



Design and Fabrication of Electric Go-kart Using 3D Printing

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Abstract

This paper presents how to bring current high technologies in engineering classes with the use of 3D printers in design and fabrication of electric go-kart parts. Students in Mechanical Engineering Technology Club with interests in automotive technology as well as manufacturing technology were given the opportunities to design and build electrically powered go-kart to learn product design, prototyping and manufacturing. Using 3D printers, students designed and built number of different go-kart body parts, including a steering wheel column cover and a front nose wing pieces. In the process, students learned to design for manufacturing, build within maximum build envelope of the 3D printers, assembly for parts, and resolve fitment issues. Additional parts to be designed include side skirts, motor and battery covers, and a rear wing. The outcome of such learning experiences from this project can be expanded to interdisciplinary project oriented courses for engineering students to enhance their learning experiences.

Introduction

The goal of this project is to introduce new technology in the class room and inspire students about using 3D printers for design and manufacturing processes. Most engineering colleges have been providing outdated technologies in current high technology era. Engineering students experience lack of next step to support theories which they are exposed in classes. For example, visualization is one of the critical validation methods of engineering design, where current three Dimensions (3D) Computer Aided Design (CAD) modeling no longer satisfies their desires. However, advent of affordable 3D printers enables engineering colleges to provide extra tools of hands-on activity capabilities to their engineering students in their engineering/technology courses and projects. This also leads them to the joys of product design by enabling them to experience at first-hand, an entire product design cycle in a few hours, students will have better mindset for learning.

3D printers have come a long way since the early days of rapid prototyping that used additive process to create a desired shape by incremental addition of material in a layer-by-layer fashion^[1]. These early machines are relatively expensive, difficult to operate and require long build time. With the advent of self-replicating rapid prototype (RepRap) movement that started in early 2005^[2], more affordable desktop 3D printers started to appear in the market^[3] starting in 2009. These 3D printers deposit melted plastics layer-by-layer in microns until the part is completed. The build times depends on the size and fill options, typically several hours. This enabled designers to evaluate different design options and finalized the part in matter of days. Uses of 3D printers have evolved into mainstream manufacturing. 3D printing has fashion designers experimenting with swimwear, shoes, and dresses^[4]. Researchers have started to use 3D printing to build buildings for off-Earth habitats^[5]. 3D printing has been widely used to print

patient specific implant and device for medical use. Successful implementations include titanium lower jaw transplant^[6] and prosthetic hand made from 3D printer^[7].

Some schools have implemented use of 3D printers in their programs to enhance learning experiences and provide hands on approach where students can verify theories and physically evaluate their designs, and re-design, if necessary, to create parts that are not only functional but prototypes for parts that can be made from other materials. Michigan Technological University has incorporated 3D printers in their STEM programs to attract and create more interest in technological field by training K-12 teachers how to use 3D printers and implement in their courses^[3]. University of Florida's Mechanical and Aerospace Engineering department has created ABS model of turbo machinery impeller to measure the performance curve against theory in Thermo-Fluids Lab^[8]. In Colorado State University, 3D printers are used in engineering courses such as Engineering Graphics, Calculus and Analytic Geometry, Material Science and Engineering, Thermodynamics, Computer Integrated Manufacturing and Controls I and II^[9].

Students at Quennsborough Community College (QCC) are encouraged to join number of different clubs as part of their student activities to enhance their learning as well as gain knowledge for their career developments. Mechanical Engineering Technology Club was established to support and encourage students interested in careers in mechanical engineering, discuss latest mechanical engineering technology and participate in student projects. Students whom have completed courses in 3D CAD modeling and rapid prototyping used 3D CAD software to first design go-kart body parts and then learned to print the parts using 3D printers. This allows the students to quickly check for design issues such as fitment, interference, and stiffness of the parts before finalizing their designs.

Design

Due to limited metal fabrication equipment available at QCC, it was decided to purchase a go-kart kit from a vendor, Azusa Engineering, Inc.^[10] in California. The kit came with all the necessary components, which included body frame, steering, wheels and brakes. The motor had to be purchased separately, as either gasoline or electrically powered motor could be used. The motor chosen for the go-kart was a DC motor to promote environmentally friendly design and also possibility to enter a nationwide student competition such as Shell Eco-marathon^[11]. After the go-kart kit components were assembled, students generated 3D models of the go-kart's main components using reverse-engineering principals. The body frame, steering column and wheels were created using SolidWorks software (see Figure 1). Once the model was generated, the body parts were designed and printed in 3D. Many different variations to the go-kart body were designed and students chose the ones that were deemed most appropriate and easy to fabricate using 3D printers. First body part to be designed was the steering wheel column cover (see Figure 2). Then the front nose wing was designed (see Figure 4). Once the motor and batteries have been selected and installed in the go-kart, additional parts will be designed, including side skirts, motor and battery covers, and a rear wing.



Figure 1: SolidWorks model of the go-kart kit

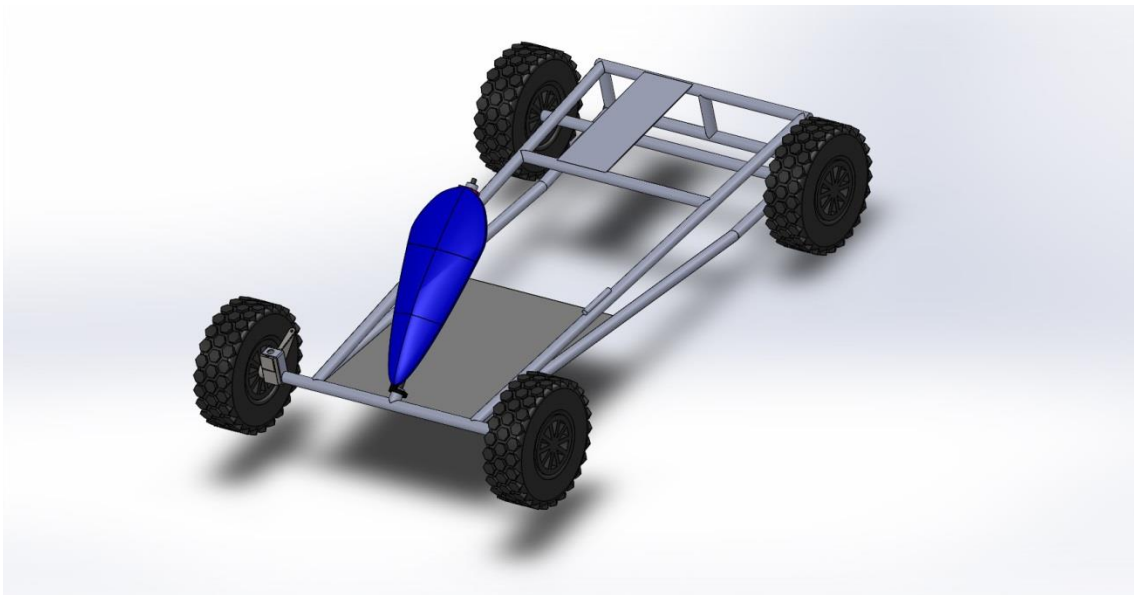


Figure 2: SolidWorks model of the steering wheel column cover

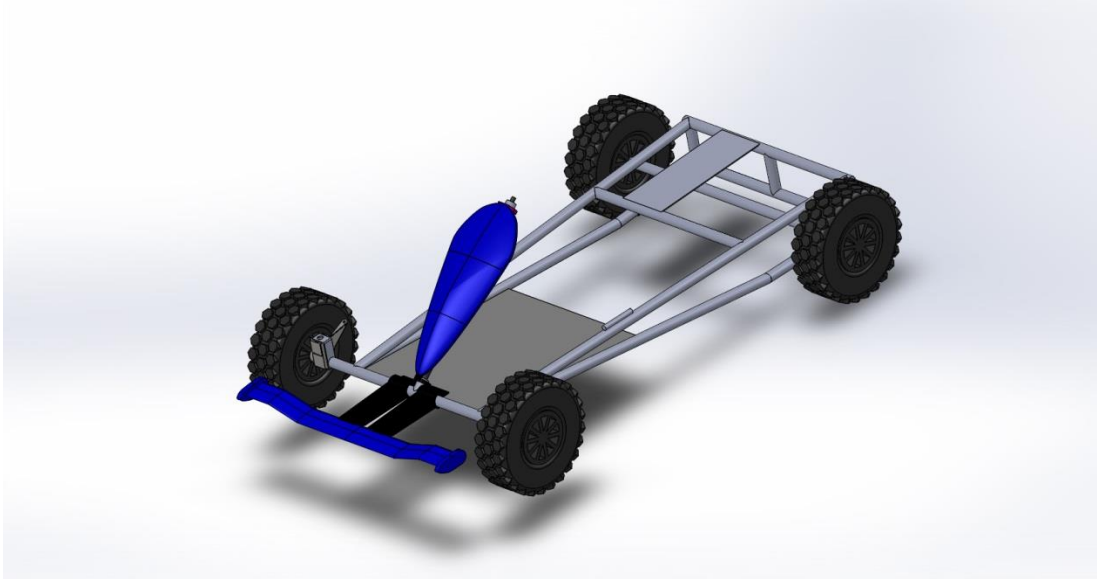


Figure 3: SolidWorks model of the front wing

3D Printing and Assembly

With the funding from CUNY 2020 Challenge Grant, QCC was able to purchase ten MakerBot Replicator 2^[12] 3D printers to be used in Engineering Technology courses and projects. MakerBot Replicator 2 is an additive process based on fused deposition modeling using Polylactic acid (PLA) filament to deposit 100 micron layer resolutions. It uses its own software called Makerbot Makerware to convert any 3D files, such as Stereo Lithography file (.STL), into printable file that can be sent directly to the printer via SD card. Due to MakerBot Replicator's limited print sizes (6" x 6" x 11"), larger parts had to be sectioned into smaller components, printed and then assembled into final parts. Students had to be creative in terms of how many components are to be sectioned and how to assemble them into final parts. Students also learned in detail, design for assembly which is not fully covered in class room settings. By analyzing each components and limiting the assembly components, it was decided that press fit would be the best choice for assembling each sectioned components into final parts.

Steering wheel column cover was sectioned into 6 components (see Figure 4) and each component was assembled using I-shaped connectors held in places with small screws (see Figure 5 and Figure 6). After the assembly, steering wheel column cover was attached to the go-kart with ring type attachment using screws (see Figure 7, Figure 8, Figure 9 and Figure 10). Fully assembled steering wheel column cover on the go-kart is shown in Figure 11.

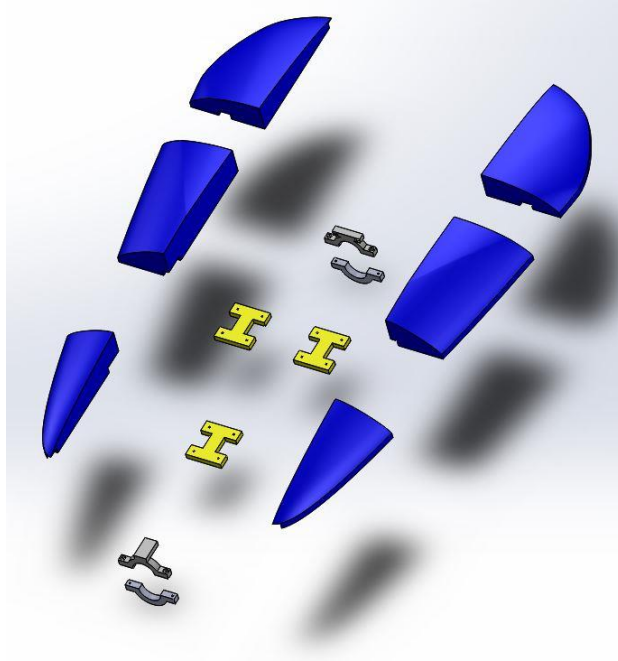


Figure 4: SolidWorks exploded view of the steering wheel column cover



Figure 5: Steering wheel column cover showing connecting pieces backside view



Figure 6: Steering wheel column cover I connector

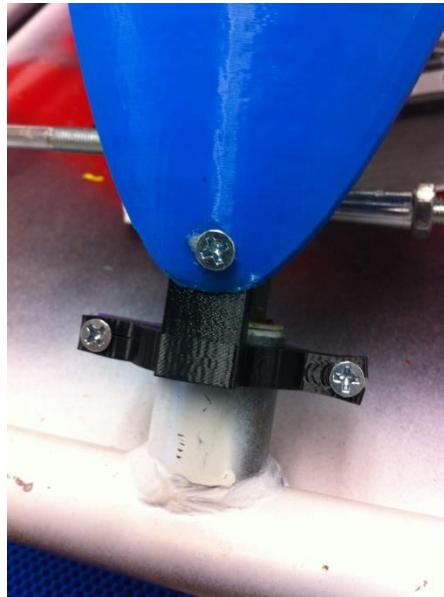


Figure 7: Steering wheel column cover bottom ring connector top view



Figure 8: Steering wheel column cover bottom ring connector backside view

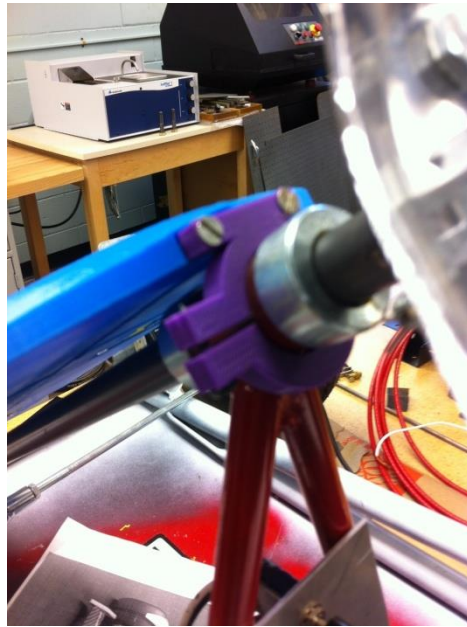


Figure 9: Steering wheel column cover top ring connector top view



Figure 10: Steering wheel column cover top ring connector bottom view

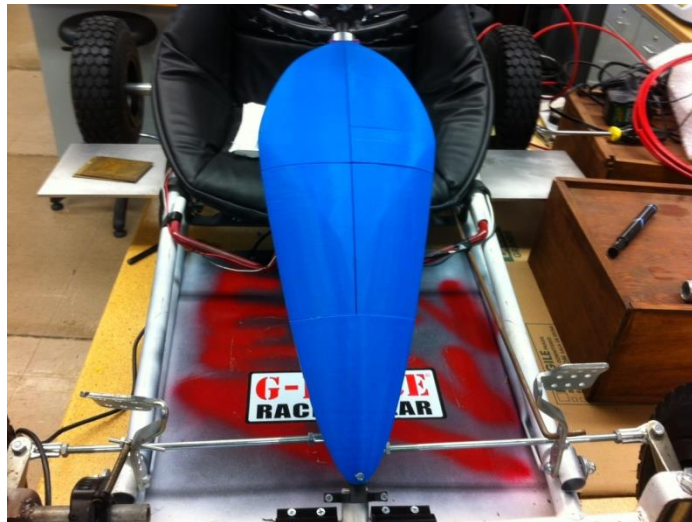


Figure 11: Steering wheel column cover front view

Front nose wing was a long part that was assembled using 12 components (see Figure 12). To minimize the use of screws, the wing pieces were assembled using tapered rods that were fitted into mating holes (see Figure 13). The final assembled piece was then attached to the go-kart's front frame with clamp type connection using screws (see Figure 15). Fully assembled nose wing parts on the go-kart in various views are shown in Figure 14, Figure 16, Figure 17 and Figure 18.

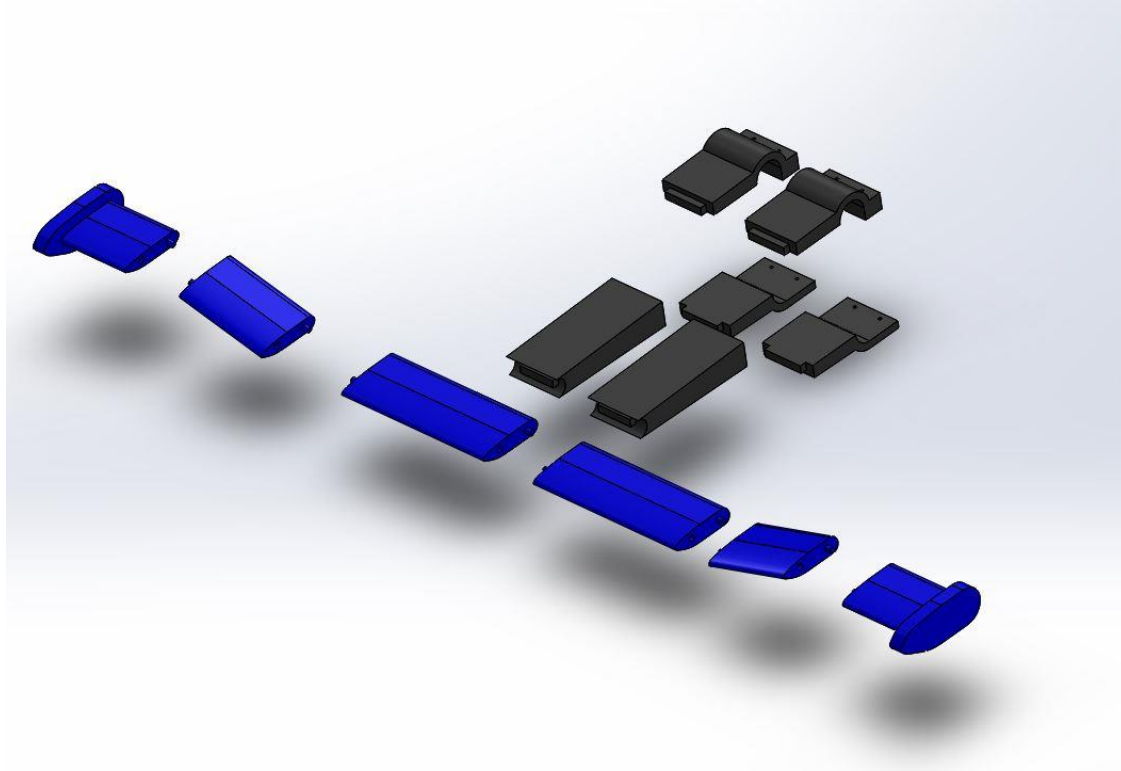


Figure 12: SolidWorks exploded view of the front wing

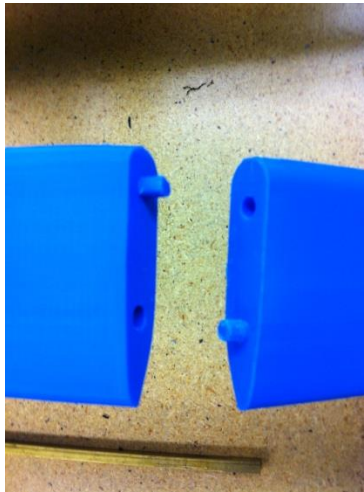


Figure 13: Front wing typical tapered rods mating into hole

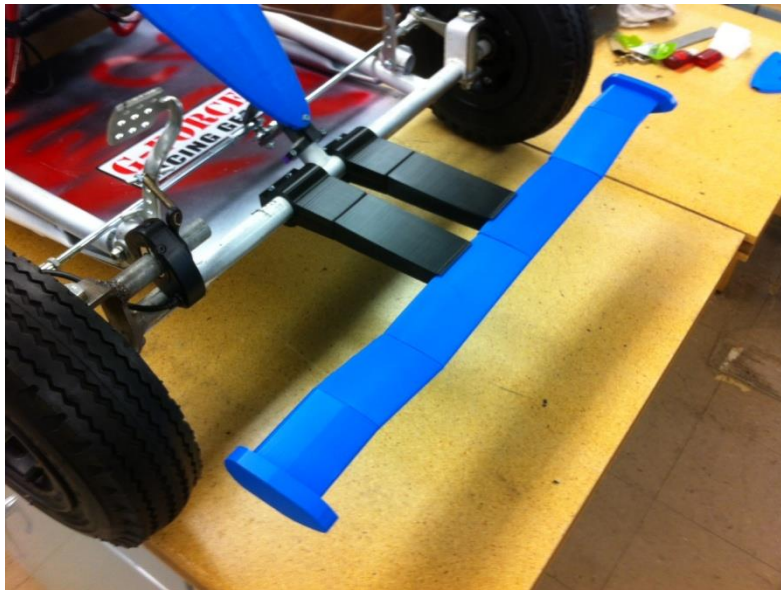


Figure 14: Front wing attached to the go kart side view

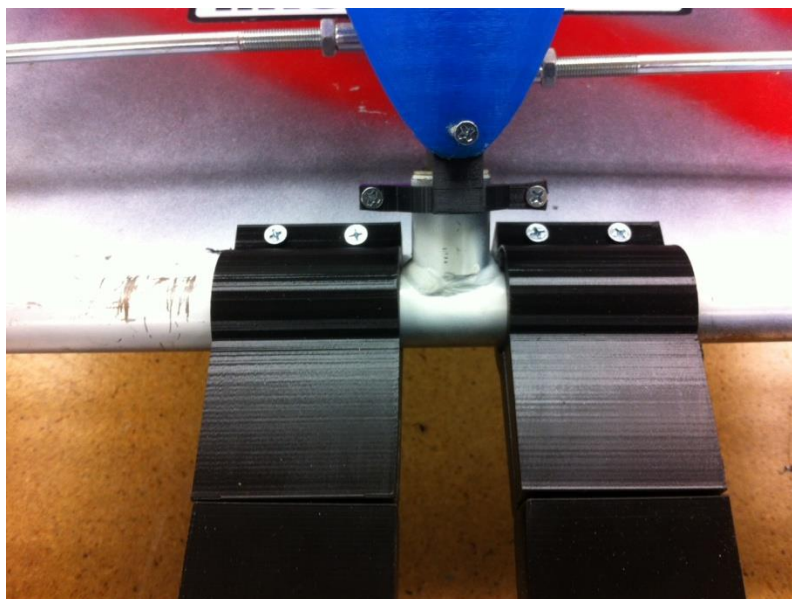


Figure 15: Front wing attaché to the go-kart with clamp type connections with screws

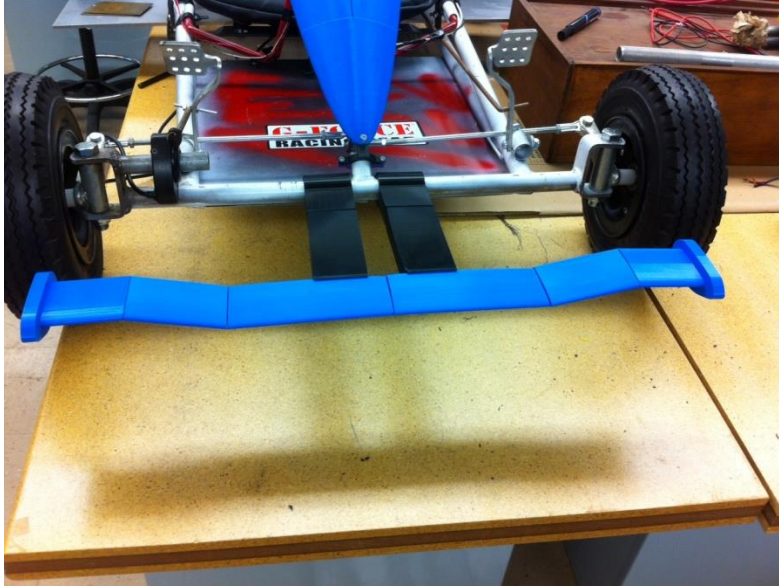


Figure 16: Front wing attached to the go kart front view

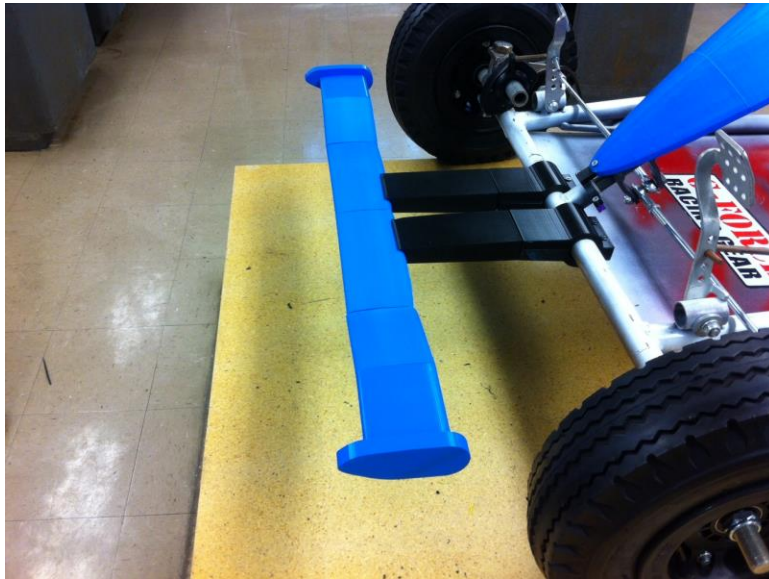


Figure 17: Front wing attached to the go kart side view



Figure 18: Front wing attached to the go kart rear view

The total print time ranged from one hour to six hours. Multiple printers were utilized to shorten the print time and there were some issues with printers, mostly clogged nozzles that needed to be cleared. Only a couple of re-design was required, such as front wing connections where the female slots had to be reduced to mate properly. The connecting locations show obvious gaps but this can be corrected by increasing the holes and slots, or filling the gaps with plastic fillers.

Conclusions

This paper presents how to bring current high technologies in engineering classes with the use of 3D printers in design and fabrication of electric go-kart parts. Students have designed and created go-kart body parts such as steering wheel column cover and front nose wing. Additional parts to be designed include side skirts, motor and battery covers, and a rear wing.

Designing a go-kart enables the students to specify appropriate manufacturing processes and appropriate tools for the fabrication of mechanical components. This project illustrated how to enhance the educational experiences of engineering technology students by using mechanical engineering concepts such as statics and strength of materials as well as interdisciplinary course such as electronics to engage students into think creatively.

The student learning outcome for this project included learning and understanding of 3D tools and technologies, design and develop product prototypes, understand the advantages and limits of 3D printing process from design concept to physical models, and use the new skills to enhance studies across the other disciplines of engineering and science courses. The students were able to accomplish these outcomes by demonstrating their abilities to understand the printable envelope size limitations of the MakerBot printers and were able to orient the parts such that build errors

were minimized, add supports option in the 3D printer to create more robust parts and control the fill percentages to minimize longer build time or stiffen the parts for load bearing applications. The students also demonstrated their abilities to operate 3D printers expertly, incorporating into their course work, such as developing prototypes for their SolidWorks course assignments and creating scale models of their architectural designs. The steering wheel column cover and front nose wing parts created by the students showed that they fully understand the state of the art capabilities of 3D tools and technologies as well as design and develop product prototypes in few hours.

The outcome of such learning experiences from this project can be expanded to hands on design approach, implementation, theoretical analysis and verification through experimental models, and design for assembly in the near future of an interdisciplinary project oriented course for engineering students to enhance their learning experiences.

In QCC, 3D printers are already used in Introduction to Virtual Automation in the Fall of 2014 and is in the process of incorporating into courses such as Manufacturing Process, Parametric Computer Aided Design and Cooperative Education & Design Projects.

Bibliography

1. Black, J. T. and Kohser, Ronald A. (2012), DeGarmo's Material and Processes in Manufacturing, 11th Edition, John Wiley & Sons, Inc., New Jersey.
2. RepRap Project. Retrieved from http://en.wikipedia.org/wiki/RepRap_Project.
3. Irwin, John L., Pearce, Joshua M., Anzalone, Gerald and Oppliger, Douglas, E. (2014). 121st ASEE Annual Conference & Exposition, (Paper ID# 8696), Indianapolis, IN.
4. "3D Printed Clothing Becoming a Reality", Resins Online (2013). Retrieved from <http://www.resins-online.com/blog/3d-printed-clothing/>.
5. Edwards, Lin (19 April 2010). "3D printer could build moon bases". Phys.org. Retrieved from <http://phys.org/news190873132.html>.
6. "Transplant jaw made by 3D printer claimed as first", BBC News Technology (2012). Retrieved from <http://www.bbc.com/news/technology-16907104>.
7. "Inverness girl Hayley Fraser gets 3D-printed hand", BBC News (2014). Retrieved from <http://www.bbc.com/news/uk-scotland-highlands-islands-29441115>.
8. Abbitt, John and Ridgeway, Shannon (2014). 2014 ASEE Southeast Section Conference, Gainesville, FL.
9. Jaksic, Nabojša I. (2014). 121st ASEE Annual Conference & Exposition, (Paper ID# 10642), Indianapolis, IN.
10. Azusa Engineering, Inc. Available <http://www.azusaeng.com/>.
11. Shell Eco Marathon. Retrieved from <http://www.shell.com/global/environment-society/ecomarathon.html>.
12. MakerBot Replicator 2. Retrieved from <http://store.makerbot.com/replicator2>.