Photo Courtesy of Hank Wolff, 2022

Steering System and Anti Roll Bar Implementation

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2022 Formula FSAE

Capstone II: Technical Report

YC Racing

York College of Pennsylvania

Department of Mechanical Engineering

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Introduction: Throughout the Summer of the 2021 Semester, the York College of PA Formula SAE team designed and researched our respective components. Now in the Spring of 2022, it was time to turn our design ideas into reality and manufacture our race car. Most of the team was anxious to get our hands dirty and start building our car. Our team entered the semester behind in some areas, but ahead in others. Being a part of the suspension team, most of our milestones were early in the semester (first half). The following report should give the reader a considerable number of details on how the steering and anti-roll bar systems were manufactured, altered, and implemented into the 2022 YCP Formula SAE car.

Ordering Parts and Assessing Needs

The first item that I wanted to take care of was inventorying everything that needed to be purchased. I knew that getting ahead on this was imperative, and I would recommend future teams do the same. Shipping always takes longer than expected, especially if you are ordering from vendors other than McMaster-Carr. All I did was simply use my bill of materials from the summer semester. See Table 1 below. I had several important parts that were chewed up, or just not useable anymore. Notable items that had to be purchased were spline inserts, and a welded quick disconnect insert. I used the table below as a reference to ensure I had all the parts I needed to manufacture and assemble the steering and anti-roll bar.

Table 1: Bill of Materials for Steering System, Items highlighted in yellow needed to be purchased in 2022

Product	Vendor	Part #	Price	QTY	Description	Notes
Steering Wheel	Pegasus Auto	3406-Blac	$174.99	1	Steering Wheel	
Steering wheel Quick connect + spline	Speedway Mtrs		$89.99	1	New quick connect	
Steering Column Tubing 0.750 OD	McMaster Carr	7767T32	$6.43	1	Welded attachments to column	
Spline Attachments Steering Column	KAZ Tech	-	$11.00	1	Splined Inserts (3/4"-20)	
U Joints	KAZ Tech	-	$103.50	2	U joints	
Steering Rack	KAZ Tech	-	$670.00	1	Steering Rack Previously owned	
Steering Coupler	KAZ Tech	-	$35.00	1	New coupler to connect rack to column	
Column Mount Bearings	McMaster Carr	5905K26	$6.94	2	Used in the frame to secure the column	
Spline Shaft for U joints	?	?	?	1		
0.5"-0.035" 4130 Chromoly Round Hollow Tube	Stock Car Steel	41	$7.20	2	Tie rod Raw Material	Noah Purchased
10-24 1.125" Shoulder Bolt	McMaster Carr	91259A509	$3.39	2	Misc Hardware for Tie Rods	Noah Purchased
10-24 0.875" Shoulder Bolt	McMaster Carr	91259A541	$3.08	2	Misc Hardware for Tie Rods	Noah Purchased
M6 25mm Shoulder bolt	McMaster Carr	92981A204	$1.62	8	Misc Hardware for Tie Rods	Noah Purchased
Right Hand Ball Joint Rod End	McMaster Carr	60645K821	$4.81	2	For tie Rod ends	Noah Purchased
Left Hand Ball Joint Rod End	McMaster Carr	60645K822	$4.81	2	For tie Rod ends	Noah Purchased

Another necessity that was noted when taking an inventory was the condition of the KAZ technologies steering rack we have. Considering it’s about $700, we want it to last several years. The condition that I found the steering in was not good condition, especially the spline that outputs to the steering column. See Figure 1 for a photo of what the chewed-up spline looked like. I had a contact at KAZ technologies from the summer semester and was able to reach out for support. We were able to purchase just a new pinion and spline piece. See the steering section for more

information.

Figure 1: Old Pinion from KAZ Tech. Steering Rack vs New Rack, Note splines

Figure 2: New Pinion Gear, Note the splines not being chewed up, steel

Control Arm Inserts Manufacturing

One of the most significant custom components we needed for the suspension team were the custom rod end inserts. A small part, Noah Dekker let me know we needed 50 of these. 25 left-hand threaded, 25 right-hand threaded. Noah Dekker oversaw manufacturing of all the control arms, tie rods, front and rear shock mounts and bell cranks. They were made from Ø0.5” in round stock steel. Dr. Kiefer and Noah developed the g-code to be used on one of the HAAS CNC lathes located in the back end of the shop. In this case I acted like the machinist and took on manufacturing all of these for the suspension components. The g-code was developed to streamline the process as much as possible, which was as follows. First the 0.5” round stock was

inserted into the lathe and tightened down. Then used a center drill to drill out a small hole for the drill bit to start. Then using a letter, **I** size drill bit, drilled out the round stock as far as I could go. Once the hole was drilled, I would back the tail stock up, and using either a left hand or right-hand tap, I would manually thread the rod end by turning the chuck with my hands. Here the program could begin, the start button was pressed, and the code was initiated; the first step was to bring the right-hand turning tool up to 0.75" away from the chuck. Which is also the length of the rod ends. Once the tool was in place; the code had a pause command. I would then loosen the chuck and bring the round stock up to the tool. From here I would let the code run. It would take 2 facing passes, which turned the Ø0.5" down to Ø0.420". It would then change the tool to a parting tool, and part the rod off the material. Typically, out of one hole drill, I could make two rod ends. So, after one was completed, I would tap the hole again, and allow the process to be repeated. Typically, I was running at 25% rapid, and when I got comfortable with the g-code I would allow it to go to 50% rapid. The run time of rod end was 2 minutes 30 seconds. When you include tapping and drilling the holes the time doubles. Note this doesn't include set-up or clean up time.

Once the rod ends were made, I would typically have to grind off the chip that was left from the parting tool and the threads. This consisted of taking a pair of locking clamps and putting them up against the belt sander and grinding this burr away. In some cases, tapping the rod end again was necessary. After they were made, I handed them off to Noah Dekker to be welded in our control arms, tie rods, and push rods.

Design of Tabs

Steering Tabs: Something most of us did not consider during the summer semester was *how* we were going to mount our components to the car. Designing tabs for my components was necessary and it was one of the first things I wanted to accomplish during the semester. Since both components I was in charge of were critical components, I needed to make the tabs sturdy and well fitting. Especially for steering. Since the frame was the first item being manufactured in the spring semester, I needed to make my tabs around what was already built. On the lower portion of the frame, there is a cross member that goes diagonal from one corner to the other. See below. This eliminates the possibility of having two equal tabs. The first constraint that I have in

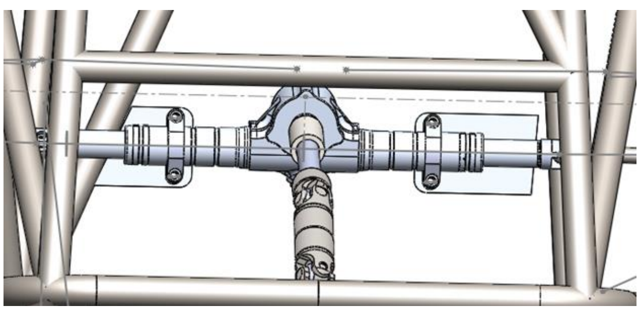


Figure 4: CAD Model of Tab Design using Iterative Process. 1st Iteration, Note the right tab is not properly fitted

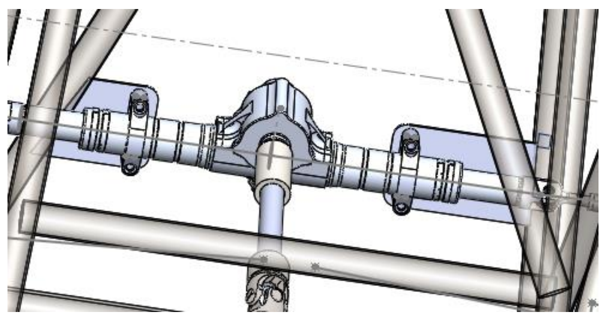


Figure 3: CAD Model of Tab design, final tab design where both tabs are properly fitted

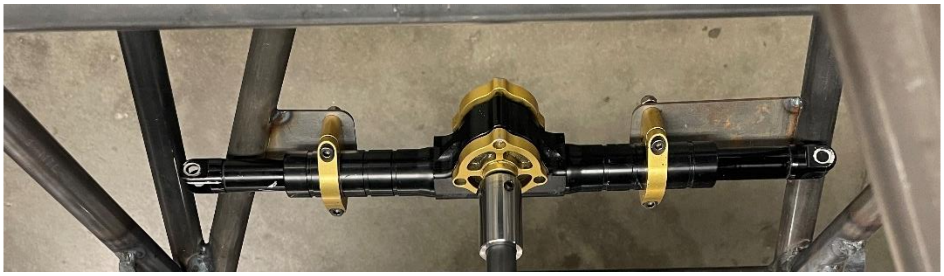


Figure 5: KAZ Technologies Steering rack mounted into frame, Top view

terms of steering tabs are the two collars that hold the rack to the tabs I will design. Using a combination of measuring the 3-D model and measuring the components in real life, I came up with the dimensions seen in Figure 6. This may be useful to future teams if they decide to also use the KAZ steering rack.

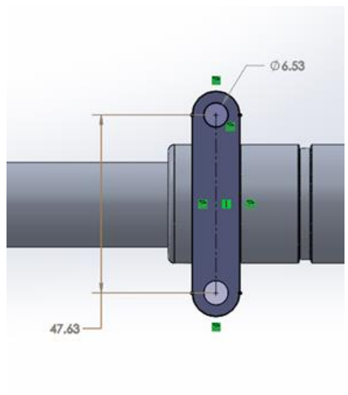


Figure 6: Dimensions of KAZ Tech. Steering Rack mount, Hole Locations and Size

Now I knew the correct hole pattern and sizes, I could begin finding the location of the tabs. Noah and I had already determined the location of the tie rods, and steering rack during the summer semester, see my Summer 2021 tech report for more about that. However, the steering rack was located 5.468 in center to center, in front of the lower member on the front roll hoop.

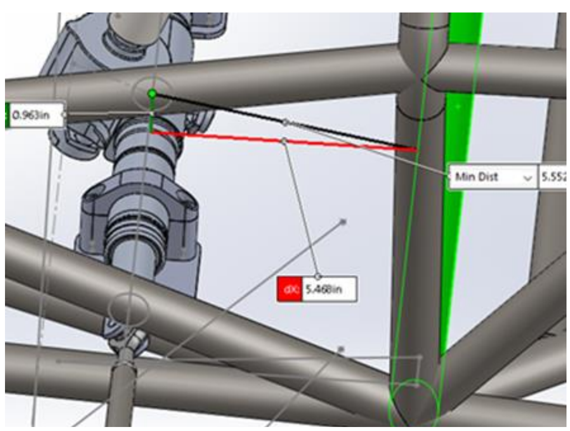


Figure 7: Distance from Center of KAZ Rack, to center of bottom member of the front roll hoop, 5.468in

See Figure 7 above. Using the same method, the height of the steering rack to the bottom of the frame is 1.550” in. From here I opened a CAD model, and placed the rack at this exact location, and started designing tabs around this. I used the iterative design process, I would make a tab I think would fit, go back to the assembly model and check, and then repeat the process until I ended up with tabs that fit almost perfectly. I made them 0.25” in oversized so that I could grind down a face if I needed too. Which ended up being the case.

Once the design was finalized, I created a .dxf file, and the two tabs were cut on the waterjet. The material was plain carbon steel, with a thickness of 0.125” in. Once they were cut out, I had to grind them down to fit well. However, the hole locations worked perfectly.

Figure 8: KAZ Steering rack with Tabs, 0.125" Thck, Plain Carbon Steel

Mounting Steering Tabs: The tabs were now created and could be welded to the frame. I ended up creating two risers out of square tubing, so that the rack would sit at the correct height when welded in the frame. I used a tape measure from the front member of the roll hoop, so the location was correct. Once we ensured that it was parallel to the front roll hoop, the two tabs were tacked in. In this case it was helpful to actually have the steering rack fastened securely to

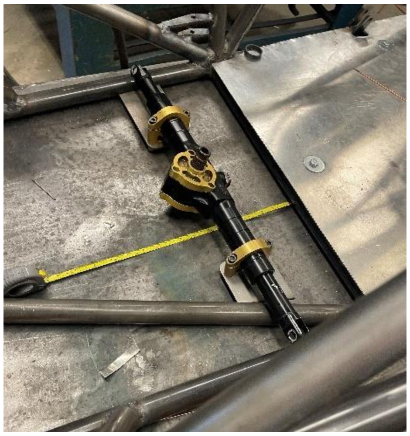


Figure 9: Steering rack location before being tacked into place, using a tape measure to ensure the location is correct

the tabs, so up the spacing between them doesn't move. Once it was tacked in place, we removed the rack and welding was completed.

Anti-Roll Bar Tabs: The ARB tabs were a bit more straightforward, since they aren't supporting a significant load like the steering rack, and we needed it to be as out of the way as possible. The location we determined to for it to sit right underneath the front envelope, hidden away under the nose cone. Similar to what I did for the steering, I used the iterative design process to design these tabs as well. I also had to find a method of mounting the ARB. I know in the automotive industry rubber bushings are used to mount the ARB in place. Since it acts as a torsion bar, you want its location in the X-Y plane to be fixed so it can rotate properly. I am using these rubber bushing mounts I happened to find on McMaster Carr. I was using a 0.375" OD rod so these would work perfectly. See figure 9 below.

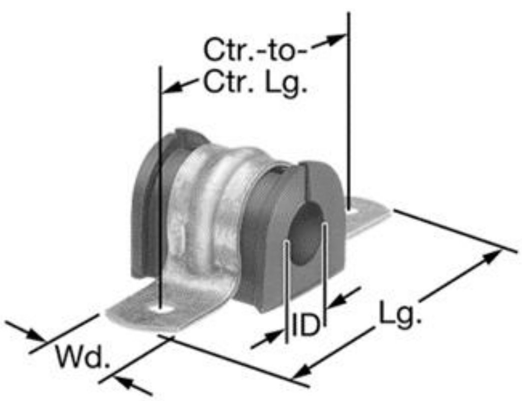


Figure 10: Rubber bushing, with a 3/8 in hole that would hold the Anti Roll Bar in place

I had two identical tabs cut out to go on the top portion of the frame. However, a similar problem occurred to the one I had with steering; there was a cross member that made it difficult for one of the tabs to fit. So, I had to make another odd shaped tab that would accommodate the cross

Figure 11: 0.125" Thck, Steel Tab used to hold up the Anti Roll bar. This tab was modified to fit the awkward frame member

member and still allow the torsion bar to fit underneath securely. See the figure below. Small spacers that are about 0.375” in long were needed so that the tabs could be properly welded, and the bar could still go underneath of the top frame members.

Steering

The steering assembly is a critical system, this is one of the drivers only connections to the entire car. Its what they feel and receive feedback on. This was important to me to get it right. My goal, as stated in my Summer 2021 technical report was to minimize the total amount of slop in the steering. Doing so would allow for the best possible experience for each of the drivers.

Before I dive into the details about manufacturing the steering column, the location of the wheel is just as important as anything else. This is something our team struggled to nail correctly, mostly decided by the frame team, our cockpit is small, no fault to them. With the firewall and seat pan, it leaves little room for the drivers, and the steering wheel sits low in the cockpit. Before anything was installed, I had to solve this problem. Our options were as follows

1. Add a small section to the front roll hoop, then move the steering wheel up
2. Push the steering wheel in as much as possible
3. Buy a smaller steering wheel

As a team we decided to move the steering in as far as possible. Adding another roll hoop would have only gained us 1.5” in more of vertical clearance from the bottom floor. We decided this was not worth all the extra work. This moved the location of the steering from the driver’s stomach to more towards over their legs. The effects it would have had on me were to shorten the steering column bars, and have my u-joints be at steeper angles. Although it sounds insignificant, a large increase in the u-joint angle would have binded our u-joints. A suggestion for future teams would be to make the front roll hoop curved instead of a flat bar, it gives you more room on the steering wheel and for the dashboard. Another solution would be to have the cockpit extended as much as possible. I.e the distance between the front and back roll hoops. Accounting for these two things in the summer semester would allow more team members to comfortably drive in the car. This is really unfortunate to the drivers who are bit taller and larger, and it makes it near impossible to fit comfortably and turn the wheel effectively. I would recommend you refer to Jake McGraths, and Ben Kelly’s tech reports. They were responsible for ergonomics/cockpit and frame, respectively.

Manufacturing

Once the steering column issue was resolved, it was welded in place. the bearings needed to be pressed into the column. After reading previous teams tech report about this, they recommended that you weld everything into place, then press the bearings in. Not the other way around, as introducing heat to bearings binds them up. We froze the bearings, and used a c-clamp and a metal plate on the other side to press them in. however the inside diameter of the bearings shrunk once they were pressed in.

Figure 12: Steering Column Mount, with 1" OD Bearing, 0.750" ID

In terms of overall manufacturing, the steering connection points were welded, if possible. This was done on purpose to mitigate the possibility of slop and free play. See my summer technical report for more on the design. I had 2 spline inserts to weld, a quick disconnect, and an adapter for the steering rack. To weld, we stood up the column bit and inserted the spline vertically. Both of the spline inserts were made to fit 0.750" in OD tubing, so fitment was not an issue. Once I had the upper and lower steering columns cut out on the vertical bandsaw, we were ready to weld. See the photos below of the welded lower assembly vs the upper assembly.

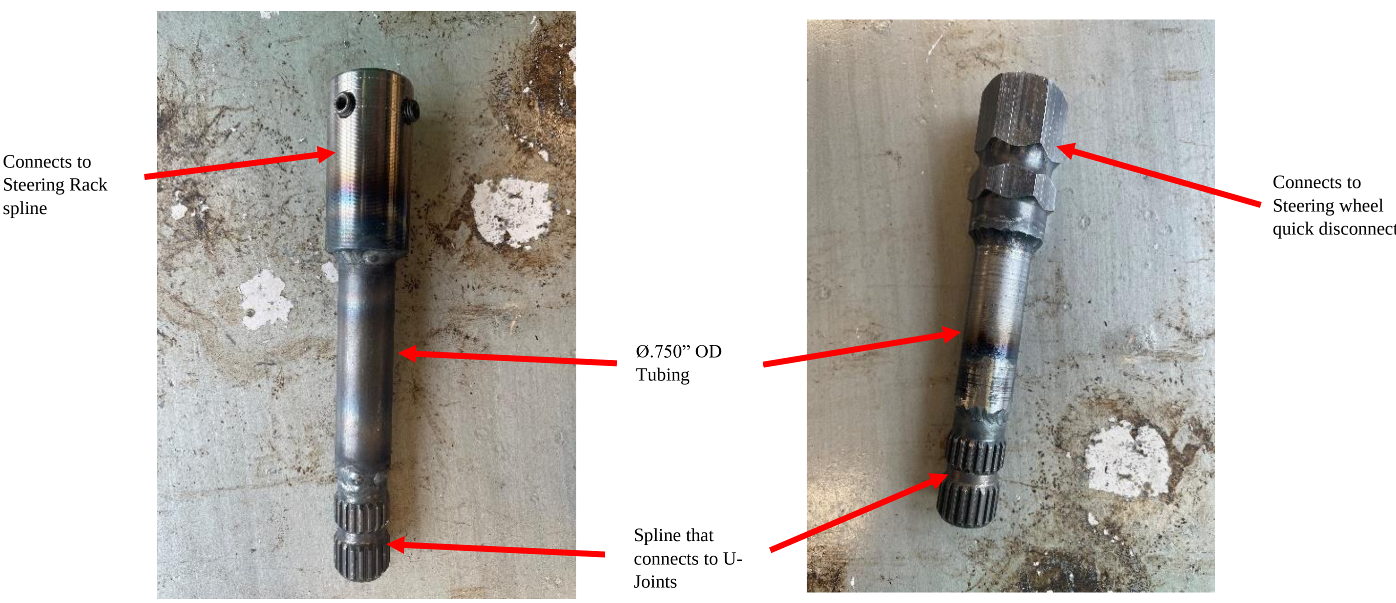


Figure 14: Lower steering column assembly, Steel, Lower piece fits into KAZ Tech Rack

Figure 14: Upper steering column assembly, Steel

Steering Assembly

Once the components were welded, it was time to assemble everything into the car. The upper column weld assembly max diameter is 0.750” so it just fits through the column mount bearings. I did have to turn down the face of the upper assembly about 0.005” so it would slide through the bearings. Otherwise, there are 2 good ways to assemble and disassemble the steering. First method is to take off the steering wheel and undo the set screws for the u-joint directly behind the steering column mount. It should be easy to slide the upper welded assembly through the column towards the driver. In some cases I used a wrench to pry it a bit if the splines get stuck. From here you hold the U-joint up and disassemble the rest. Just un-doing the set screws on each of the components one at time and sliding the components apart. The rack is bolted down with regular machine screws and lock nuts, so you will need a 3/8” wrench and a 1/8” Allen key. The second method to disassemble the steering would be the take the steering rack off, like described above, and undo the set screws on the u-joints from the bottom up. Both methods require a similar amount of work. I designed it to be accessibly and have the ability to disassemble, something last year’s car didn’t have.

Figure 15: Fully Disassembled Steering System (Excluding KAZ Steering Rack)

The tie rods were made from the same steel tubing that the control arms were made from 0.5"-0.035" 4130 Chromoly I had to cut these to length (12.25” in) then Noah welded the inserts in. The hardware used to secure the tie rods was typical to what is used throughout the rest of the suspension. See Noah Dekker’s Tech Report for more information.

Steering Issues and Resolutions

Once everything was assembled into the car, I had to work through some minor issues. The first issue I recognized was that the rack was off center by about a half an inch. This was visible when looking down the centerline. See the photos below. It was a simple fix, the clamps that hold the rack down have slits to fit onto the rack housing. For some reason these slits are on the end face of the part.

Figure 16: Off center steering rack after the rack was initially installed in the car

Figure 17: Looking straight down the center, after resolving the off center steering column

The holes in the end clevises for the KAZ Tech rack are a bit too wide after a few years of use. Noah and I 3-D printed some small spacers to minimize the gap and allow the shoulder bolts to tightly fit in the allotted holes. Ironically KAZ Tech sent us a new steering rack mistakenly. I would recommend using this steering rack and the end links.

Anti-Roll Bar

The 2021 Formula SAE Team implemented an Anti-Roll Bar (ARB), however not much data was provided, and they were not able to take their car to competition and gain valuable insight as to whether these were worthy implementations.

My goal was to implement an ARB and allow our team to evaluate it, so we have good data that we can provide to next years teams on information such as stiffness, length and overall driving improvements.

Design Changes

I originally had a slightly different design in the summer semester. However, throughout the fall and the beginning of the spring semester, I realized shortcomings in the design. The idea of one long slot cut out in the ARB worried me. I believed that using one long slot instead of holes would have allowed the end linkage to slide back and forth. The first change I made was to get rid of the slot and implement 4 evenly spaced holes instead. Another design change was the outside dimensions. I had found a billet of 1.25” in thick aluminum in the shop. So rather than buy new aluminum and wait around for it, I decided to use what we have and slightly alter the design. Originally it was supposed to be 1” in thick, I increased the thickness by a quarter inch to use the billet of Al.

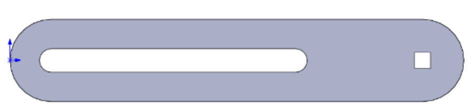


Figure 18: Previous design of ARB with Slot cutout in center, Aluminum

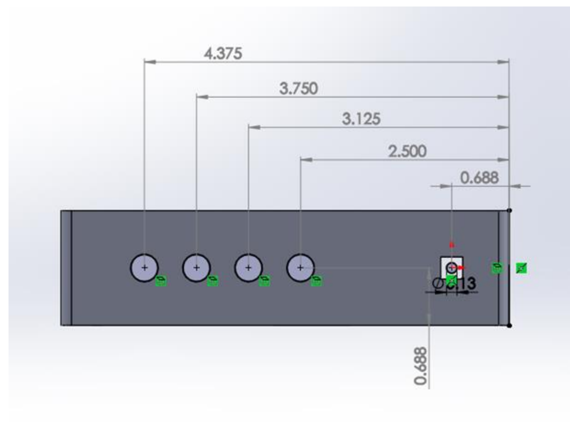


Figure 19: Updated ARB Design with Holes evenly spaced

Manufacturing

After I found the billet of aluminum, I started working on the manufacturing portion of the ARB. The process was as follows; first, drill two ¼” holes to allow the Wire EDM to center itself. Once two holes were drilled, I put the raw material in the wire EDM and allowed it to cut out the top view section. Once this was done, I took the piece, put it in the Tormach and drilled out the 4 3/8” end linkage holes. After the holes were drilled, the last thing I wanted to do was cut a small slit, and the square hole out. The slit so it could be clamped down, and the square hole as that’s what the end linkage would be.

After the end links were manufactured, I needed to cut the actual bar piece to length of 21.75” in. I also needed to face down the ends to be square, to allow it to fit into the square hole I had cut out. To square down the ends I used a 3/8” in collet, and a square block that was made to fit collets. This allowed me to use a 3/8” end mill and shave down one face, then rotate it 90, and repeat until I ended up with a square end.

Assembly

For assembly, I had cut small slots in the ARB end linkage so the square ends could slide in, then be clamped down. This worked out perfectly. Using the typical suspension components, assembled everything together. The end links are connected to the bell cranks via small push rods with control arm inserts. These were cut using the same material as control arm and tie rods. (4130 Chromoly). All in all, in fit in the car well, and does not impede the driver's space by any means. When cutting the square ends on the rod, one of them is a bit undersized, so it didn't fit quite as nice. The other end was oversized, and I used a hammer to put that end in. It was a much more secure connection.

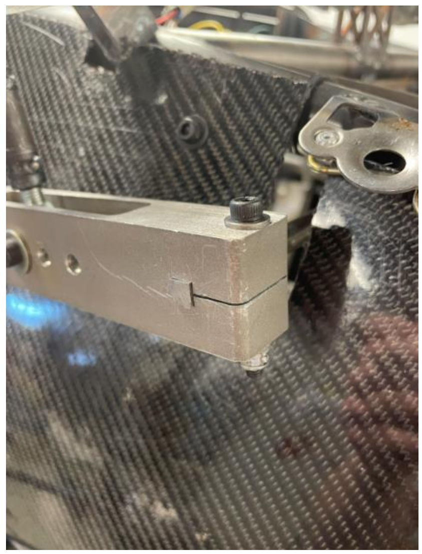


Figure 20: Anti Roll Bar assembled onto car, with end link clamped down to secure in place. Note Square ends

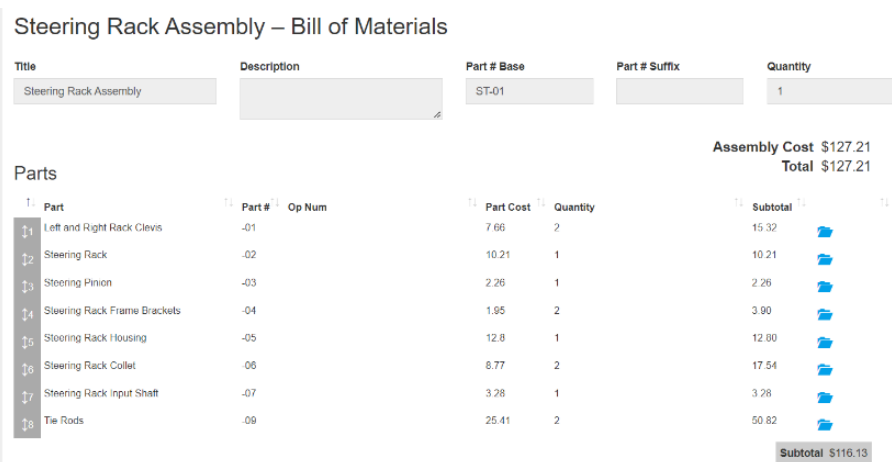
Cost Report

The cost report is an essential item that needs to be completed thoroughly to be able to compete at competition. After my workload had gotten a bit lighter, Ethan Hoffman and I volunteered ourselves for the cost report. For some more information on the cost report please see Ethan Hoffman's tech report, since we both contributed equally. The cost reports intention is to determine the cost of making the entire car from scratch. Initially Ethan and I had thought it was what we paid for all of the raw materials and components. For example, if I were to enter Mike Spagnoli's rear uprights, we know the actual raw material cost around $300. However, if you enter the raw material volume and material spec, it will calculate a cost for you. Then it would also factor in any process's that go along with that. So FSAE online might say the raw material cost is $40, and the machining cost was another $20.

Starting in 2021 the entire cost report was to be completed on FSAE online in their system. Like an ERP system, the process is tedious and involves entering every single step of the manufacturing, assembly, and other processes manually. Initially the cost report was to be submitted online By April 11th, at 11:59 pm. We sent an email to the team, asking for everyone individually to send their Bill of materials over. Once we had bill of materials, we would then break it down and enter all of material information, processes, etc.

Entering Information correctly was crucial to the cost of our car. Something Ethan and I had to spend a lot of time doing. The process to entering information was as follows:

1. Receive Bill of Materials from Team Member
2. Proceed to FSAE Online
3. Proceed to correct Subcategory, Engine, Steering, Wiring, etc.
4. If there is another subcategory, then create a new part with its name
5. Enter all Raw Material Information, i.e Volume
6. Enter all Process information, Such as machining, or Wire EDM
7. If there was mold, enter tooling information
8. Attach a drawing .pdf to the part if that was applicable



Steering Rack Assembly – Bill of Materials

Title	Description	Part # Base	Part # Suffix	Quantity
Steering Rack Assembly		ST-01		1

Assembly Cost $127.21
Total $127.21

Parts

	Part	Part #	Op Num	Part Cost	Quantity	Subtotal
1	Left and Right Rack Clevis	-01		7.66	2	15.32
2	Steering Rack	-02		10.21	1	10.21
3	Steering Pinion	-03		2.26	1	2.26
4	Steering Rack Frame Brackets	-04		1.95	2	3.90
5	Steering Rack Housing	-05		12.8	1	12.80
6	Steering Rack Collet	-06		8.77	2	17.54
7	Steering Rack Input Shaft	-07		3.28	1	3.28
8	Tie Rods	-09		25.41	2	50.82

Subtotal $116.13

Figure 22: Example Bill of Materials, online for the FSAE Cost report. Steering Components

Upright – Front Uprights – Bill of Materials

Title	Description	Part # Base	Part # Suffix
Upright			03

Part Cost $193.10

Materials

	Material	Use	Op Num	Size 1	Size 2	Area Name	Area	Length	Density	Quantity	Unit Cost	Subtotal
1	Aluminum, Premium (per kg)			15 kg						1	63	63.00

Subtotal $63.00

Processes

	Process	Use	Op Num	Quantity	Multiplier	Mult. Val.	Unit Cost	Subtotal
1	Machining Setup, Install and remove			1		1	1.3	1.30
2	EDM - Wire			100		1	0.2	20.00
3	Machining			2720		1	0.04	108.80

Subtotal $130.10

Figure 21: Example cost report item, FSAE Online, Uprights

Drawings: Drawings make up 30% of the available points for the cost. They are essential to earning a good score on the cost report section of the competition. Once Ethan and I were aware of this, we sent an email to the entire team asking for as many drawings as possible. Our goal was to have drawings for all the top-level assemblies. Such as drivetrain, steering, suspension, etc. Having a simple drawing with a couple dimensions can still portray significant details about the parts. The judges most definitely want to see that we were entering information in correctly and giving them a sense of scale in terms of drawings should allow to maintain a good score on the cost report section of the competition.

Once we had clicked submit, a .pdf was generated and automatically sent to the judges for review. For reference on our cost compared with previous teams cost, see the table below. The total cost to manufacture our car, is $17,159.18.

Table 2: Cost report breakdown per subcategory, as calculated by FSAE Online

Category	**Cost**
Brake System	$514.88
Engine & Drivetrain	$7,121.76
Frame & Body	$3,371.29
Instruments, Wiring & Accessories	$1,260.89
Miscellaneous, Safety & Wiring	$606.74
Steering System	$219.46
Suspension & Shocks	$3,196.86
Wheels, Wheel Bearings & Tires	$867.33
Total Cost	$17,159.18

Final Specifications

This section of my technical report is simply to provide future YCP racing team members with valuable information about the systems that I built. I remember almost a year ago beginning capstone with wide open eyes, being extremely overwhelmed, and not knowing where to start. However, I distinctly remember having to research statistics about previous teams systems. Well look no further for the 2022 Team specifications for steering and anti-roll bar systems. I also included my general thoughts on what could be improved, what is a good metric, how did it do in competition and general notes. Please see my 2021 Summer tech report for a full table on previous years team goals and data.

Table 3: Final Specifications involving the steering components for the 2022 YCP FSAE Car

Metric	Goal	Actual	Notes
Turn Radius	10 ft	13.5 ft	
Ackermann %	100%	~75%	

Engineering Impact of our FSAE Car

Engineering has a significant impact on society. As engineers we must understand and realize the importance of the decisions we make. Confidently the capstone project at York College allows us as students to really understand the impacts that our designs have. Although we have only built one race car, it's very interesting to think about the car in terms of mass production, and how engineers make certain decisions to save money in some areas. As we turn into 2022, global warming and overall waste are at forefront of our economy. As a society we should be concerned about these issues that will affect future generations to come. Having components on the car has allowed to realize the importance of these decisions that future engineers will have to make. How will part be recycled? Is it economically smart to replace this part? How can we design this part so its accessible? Can we use a part that's already common instead? Will this part sustain a lifecycle? Although our decision now might not have a significant impact, we understand that it could have implications in the future. Thinking about all of the above questions will be important as most of start our careers.

Recommendations for Future Teams

Being a good team member is essential to any team. In terms of engineering allowing yourself to be open minded, always willing to help, answer questions and give your opinions is incredibly important. I would recommend if you had a small amount of free time to make yourself available in the shop and project workspace. Even just sitting there doing your homework, others can ask questions, you can scope around in others work and gain valuable knowledge about what your teammates are doing. The following is advice to those who read this technical report.

1. Lay out a realistic plan for your semester
2. Order parts as soon as possible. The earlier the parts are in your hands the better
3. Make sure you are compliant with FSAE rules

4. Always involve other team members if you are unsure, getting a second opinion is invaluable and most of the time creates a new perspective that you wouldn’t have seen otherwise.
5. When you make a mistake, take a step back and devise a proper solution. Don’t allow yourself to become too frustrated and make more mistakes on top of that.
6. Have someone start the cost report early in the semester. We did ours in 2 weeks, and more time put into something like this could lead to less points lost in competition.

Works Cited

(1) Frangdiadis, Gabriella. York College, 2019, Summer Tech Report 2019

(2) McRae, John and Potter, James Jackson, "Design Considerations of an FSAE Steering System" (2019). Mechanical Engineering and Materials Science Independent Study. 94. https://openscholarship.wustl.edu/mems500/94

(3) Tarlton, Brett. York College, 2017, Steering, Machining, and Random Fabrication, Spring Tech Report 2017

(4) Yee, Johnathan. York College, 2018 Control Arms and Steering System, Spring Tech Report 2018

Appendices

Appendix I: Bill of Materials (BOM)

(A) Steering BOM

Product	Vendor	Part #	Price	QTY	Description		Prices
Steering Wheel	Pegasus Auto	3406-Blac	$174.99	1	Steering Wheel		$174.99
Steering wheel Quick connect + spline	Speedway Mtrs		$89.99	1	New quick connect		$89.99
Steering Column Tubing 0.750 OD	McMaster Carr	7767T32	$6.43	1	Welded attachments to column		$6.43
Spline Attachments Steering Column	KAZ Tech	-	$11.00	1	Splined Inserts (3/4"-20)		$11.00
U Joints	KAZ Tech	-	$103.50	2	U joints		$207.00
Steering Rack	KAZ Tech	-	$670.00	1	Steering Rack Previoulsy owned		$670.00
Steering Coupler	KAZ Tech	-	$35.00	1	New coupler to connect rack to column		$35.00
Column Mount Bearins	McMaster Carr	5905K26	$6.94	2	Used in the frame to secure the column		$13.88
Spline Shaft for U joints	?	?	?	1			
0.5"-0.035" 4130 Chromoly Round Hollow Tube	Stock Car Steel	41	$7.20	2	Tie rod Raw Material	$0.00	$14.40
10-24 1.125" Shoulder Bolt	McMaster Carr	91259A509	$3.39	2	Misc Hardware for Tie Rods		$3.39
10-24 0.875" Shoulder Bolt	McMaster Carr	91259A541	$3.08	2	Misc Hardware for Tie Rods		$3.08
M6 25mm Shoulder bolt	McMaster Carr	92981A204	$1.62	8	Misc Hardware for Tie Rods		$1.62
Right Hand Ball Joint Rod End	McMaster Carr	60645K821	$4.81	2	For tie Rod ends		$4.81
Left Hand Ball Joint Rod End	McMaster Carr	60645K822	$4.81	2	For tie Rod ends		$4.81

(B) Anti-Roll Bar BOM

Product	Vendor	Part #	Price	QTY	Description		Prices
Right Hand Ball Joint Rod End	McMaster Carr	60645K821	$4.81	4	For connecter to rockers		$4.81
Left Hand Ball Joint Rod End	McMaster Carr	60645K822	$4.81	4	For connecter to rockers		$4.81
Set Screw	McMaster Carr	94355A229	$6.40	1 (Pack of 25)	for shaft connection		$6.40
ARB Rods	McMaster Carr	8920K135	8.36	1	Arb Rods (0.375 OD Steel)		8.36
ARB Connecters	McMaster Carr		17.04	1	Connecter 4x 6061		17.04

Appendix II: Photos

Figure 23: Anti Roll Bar full installed underneath frame

Figure 25: Anti Roll Bar End link: 6061-T6 Al.

Figure 24: Steering Wheel quick disconnect