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# Interdisciplinary Senior Design Project to Develop a Retrofit Shock Absorbing Go-Kart Seat

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## Abstract

In recent years there has been a big push to get students into the STEM fields. However, what seems to be lacking in this academic push is the hands on side of it. Engineering simply just isn't about equations, but actually design and developing as well as fabricating a physical product. Something you can touch and in most cases see work. The Engineering Technology field fits into STEM academics and is very important. In order for companies to compete in the global marketplace, employers in the 21st century require their engineers couple the traditional engineering design skills with new skills in design and development, as well as the ability to function multi-disciplinary. With learning the importance of prototype development and manufacturing, the Senior Design team at Drexel University's Engineering Technology Department have decided to take on a challenge in the entertainment industry specifically driving a go-kart vehicle in a closed track. To do this they have addressed the most common issue with driving a go-kart, which is experiencing potential pressure ulcers as well as upper and lower back pain after driving in the kart. The project seeks to solve this problem by creating a retrofit kit using interlinked air pockets with a gel pad covering to evenly distribute the pressure on the driver's body and absorb the vibration of the seat that the driver normally experiences. The pressure the driver experiences during the ride is measured using a network of 8 sensors placed at the major points of contact between the driver's body, and the body of the seat. The vibration level experienced by the driver is measured using an accelerometer on the seat itself. The seat retrofit is made using polyurethane coated polyester for the main structure of the seat. The air pockets are made using flexible polyvinyl chloride fabric. The air pockets themselves have an interconnected design for optimal pressure redistribution. The target cost for each individual retrofit is $93 with a selling price for $600. The significance of the methodology to be applied in this capstone course project is to combine theory and practice to prepare the students to become better problem solvers and obtain practical solutions to real life/simulated problems using a project based approach. Senior Design capstone project has the following major goals. 1) Raise student awareness of contemporary issues as they relate to the Engineering Technology field. 2) Enhance student decision-making and problem solving skills in a multi-attribute and team setting. Students in the Mechanical, Electrical, and Industrial fields along with many others can learn many new skills from multi-disciplinary projects such as the design and development of a go-kart seat to minimize vibrations felt by drivers. Such projects show students how to use different types of technology, and demonstrate how advanced technology can be used in an innovative product improvement. Overall, many different fields of engineering can benefit from this application, enabling the development of skill and knowledge in many different engineering aspects and processes. This capstone design project stimulates the students' interest in real-world product realization.

Expected student learning outcomes assessment in this capstone course was performed using written reports and oral presentations as well as an evaluation of each student's contribution to the project. Oral presentations were assessed at the end of the first and last quarter and written reports at the end of each quarter. Both written reports and oral presentations were assessed by all faculty members and a number of outside assessors from regional industries. The assessment of individual student contributions was performed by the project advisor and co-advisor. The students' performance was assessed using a set of performance indicators that are also used to assess the program's student a-k outcomes (ABET). Each indicator is assessed according to a Likert-type scale and the results weighted to emphasize technical qualities of the work and scaled to produce a score from 0 to 100 in order to determine the students' final grades.

## Background and Literature Review

This senior design project seeks to solve the problem of driver's experiencing upper and lower back pain, and other more severe symptoms such as pressure ulcers after driving a go-kart. There are innumerable posts on the internet of drivers complaining about significant pain in their backs, and many even complaining about having red welts on the back, usually over the two bony protrusions in the lower back, which lines up with the description of a stage one pressure ulcer. This common side effect of back pain can have an especially debilitating effect on drivers who have suffered a serious injury in the past, especially for those who suffered spinal injuries. Our original design was to create a suspension that would go on the wheels of the go-kart like in a traditional vehicle, but as previously stated, go-karts don't have a suspension. This is because the frame of the go-kart is designed to be the suspension for the vehicle, which is examined by G. Mirone in his study "Multi-body Elastic Simulation of a Go-Kart: Correlation Between Frame Stiffness and Dynamic Performance". It was due to this fact that design team decided to look at the seat for the focus of our project rather than a suspension itself. The design team started by examining whether making the seat suspended from the frame of the go-kart would be the next best alternative to a traditional suspension, but a quick examination of the regulations for both the United States Pro Kart Series (USPKS) and the National Karting Alliance (NKA) showed that seat had to be mounted to the frame at a minimum of four (4) points. Because of these regulations, it was decided that the easiest way to accomplish the goals of the project would be to create a retrofit of the seat itself rather than try to alter the seat or frame itself.

When deciding on how to design the retrofit, design group consulted multiple studies to determine the best design for the retrofit. The first study that was looked at was "Comparing the Interface Pressure Redistribution of Three Different Types of Cushions: Differences According to Age Groups and Cushion Preferences" by Ji-Su Park and Sang Heon Lee. This study showed the preferred cushion type of people in the 20 years and older range to be an air cushion over memory foam, or honeycomb style cushions. The next study was "A Comparison of the Average Sitting Pressures and Symmetry Indexes between Air-adjustable and Foam Cushions" by Won-Jin Kim and Moonyoung Chang [7]. This study did a comparison of the average sitting pressure and symmetry index of the two types of cushions in the study, finding that air-adjustable cushions have a lower symmetry index than a seat without a cushion, while the foam cushions have a higher symmetry index. Symmetry index is a measurement of the difference in a variable across a line of symmetry. In this study, the variable being examined is the pressure acting on a person sitting in a chair, and the difference is between the left and right side of the person's body. This means that the pressure was more evenly distributed in the air-adjustable cushion than in the seat without a cushion, and the foam cushions. This helped the team to confirm that going with an air pocket design for the retrofit would potentially work. The last study that was considered was "Comparison of the Pressure Redistribution Qualities of Two Air-Filled Wheelchair Cushions for People with Spinal Cord Injuries" by Madeleine Trewartha and Kathy Stiller. This study showed that air cushions that use completely separated air pockets resulted in having more pockets with high pressures than air cushions with interconnected air pockets. This also helped the group to decide on the interconnected air pocket design for the retrofit.

## Patent Research

The design team looked at several patents related to design considerations were US D798,634 S and US 9,775,443 B2. US D798,634 S is a design patent for an interconnected air pocket seat cushion. The only claim made by this patent is "the ornamental design for an air cushion, as shown and described". This claim does not conflict with the project because it only affects seat cushions that match the design shown:

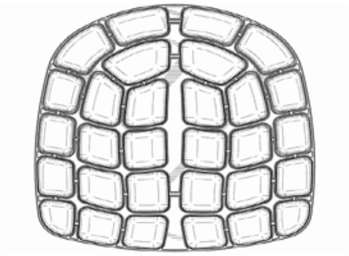


Figure 1. Seat cushion design patent

US 9,775,443 B2 is a patent for a "discontinuous air delivery system for inflatable static medical device" that maintains a preset pressure throughout the entirety of an air mattress using a computer controlled air pump. This patent has 18 claims that are very specific and detailed, but the easiest one that proves that the design team not infringing on this patent is claim 17 which states "The air delivery system of claim 16, wherein the inflatable cushion device is an air mattress…". Since this project is not using an air mattress, they will not be infringing on this patent.

## Problem Definition and Project Goals

Today's go-karts are designed to offer drivers the most raw user experience out of a motorized vehicle at a relatively affordable price. This is achieved by creating a platform that is as lightweight as possible with no suspension. All designs have their tradeoffs, and though it is a lot of fun to drive a go kart, discomfort often occurs after driving one for an extended period of time. While they were not able to find any statistics regarding assessment of the comfort level or any lack of it during or after the ride, a quick internet search will result in hundreds of complaints about the soreness and aching after driving a go-kart, and many complaints of symptoms as severe as stage 1 pressure ulcers.

This senior design project seeks to solve the problem of the driver's back pain while riding a go-kart, and other more severe symptoms such as potential pressure ulcers after driving a go-kart over an average course length of 15 laps. In order to achieve this goal, team initially sought to reduce the amplitude of vibration experienced by the driver by at least 80% further bringing the vibrations into the whole-body vibration dosage described by ISO 2631, shown by the chart in Figure 1.

Another project goal was to keep the go-kart seat legal to use in the professional racing societies, so The United States Professional Karting Society and the National Karting Alliance regulations for seat construction were followed to make sure they do not make the seat illegal by using our retrofit.

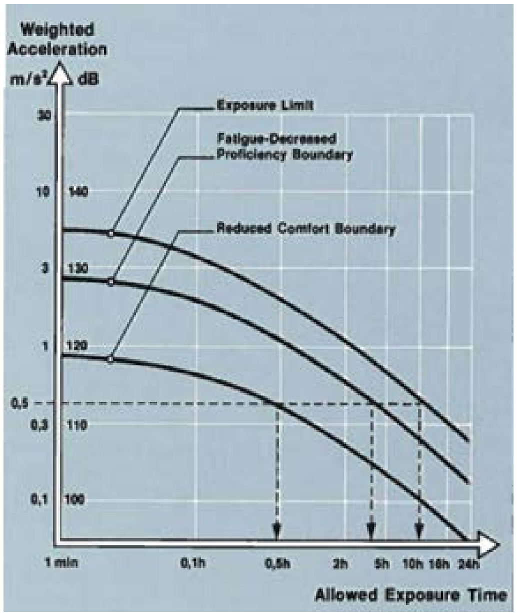


*Figure 1. ISO Dosage Chart. Brüel and Kjær, "Human Vibration" [9].*

**Product Design Specifications**

Problem definition in the engineering design process takes the form of identifying the needs of the customer that a product will satisfy. If the needs are not properly defined, then the design effort may be futile. This is especially true in product design, where considerable time and effort is invested in listening to and analyzing the "voice of the customer." Target specifications are the goals of the senior design team, describing the product that the team believes would succeed in the marketplace. These specifications are refined based on the limitations of the product concept actually selected in the fall and winter quarters.The below table outlines a brief listing of product design specifications which satisfy customer needs for go-kart seat retrofit project.

| Specification Metric | Target Value | Source |
|---|---|---|
| Seat Angle | <30° From Vertical | USPKS/NKA[1][2] |
| Room to Move | None | USPKS/NKA |
| No. Seat Body Pieces | 1 | USPKS/NKA |
| No. Spots Mounted to Frame | ≥4 | USPKS/NKA |
| Adjustable on Track? | No | USPKS/NKA |
| Weighted Vibration Amplitude | 0.5 $m/s^2$ | ISO 2631 |
| Vibration Reduction | 80% | Experimental |

*Table 1. Project Design Specifications*

## Design Limitations and Scope

### Seat Design Using SolidWorks

The team has set out to improve upon a standard (via retrofit comfort packages) instead of trying force a new kart seat standard. With this scope in mind, the plan to action for seat design was much more focused towards development of “comfort pockets” to be added to the seat. Over the course of development thus far, the path taken has evolved. Through extensive research of existing materials and the use of SolidWorks to identify the high load areas of the seat (above), refinement has taken place. Moving into the design stage, the most important aspects were - an easy to use, highly comfortable cushioning insert that is durable and functional. Studies have shown that benefits exist from use of air pockets and hydrogel bladders in such an assembly. According to the project goals the project scope pointed the team in a direction that looks to focus on that criteria. By now a preliminary design is in place, where an interconnected web of air pockets that have a hydrogel coating will be used for optimal results. Data analysis that is to come will move the team forward by identifying ideal sizing and placement of these comfort bladders. The depiction below showcases a standard go kart seat, modeled in SolidWorks undergoing stress testing. The arrows are indicating a load of 200 pounds on the base of the tub to mimic the loading from a driver. Very early on, the highest stress areas can be identified through this simulation - which outlines the rough placement of cushioning. Typically stress regions would only indicate an area that is likely to fail first. Although that is true still for this seat, the stress regions indicate where the seat is mounted which are areas where the seat will be the most rigid - requiring more focus on cushioning. Looking closely shows that upper ribcage and hamstrings are susceptible to the unforgiving sections. As stated before, further analysis with sensors and in general real time feedback will aid in the process of improving the end product.

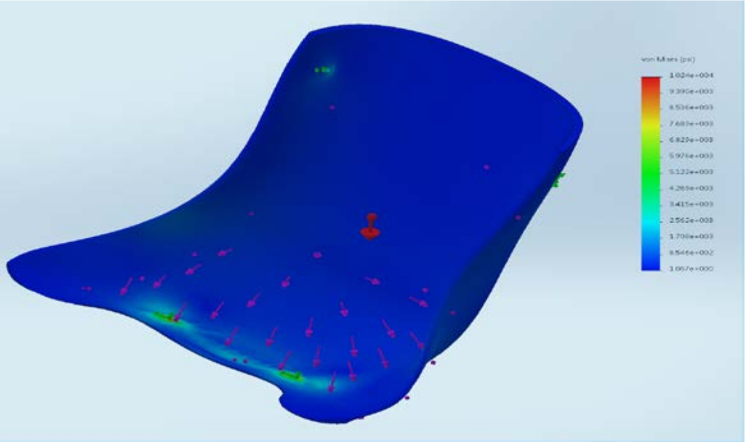


*Figure 2. SolidWorks Load Analysis*

With any platform that aims to add comfort, the true aim is to remove vibrations and or impacts. The team is currently hard at work identifying the best placement and size of the bladders for design, there’s more to improve upon. Since air and hydrogel have different properties and subsequently different reactions to forces, the team has to think of the optimal design to utilize the best qualities of the available materials. A vibration analysis will further identify the desired ratio of materials used to help achieve maximum comfort. Once this information is gathered, the knowledge will be taken into account so a happy medium can be reached since comfort and durability are objectives.

### Design Alternatives

There are other alternative approaches that the design team could take to meet the design requirements in the event that primary design does not produce satisfactory results. This part of the design process is contingent on the findings from test results. A plan to action has already been implemented with the general bladder configuration and composition. To move beyond this point, the team will need to analyze feedback from drivers that use the kart laced with sensors. Moreover, surveys answers utilized to ensure the data is normalized to the wants of the general public. Design alternatives will continually be a part of the developmental refinement, before the product will be "released."

## Prototype Retrofit Fabrication

In order to achieve the project goals, a few different materials were considered to use for damping the vibrations. The team considered using magnets, gel, or air pockets as a material to be used, however were quickly able to eliminate using magnets as a means of vibration damping since it would require altering the seat outside of the professional karting seat regulations. For the next two material choices, they conducted research into which materials were considered the most comfortable to sit on, since the main focus early on was increasing comfort over reducing vibration. A study by Ji-Su Park and Sang-Heon Lee [3] examining the comfort preferences of different cushion materials across 4 different age/gender groups showed that both men and women in their 20's to 50's preferred an air cushion to sit on over a honeycomb and a memory foam cushion. A study by Madeleine Trewartha and Kathy Stiller [5] showed that connected air pockets have a more even distribution of pressure than separate air pockets, which was shown to be beneficial for spinal injuries. Finally, a study by Won-Jin Kim and Moonyoung Chang [7] showed that air pocket cushions showed a lower symmetry index than both a bare seat and a memory foam seat cushion, which supports a symmetrical sitting position. Therefore the optimal solution was to design a seat cushion that was comprised of interconnected air pockets. First selection for the air pocket material was a polyurethane coated nylon fabric because it was affordable and supposedly air tight. Upon doing air tightness testing on the material, it was determined that it did hold air well when sealed properly, but still leaked too much air out to be usable for an air pocket material. The next tried material was to coat the fabric in FlexSeal to make the material airtight. This solution made the material air tight. Once determining they had an airtight material, initial design for the pockets were produced. They had a couple concepts early on as to how to design the pockets. The two main ones were to have the seat fully covered by a network of pockets and to provide a minimal network of pockets to support the driver. Due to limited space available to work with in the seat, it was decided that the minimal network would be best. The pockets were initially designed to be made separately and connected to each other pocket via a plastic tube such that the pockets filled the air gaps normally present between the driver's body and the seat. This design presented a new problem to get air pockets to properly seal around the inlet valve and connecting tubes. Due to this complication, a new alternate material was used for the air pockets. The new material selected was flexible polyvinyl chloride (PVC). This is the material that is used in making air mattresses. The final design kept the same shape for the pockets, but made all of the pockets out of one continuous piece of material instead of separate pieces for each pocket. This design eliminated the need to try and seal multiple openings between pockets, and made it so they only had to worry about sealing the top and bottom pieces together, and the air inlet valve. Figure 3 shows the final design of the air pockets.

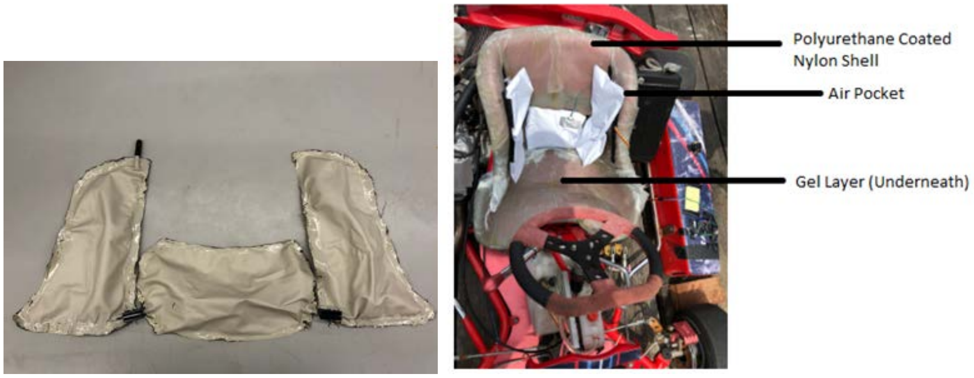


*Figure 3. Air pocket design (left) Retrofit testing setup (right)*

In addition to the air pockets, a layer of semi-liquid polymer gel was used to coat the whole seat. This allowed to always have a vibration damping material between the driver's body and the seat surface. They used polyurethane coated nylon fabric to create a shell to house the gel layer, and mount the air pockets.

For testing purposes, the team had to use premade separate air pockets due to trouble creating airtight pockets of our own design, however, if they had access to a method of professionally making air pockets, this would not have been an issue. Figure 3 shows the testing set up used.

**Prototype Testing**

The design team developed testing procedures directly from Section 5 of ISO 2631 [10], the Vibration Measurement section of the standard. Section 5.3 of ISO 2631 describes where the accelerometer should be located at the "principal area of contact between the body and the vibrating surface". This principal area of contact was on the seat back, approximately halfway up the seat back, slightly left of center (facing the front of the kart). Figure 4 shows the location of the accelerometer on retrofit. The accelerometer was placed in the equivalent location on the seat for baseline testing (no retrofit). For a location, the team used the street where one of the team members lives to drive the kart since it had low traffic, a smooth surface (no bumps or potholes), and was easy to access. Team used micro SD cards to log the data recorded by our sensors by programing an arduino to read the data from the sensor and then write that data into a data file on the SD card. This allowed them to use a wireless form of data collection that did not depend on maintaining a wireless signal. To collect force distribution data, they attached FSR sensors to the seat as shown in Figure 4.

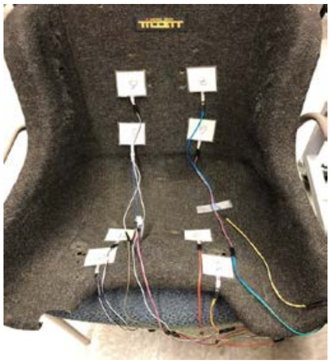


*Figure 4. FSR sensor placement*

Once the sensors were set up, they tested functionality of each sensor by running the program while connected to a computer, pulling up the serial monitor, and applying a force to each sensor and checking for an appropriate response. After ensuring that each sensor was working, they had the driver sit in the seat. Once the driver settleed in the seat, they rechecked all connections. After connections were determined to be good, a timer was set for one minute, and connected power to the arduino. The data were recorded at a speed of 1 Hz. After recording the force distribution of the bare seat, the retrofit was installed.

**Results**

Figures 5 below are representative of the acceleration data for our baseline and retrofit runs respectively. These waveform graphs are in the time domain and measure acceleration in units of milli g's.

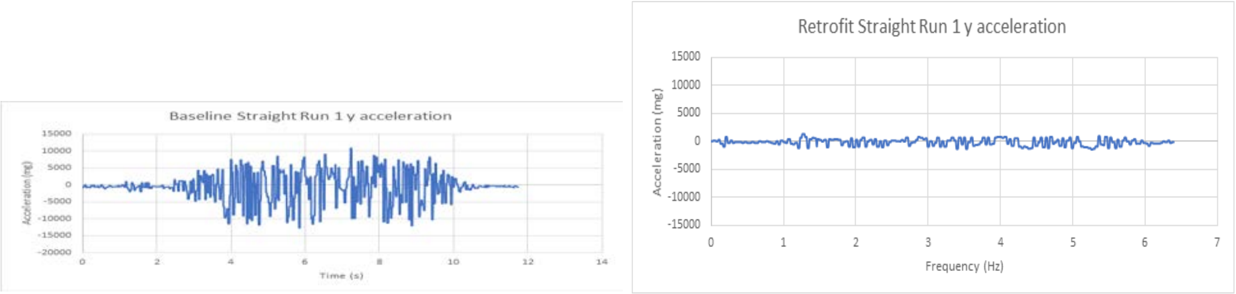


*Figure 5. Baseline acceleration waveform (left), Retrofit acceleration waveform (right) (time domain)*

Figures 6 below are representative of the acceleration data transformed using a Fast Fourier Transform (FFT) for the baseline and retrofit runs respectively. These waveform graphs are in the frequency domain and measure acceleration in units of milli g's. The FFT algorithm finds the component signals that make up the overall signal observed in the waveform graphs depicted in Figures 6.

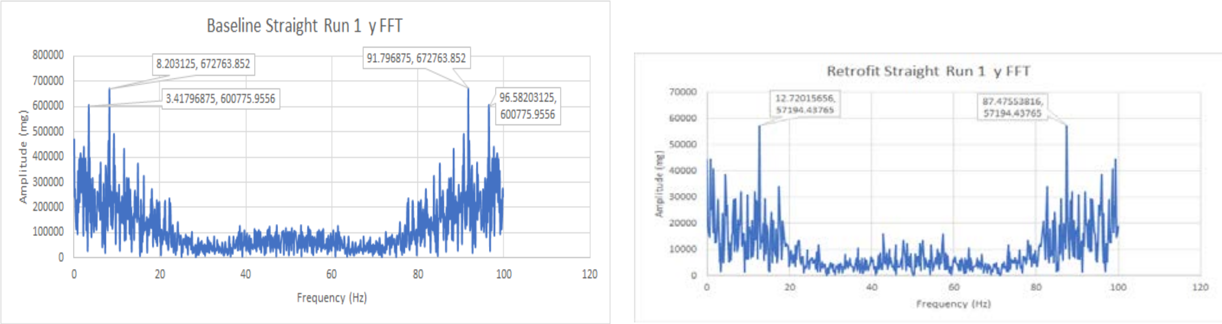
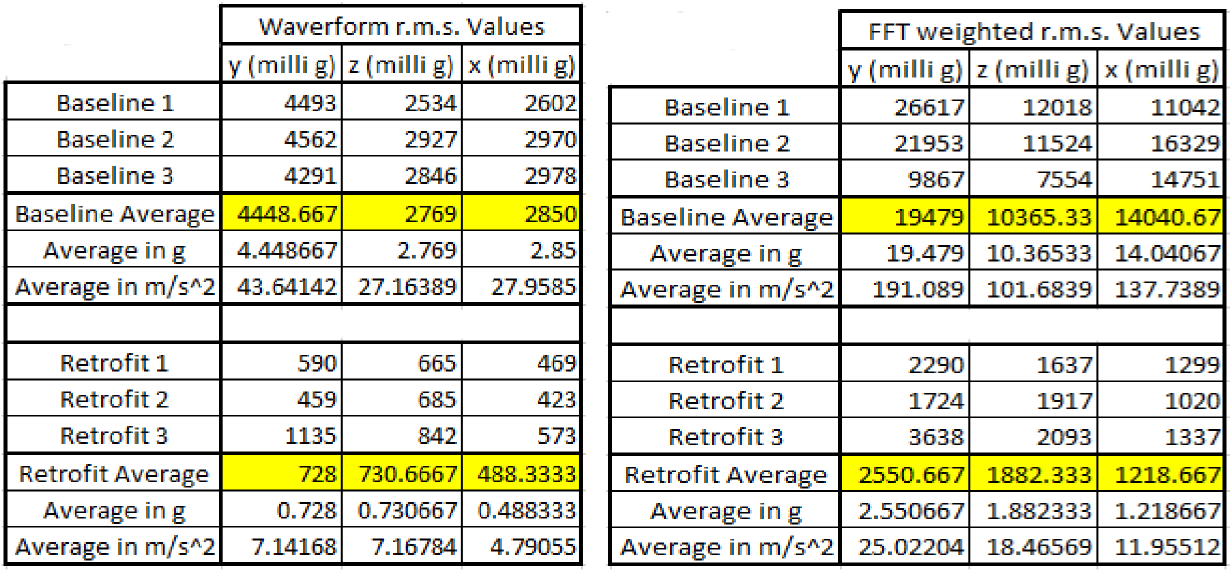


*Figure 6. Baseline acceleration FFT (left), Retrofit acceleration FFT (right) (frequency domain)*

Tables 3 and 4 below show the root mean square (r.m.s.) values for the time domain signals and frequency domain signals respectively. The r.m.s. value is calculated using the following equation:

$$r.m.s. = \sqrt{\frac{1}{n}\sum a^2}$$

The r.m.s. values show the overall power of the observed signal, which is the best way to determine the effect the acceleration has on the body according to ISO 2631 [10].



| | Waverform r.m.s. Values | | |
|---|---|---|---|
| | y (milli g) | z (milli g) | x (milli g) |
| Baseline 1 | 4493 | 2534 | 2602 |
| Baseline 2 | 4562 | 2927 | 2970 |
| Baseline 3 | 4291 | 2846 | 2978 |
| Baseline Average | 4448.667 | 2769 | 2850 |
| Average in g | 4.448667 | 2.769 | 2.85 |
| Average in m/s^2 | 43.64142 | 27.16389 | 27.9585 |
| | | | |
| Retrofit 1 | 590 | 665 | 469 |
| Retrofit 2 | 459 | 685 | 423 |
| Retrofit 3 | 1135 | 842 | 573 |
| Retrofit Average | 728 | 730.6667 | 488.3333 |
| Average in g | 0.728 | 0.730667 | 0.488333 |
| Average in m/s^2 | 7.14168 | 7.16784 | 4.79055 |

| | FFT weighted r.m.s. Values | | |
|---|---|---|---|
| | y (milli g) | z (milli g) | x (milli g) |
| Baseline 1 | 26617 | 12018 | 11042 |
| Baseline 2 | 21953 | 11524 | 16329 |
| Baseline 3 | 9867 | 7554 | 14751 |
| Baseline Average | 19479 | 10365.33 | 14040.67 |
| Average in g | 19.479 | 10.36533 | 14.04067 |
| Average in m/s^2 | 191.089 | 101.6839 | 137.7389 |
| | | | |
| Retrofit 1 | 2290 | 1637 | 1299 |
| Retrofit 2 | 1724 | 1917 | 1020 |
| Retrofit 3 | 3638 | 2093 | 1337 |
| Retrofit Average | 2550.667 | 1882.333 | 1218.667 |
| Average in g | 2.550667 | 1.882333 | 1.218667 |
| Average in m/s^2 | 25.02204 | 18.46569 | 11.95512 |

*Table 2. Waveform r.m.s. values (left), FFT r.m.s. Values (right)*

Table 3 shows the overall observed symmetry index (SI) of the seat with and without the retrofit installed. The values shown are the averages of all observed SI's from the sensor pairs installed on the seat for measuring the force distribution.

| Baseline Symmetry Index | Retrofit Baseline Index |
|---|---|
| 109.50% | 63.30% |

*Table 3. Symmetry Index Values*

Tables 2 and 3 show the significant decrease in level of vibration experienced by driver. Table 2 shows an 83.6% decrease in r.m.s. value in the y direction, a 73.6% decrease in the z direction, and an 82.9% decrease in the x direction. This shows the observable improvement made by using the retrofit in the go-kart seat. Design team also consulted test drivers after driving the go-kart without the retrofit and again after driving the kart with the retrofit in. Both test drivers described a significant improvement in the comfort of driving the go-kart. Without the retrofit in the kart, our drivers were already noticing pain in their backs just from sitting in the kart while it was idle, describing the sensation as "getting stung by a thousand bees", and would require breaks between test runs because of the discomfort. With the retrofit in the go-kart, our test drivers were able to sit in the kart and go through all of the testing without having to take a break or complain of discomfort at all.

**Economic Analysis**

Design team's 5-Year economic analysis has changed from the original estimate. The biggest change was the addition of labor, rent, and outsourcing, which was not included in the original estimate. They also changed selling price from $350 to $600 to account for these additional cost. The amount of production and sales also increased due to more in depth research of local go-karting facilities and buyers in the area. Through research they were able to make a more precise estimate. The total sales after 4 years changed from 530 units to 900 units. Due to our decrease in production cost and increase in sales and selling price, the net worth after 5 years significantly increased.

| Bill of Materials | |
|---|---|
| Material | Description |
| Polyurethane Coated Nylon Fabric | Provides base material used for forming retrofit and pockets |
| Magnatec Adhesive | Bonding agent used to create prototype |
| FlexSeal | Rubber sealing agent used to create air tight connections |
| Flexible Hose | Plastic hosing used to create connecting links between pockets |
| Schrader Valve | Check valve used to allow air into the retrofit. Same valve used for inner tubes |
| Fiberglass cloth | Cloth used to create a set form for the retrofit |
| Fiberglass Resin | Bonding agent used to set the form of the retrofit and bond nylon fabric to fiberglass cloth |
| Extra Large Tillett Go Kart Seat | Seat being used in test procedures |
| Flexible Polyvinyl Chloride | Material used to create bladders for air pockets. |

*Table 4 - Breakdown of costs associated to the prototype and the entire project*

**Assessment and Student Outcomes:**

Oral presentations and written reports during the senior capstone course series are evaluated by department faculty and qualified external engineering professionals according to the Likert-type scale. External assessors are from regional industry located in the Greater Philadelphia area and generally serve as members of Industry Advisory Committee for the Engineering Technology program. Each assessor assigns a value for Performance Indicators according to a Likert-type scale for each ABET 1-5 student outcome. Engineering Technology program recently adopted new ABET 1-5 outcomes, therefore trend data is provided in these newly adopted student outcomes. The scale (rubric) indicates the following three levels: Exceeds, Meets, and Minimally Meets (these values may be interpolated resulting in a 5-level scale). These results are used to produce an average assessment of a student team's oral and written presentation. Overall assessment scores are provided in Figure 7 for fall, winter and spring quarters indicates that the senior design team attained ABET student learning outcomes in each assessed category. In addition to assessment by internal and external assessors, advisor of the project assigns scores for individual student performance (not shown in Figure 7).

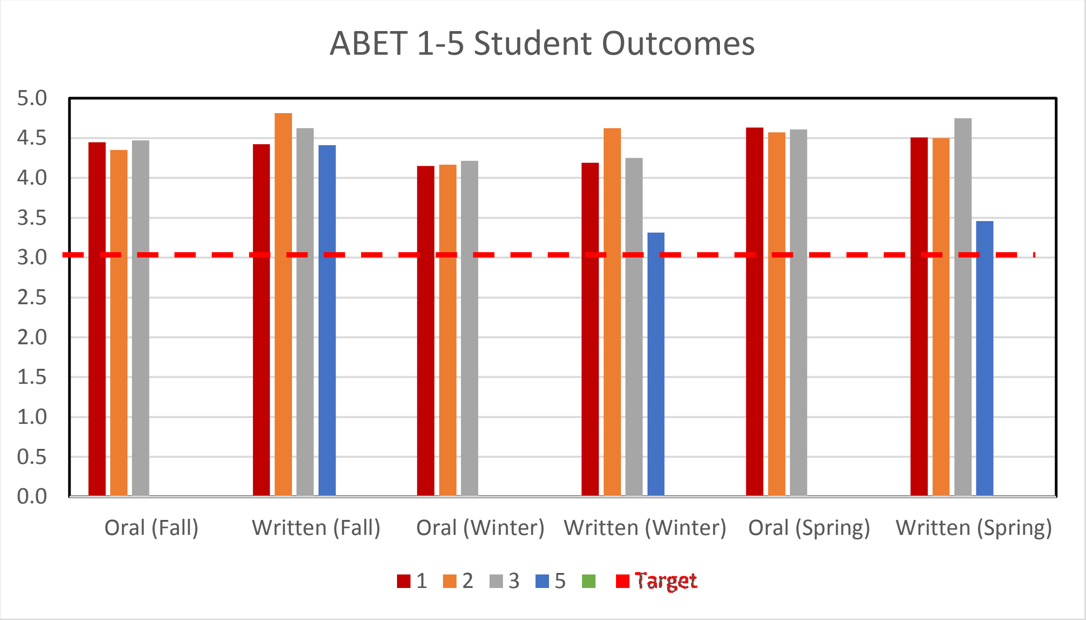


*Figure 7. ABET assessment for retrofit go-kart senior design team during Fall, Winter and Spring 2017-18 AY.*

## Conclusion

Overall, the r.m.s. values of the acceleration in the time domain were reduced from 4448.67 milli g's to 728 milli g's in the y direction, 2769 milli g's to 730.67 milli g's in the z direction, and 2850 milli g's to 483.33 milli g's in the x direction. The weighted r.m.s. values in the frequency domain were reduced from 19479 milli g's to 2550.67 milli g's in the y direction, 10635.33 milli g's to 1882.33 milli g's in the z direction, and 14040.67 milli g's in the x direction. They also reduced the symmetry index of the seat from 109% to 63%. The senior design team was able to create the retrofit for a unit cost of $93.15 with plans to sell each unit at a cost of $600. The total cost of the project was $5209.72, with a majority of the cost coming from purchasing the go-kart ($3700). In conclusion, they created a retrofit for a go-kart seat that reduces the vibration experienced by the driver by an average of 83%, and was noted by the test drivers to make the drive considerably more comfortable. This paper has documented the complete process it entailed to reach the end goal of creating a retrofit go-kart seat.

## Acknowledgement

The authors would like to thank senior design students Nathaniel Frey, Stuart Collymore, Andrew Chi, and Thomas Hays who took keen interest on this subject and successfully accomplished the project goals. This senior design project was partially supported by Drexel University's Botstiber Senior Design Entrepreneurship Competition.

## Bibliography

[1] “USPKS 2017 Rule Book." Uspks.com. July 20, 2017. Accessed October 2, 2017. http://uspks.com/documents/2017/03/2017-uspks-rulebook.pdf

[2] "NKA 2014 TrakBOOK." Nkaonline. Accessed October 2, 2017. http://www.nkaonline.com/wp-content/uploads/2014/02/TrakBOOK-2014_web-version.pdf

[3] Park, Ji-Su, and Sang-Heon Lee. "Comparing the interface pressure redistribution of

[4] Three different types of cushions: differences according to age groups and cushion preferences." Journal of Physical Therapy Science 29, no. 1 (2017): 57-63. Accessed October 17, 2017. doi:10.1589/jpts.29.57.

[5] Trewartha, Madeleine, and Kathy Stiller. "Comparison of the pressure redistribution

[6] Qualities of two air-filled wheelchair cushions for people with spinal cord injuries." Australian Occupational Therapy Journal 58, no. 4 (2011): 287-92. Accessed October 20, 2017. doi:10.1111/j.1440-1630.2011.00932.x.

[7] Kim, Won-Jin, and Moonyoung Chang. "A Comparison of the Average Sitting Pressures and Symmetry Indexes between Air-adjustable and Foam Cushions." Journal of Physical Therapy Science 25, no. 9 (2013): 1185-187. Accessed October 5, 2017. doi:10.1589/jpts.25.1185.

[8] "FlexiForce Standard Model A502." Tekscan.com. Accessed October 20, 2017. https://www.tekscan.com/support/faqs/flexiforce-user-manual.

[9] Brüel and Kjær. “Human Vibration”. Denmark. K. Larson and Son A/S, 1989. Brüel and Kjær. PDF.

[10] “ISO 2631: Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration”. International Organization for Standardization, 1997. International Organization for Standardization, 2004. PDF.

[11] “Gravity: I2C Triple Axis Accelerometer - LIS2DH SKU:SEN0224”. DFRobot, 2018. PDF.