ceramic, and metal objects based on thin horizontal cross sections taken from a computer model [3]. A rapid prototyping machine reads the data from the CAD drawing and lays down a liquid material layer by layer until the three-dimensional model is completed.

The material used to make the part has a high melting point; in contrast, the material used to support the structure as successive layers are added possesses a low melting point. Upon completion, the machine heats the model until the support material melts away, leaving only the plastic prototype. Usually, the overall process can take anywhere between three to twenty hours, depending on the size and intricacy of the piece being built [4].

During the early design phase, we used one of our own remote-controlled cars as a template. An HPI Evo-3 car (Figure 1) was examined as a reference. This specific model employed a suspension system [2].


Figure 1 HPI Evo-3

However, due to the time constraints, engineers of the car opted for a rigid body design which would require fewer parts. Overall, the HPI Evo-3 served as a reference to work off of. After completing observations and examinations, the parts deemed essential – motor, battery, differential, receiver, speed control, and wheels – were purchased.

In order to protect the parts from damage and overheating, casings were constructed (using Pro-Engineer and the rapid prototyping machine). Each casing, though different in design, featured 3-millimeter-thick walls. All were customized to suit the needs and orientation of the individual part. For instance, the battery casing was build to support the battery in a position that would permit it to lie on its thin side rather than its flatter, blunter surface as to minimize surface area consumed on the board of the car. As a personal flair, initials were engraved on one of the casings.

In order to ensure that there would be ample space for each part, measurements that allowed for ample space were taken. From there, the basic blueprint of the car, including the locations of the motor, speed control, and other essential parts, could be constructed. In determining the locations for the motor, battery, and speed control, it was important to account for the fact that these parts tend to heat up while the car is in drive. We also needed to find a way to secure each part to the body itself and make sure that they did not affect each other negatively. Overall, spacing was essential to allow for tolerances.

Under a budget constraint of four-hundred and fifty dollars, some parts had to be manufactured, rather than purchased, using the rapid prototyping machine. Measurements of other parts such as the drive shaft support, which had no precedent from which measurements could be taken, relied on careful estimation based on related parts, such as the drive shaft, so that they would fit properly.

Specifically, the remote-control car relies on two batteries: one 7.2-Volt battery and one mega-volt battery. Airplane tires, though not optimal in terms of efficiency, were chosen because they are more cost-effective than other options. Furthermore, since four-wheel drive proved too complex, only rear-wheel drive controls steering. Two back wheels which remain responsible for directional control are connected to a drive shaft of diameter 0.25-inches that rests on a support consisting of four pillars, each with 0.27-inch diameter holes. The rod spears through these openings, allowing the pillars to hold it up.

<u>Experimental/Engineering Design</u>

First we identified the problem, which was manufacturing a radio controlled car. We also had constraints that we had to abide by. Our budget for the radio controlled car was only 450 dollars. This included tools that we needed to buy, like calipers. We also had a time constraint of three weeks. The three weeks included the time it took to learn how to operate the Pro-E program. Along with the three week time constraint we only had limited time every day to use the CAD software in the computer labs. Another constraint was that the rapid prototyping machine only printed out ABS 400 plastic. This meant that our designs had to compensate for the brittle nature of the material.

We had to consider these factors in our design of the car. We needed to design several systems that were critical to the car. The steering, drive train, and the electronic component layout were critical systems. The money gave us some leeway as to what we could buy as well as how much we would be forced to make.

With the constraints recognized, we moved to the design solutions process phase of our project. We had several differing designs for the various components in the car. One of the biggest problems was deciding which designs were the best, and most realistic. There were, however, many crucial systems and parts to be made for the car.

We decided to start from the ground up when building the car. This made the base the first part we worked on. We had the options of buying an acrylic plate and cutting it into what we want, modeling one and printing it out, or simply buying a premade frame. We settled on buying an acrylic plate and cutting it out because we figured that the ABS 400 provided by the rapid prototyping machine would not be strong enough to support the stresses the car would undergo during use [1]. We also decided against buying a premade frame because it would cut into our budget and it was against the overall engineering aspect of this project [6].

The next system up for discussion was the steering system. The steering had to be reliable but not so complex that time would become a problem. Furthermore, we tried to keep from making one part hold too much stress during turns. We came up with many variations of the steering. One idea consisted of a single steering bar which would attach to the bearing that the wheel is mounted to. This idea was discarded because it put a lot of stress on the solo steering bar which would have to control not only one, but two wheels. The problem was that if this one bar were to fail, the entire car would become immobilized. Another idea was to have two bars, similar to the first idea; instead the single bar would be cut into two. This idea was also put to rest because the stress that each bar would have to sustain would take the ABS plastic too close to its deformation point and possibly end up snapping or bending it. The final design was comprised of two bars that spanned across the width of the car. This design prevailed because it shared the load over two separate bars, thus lowering the probability of a failure. Also because there were to separate bars, if one bar did fail the car would still be able to maneuver and run until the necessary repairs could be made.

Another problem that had to be resolved was how we were going to get the power from the motor to the driveshaft. All the ideas that were brought up had the potential to be successful. The overall question was, "Which one would work the best?" The first proposal was to have two pulleys and have a belt that resembles an o-ring to connect them. This idea was heavily considered but was ultimately thrown away because there was a major concern that the belt would possibly slip. Another idea was to connect them using a timing belt. This was a great connection system because the teeth on the timing belt do not slip like regular pulleys. However, the timing belt would have to be custom made for our application. We would not have been able to afford such custom parts, and in response, the idea was not put into action. The final proposed idea was to use gears to make the connection. This idea was ideal because it not only allowed use to make the connection but it also allowed us to make the gear reduction that we needed to design in order to take advantage of the motors ridiculously high number of revolutions. We also had access to several gears that were donated by past project groups.

The suspension system brought about many challenges and its many design solutions proved to be controversial. Suspension was not a necessary system, but its benefits were substantial and highly noticeable. No matter which idea we came up with, it would be complicated and very difficult to incorporate suspension into the radio controlled car. Our suspension ideas spanned from having each wheel have its own independent suspension to each pair of wheels having its own suspension.

We began to design a suspension system that allows each wheel to rotate freely. We began to design the parts for our suspension system when we came to the realization that the time needed to make the suspension parts would be greater than the time we actually had to work. We then chose to go with a rigid body type, free of suspension.

Modeling Parts with Pro-Engineer

After we had a general idea of what we wanted the car to look like we began to work on Pro-Engineer. We spent the most part of the first week learning how to use Pro-E to create parts and assemblies. Some of us were quick learners, mastering the program within the first few days, while others struggled.

The first things that were modeled on Pro-Engineer were the cases for all of the electronic parts that were needed to run the car (Figure 2). Cases were made for the battery, speed controller, and the transmitter. Each of these cases were required to fit their respected part snuggly within them and they also needed to have holes at the bottom to fasten them to the piece of acrylic that was

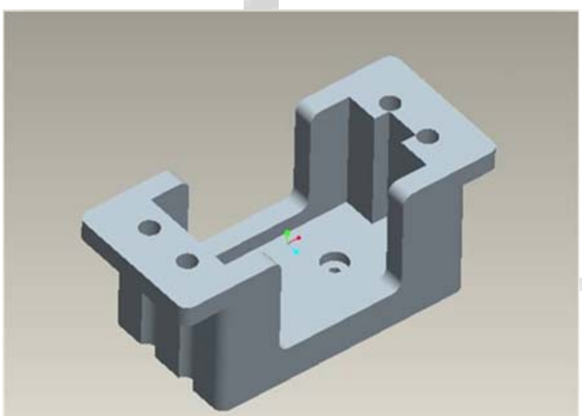


Figure 3

being used as a base. These cases were also made with walls with a thickness no less than 3mm to withstand vibration and other impacts that the car will have to endure during use.

Once these parts were modeled and their sizes were known they were put into a layout to view how much space was left for the other components. This was done in the assembly feature of Pro-Engineer, where one can take all of their modeled parts and place them in one convenient window to make sure everything fits together. After the cases were modeled and accounted for, we began work on the more intricate and crucial pieces.

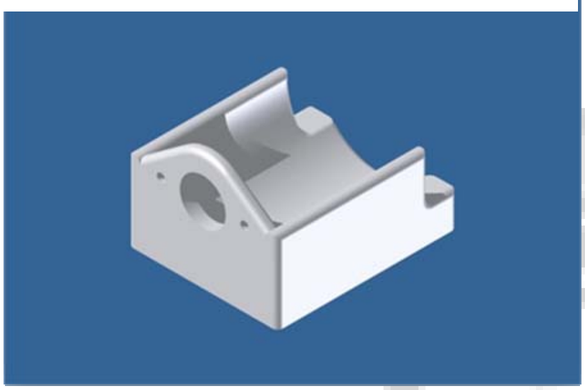
The first system to be modeled was the steering system (Figure 3). The design was agreed upon earlier, but at status quo it was only a two-dimensioned sketch by hand so by using Pro-Engineer, we were able to model it accurately and see if the system would work. Once the parts were made on Pro-E we did notice one flaw in the design. We planned to use servos to turn the steering

Figure 2

system. The output of the servo did not match what we needed for the steering, so an adapter had to be modeled to make the steering system operate. Once it was all modeled and assembled in Pro-E it was sent off to the rapid prototyping machine to be printed out.

The motor mount was next to be modeled (Figure 4). It needed to hold the motor tightly but also needed to let the motor's gears rotate and circulate air to cool it off to prevent overheating. A motor mount was made that screwed into the front of the motor and that had an open back end. This set the motor in place but was open enough to allow air circulation to keep it cool.

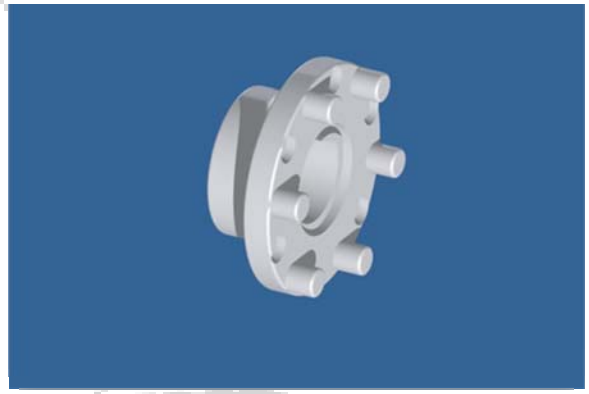
Figure 4



Next on the list to model was the gear system (Figure 5). The gears were pre-made out of steel but they still needed to be mounted to the axle and the motor. The axle that we used was a 3/8th D-Hole axle made from steel. This axle connected the powered wheels to the gear using an adapter that mated to the D-Holed bar to the gear. This adapter was also modeled on Pro-E and took advantage of the D-profiling on the axle and holes that were readily made on the gear.

At the same time, the axle holder was being modeled. The holder had to keep the axle in place so it would keep the gear meshing with motor. During the modeling of this we thought it would be better to mount the axle under the car. Before this point the axle was planned to have been above the frame. This change gave the car more ground clearance, as well as better protection from something snagging the underside of the car.

Figure 5



Once all the modeling was done and all the parts were printed, we could begin the assembly of parts. The acrylic sheet needed to be cut to the right dimensions for the car. Also the sheet needed the mounting holes to mount the components. Other holes like the wheel wells and the gear pocket needed to be made as well.

Once the acrylic was cut we could mount the pieces to the plate. The steering system was the first to be mounted because it contained two of the wheels and was of the highest priority. We wanted to mount the steering to check it for any flaws. The steering system consisted of the servo, the steering cross bars, and the two steering knuckles.

With the steering mounted the rear wheels were next to be mounted. The axle mounts went on first. Then the axle and gear were placed simultaneously. The motor was mounted and inspected to make sure the two gears meshed correctly. Once the core mechanical parts and systems were placed we could move on the electronics.

The first electronic component that was mounted was the battery because it took up the most space. Once the battery was in place it was inspected to make sure it could easily come in and out of its case, we moved to the next part. The speed controller had to be placed in a certain orientation because the wires came in and out of it. Also the speed controller needed to have a good air flow to make sure that it did not overheat. Once the position was inspected for the speed controller, the other pieces fit accordingly.

The transmitter was placed away from the rear wheels too keep it away from the metal object that were in that system. This made it possible for the best transmission of signal between the controller and the car. The power switch was placed on the outer edge of the base so that it was easy to access.

Results

After our various efforts, the group was able to take apart an existing radio controlled car and pick out pieces which were found to be useful to the prototype that we wanted to create. After careful research and discussion among us, we decided on which systems to use. The group decided on a gear system which would prevent the slippage that might occur with a pulley system. We also decided on a steering system that utilized only one servo. This proved to be more energy efficient.

We also needed to create casings which would hold the different pieces of the car to the base. The group created a battery casing, a servo casing, switch casing, motor casing, and speed control casing among others. The casings and parts that were created in Pro-Engineer were then created with a 3-D printer commonly known as rapid prototyping that printed the parts out with ABS-400 plastic, layer by layer. The casings that were made by the printer fit the parts well and held the battery, motor, speed control, etc. down to the base as the group intended it to. In addition, the project helped each of the group members to learn how to use a caliper to measure the dimensions of each different piece. The project then allowed us to learn how to use Pro-Engineer to duplicate parts on the computer using the dimensions taken from the calipers.

Future Work

After the final design was complete, the group realized that there were improvements that could have been made to the project in the future. The steering system of the car and the addition of a suspension system were two areas in which future projects could have been worked on for improvement. Rear differential and better tires could also be added by future groups in order to improve the project, making the car more efficient.

The steering system presented many problems. Initial steering designs were unstable and complicated. These designs consisted of many small parts, with equally as many hinges and connections to the base. Furthermore, final designs for the steering system were too basic. Though these designs functioned properly, they consisted of merely basic parts, hinges, and connections. The final designs only allowed for a turning radius that was sufficient only to make wide angle turns. In a future project the steering system should contain fewer parts, yet still allow for a smaller turning radius in order to turn more efficiently.

The final design excluded any type of suspension system. The lack of the suspension system compromised the efficiency of the car. Without any type of suspension system the car has no protection against rough terrain, bumps, or collisions, thus limiting the car to flat surfaces. The initial designs included a suspension system, yet this proved to be far more complicated than it needed to be and hard to manufacture and assemble. The parts needed were simplistic in design, but they were numerous. The assembly of these parts would be too difficult under the given time constraints. In future projects, groups could add a suspension system in order to circumvent the problem of only being able to ride on flat surfaces.

Final designs used model airplane tires, and had no rear differential. The usage of the model airplane tires causes the car to have less traction. Model airplane tires have a small surface area on the ground. This cuts down on the efficiency of the car by allowing slippage between the tires and the ground. The lack of a rear deferential also cuts down on the efficiency of the car. The rear deferential allows the outside tires of the car to spin faster as the car turns. This causes greater efficiency through turns. Future groups may consider these improvements while conducting this project.

Conclusions

Throughout each phase of the project, various obstacles were encountered and overcome. Overall, though things did not go as planned, we accomplished our main goal and sub-objectives. Dissection of an already-functional R/C car enabled us to learn more about the important functions that each piece contributed to the car. Using calipers, we then proceeded to take accurate measurements with which we used to re-create accurate replicas of the parts in Pro-Engineer.

When it came time to create casings for the servo, switch, speed control box, etc. certain parts did not allow enough extra space for the actual piece to slip in comfortably.

Rather than risk fracturing the casings or damaging the parts, some of the pieces had to be altered and remade. Since the rapid prototyping machine created parts layer by layer, it took about 10 hours for each group of parts to be created. This meant that we would have less time to assemble our car because we would have to wait for the parts to be completed by the machine, leaving us with less time to assemble car pieces together and fine tune the pieces.

The project also experienced a setback with the three-day absence of an important person in the research group. The remaining members decided to dispose of the R/C car's suspension system, as it proved too complicated and time-consuming. However, many of the parts for the suspension had already been made. In essence, we had to start over from scratch with a brand new design featuring a rigid body and rear-wheel steering. Had the group chosen to remain with a simple design from the very beginning, ignoring the suspension system, efforts could have been channeled to finishing the casings and steering pieces of the car. Thus, the car could have been finished earlier.

Furthermore, although most pieces were created using Pro-Engineer, other more complex pieces were designed using The Inventor. As a consequence, the files were in a different format, one that the rapid prototyping machine was unable to read. Since the rapid prototyping machine requires at least ten hours for each group of parts, it could not made in time for the first meeting scheduled with the technician. The assembly was thus postponed, forcing us to complete the actual construction of the car at a later date. Fortunately, in the waiting period, the group managed to complete the research paper and presentation.

To complete this assignment, we applied the principles of mechanical engineering. This discipline implements physics to design. Aside from the basic kinematics and dynamics of an automobile, we also took into account the thermodynamics of the parts by constructing casings to protect the parts from overheating. These casings had to be made from durable material, resistance to high temperatures. The material of the base, itself, had to be strong enough to support the car.

After gathering all the parts and finishing the remote control car, the group completed its first test drive, which proved to be a success.

Acknowledgements

As is apparent, this project would not have been possible without the help of some important figures. We would like to thank The Governor School for Engineering and Technology as well as all of their affiliates for this great experience. We would also like to express our gratitude for Dean Brown, the Director of The Governor School of Engineering and Technology as well as Blase Ur, the Program Coordinator, for selecting us for this immensely rewarding opportunity. This would not have even been a choice for a program if it hadn't been for our project coordinator Dan Wong's selflessness and helping nature. He made the GSET experience a great deal more rewarding. At the same time, we would like to thank Angel Irizarry for guiding and providing us with assistance throughout the project. He also kept our spirits up when we faced problems during our project.

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Citations

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