Differential Carrier Design Project

Project Description: You have been tasked with designing either the left or right differential carrier for an FSAE car. Some architectural decisions will be taken for you, while you will need to use good engineering judgement to make other decisions. Remember that any decision you take will need some kind of justification to go alongside it, so make informed decisions. You will assume in this scenario that you will be building to the same loading conditions as experienced on PF25. This data will be given to you. In addition, you will use the same bearings as on PF25.

Bearings used on PF25:

- Left: 6011-2RS1 - Deep groove ball bearings | SKF
- Right: 61910-2RS1 - Deep groove ball bearings | SKF

Quick Note: You can honestly pick either the left or right differential carrier. I would recommend sticking to the left one since that is the one that would be taking the most load and slightly more difficult to optimize. One thing to note is that you would usually run individual FEA and then run an assembly FEA. Individual FEA includes one carrier, while assembly FEA includes both carriers and stability bar. Usually when running FEA on individual carriers, the right one is nowhere near the limit of optimization since the whole system must not fail under the loading. The left one is closer, but usually the assembly FEA yields result closer to the stress value you want. If this doesn't make sense now, it's alright. I will go over this with you all at some point.

Safety Factors:

- 1.1 to yield
- 1.4 to ultimate

Goals:

- Leverage CAD knowledge to design a component while making good engineering decisions along the way
- Design a differential carrier under conservative launch conditions
- Leverage FEA and analysis knowledge to perform ONE mass optimization (more is welcome, but out of scope)
    - I would ask that your primary and mass optimized versions have cutouts and explain what was changed with regard to parameters (i.e. rib thicknesses, etc). This is to ensure that you know how to optimize mass rather than just knowing that mass can be removed.

What you need to decide:

- Material
    - Pick a material that is best suited for the application. This is a component that will experience peak stresses under launch conditions and needs to hold the differential in place.
- Nuances in the geometry
    - Referring to how much thicker you need to make this to properly house the bearing and design to the load. You will most likely have to add this thickness to what the thickness of the bearing already is if you are doing the left carrier.
    - You may also consider adding a lip to better distribute stresses

Deliverables:

- Written Report/Document
    - Outlining any justifications that had to be made
    - Show pictures of final CAD
    - Show pictures of FEA
- Excel calculator with loads
- NX part file with final CAD

The following tests will be conducted on your CAD file:

1. General sizing of the carrier:
    a. If coordinates of top and bottom node change, can your CAD file adjust to those changes?
2. Cutouts will be adjusted based on the sizing of the teeth, but also some other parameters such as rib thicknesses may be adjusted to see if CAD is robust
3. It is okay to have your bearing sizes "hard-coded" since you know for a fact you will be accommodating one type of bearing

Bearings:

1. If you are doing the left carrier, you might benefit from adding additional thickness to the carrier to accommodate the higher loading (rather than having the thickness of the carrier equal to the thickness of the bearing
2. Make sure there is nothing that pushes up against the seal of the bearing, as that would lead to issues during operation

Before modelling the carriers in CAD, make sure to come up with a good list of expressions that you can use to parametrize. I would start by thinking about parameters you would want to change and come up with a list of them. When you submit your document, provide a list of the most important parameters and explain what they are if not obvious by the name.

Rear Sprocket Design Project

Project Description: You have been tasked with designing a rear sprocket for an FSAE car. Some architectural decisions will be taken for you, while you will need to use good engineering judgement to make other decisions. Remember that any decision you take will need some kind of justification to go alongside it, so make informed decisions. The team has decided it is best to stick with a Drexler Limited Slip Differential, so you will integrate your design around that.

Safety Factors:

- 1.2 to yield
- 1.4 to ultimate

Goals:

- Leverage CAD knowledge to design a component while making good engineering decisions along the way
- Design a working rear sprocket under conservative launch conditions
- Leverage FEA and analysis knowledge to perform ONE mass optimization (more is welcome, but out of scope)
  - I would ask that your primary and mass optimized versions have cutouts and explain what was changed with regard to parameters (i.e. rib thicknesses, etc). This is to ensure that you know how to optimize mass rather than just knowing that mass can be removed.

What you need to decide:

- Final Drive Ratio
  - This will be decided based on lapsim. You will be using the MATLAB file provided in the folder to be able to do this.
  - Note – For the number of front teeth, pick between 11, 12, or 13 since that is what would be available to you if you were to design a sprocket for the current architecture.
- Material
  - Pick a material that is best suited for the application. Remember it is a rotating component that would also be experiencing high loads.

Deliverables:

- Written Report/Document
  - Outlining any justifications that had to be made
  - Show pictures of final CAD

- Show pictures of FEA

- MATLAB file in which you worked out of for lapsim
- Excel calculator with loads
- NX part file with final CAD
- Tradeoff Excel Sheet

The following tests will be conducted on your CAD file:

1. Number of teeth will be changed anywhere from 26 to 40 teeth and the CAD file should not return any errors
2. Cutouts will be adjusted based on the sizing of the teeth, but also some other parameters such as rib thicknesses may be adjusted to see if CAD is robust

Before modelling sprocket in CAD, add the following expressions:

P = Chain Pitch **N** = Number of Teeth **Dr** = Roller Diameter (See Table)	**yz** = $Dr\left[1.4\sin(17^\circ-\frac{64}{N})-0.8\sin(18^\circ-\frac{56^\circ}{N})\right]$
Ds = (Seating curve diameter) = 1.0005 Dr + 0.003	**ab** = 1.4 Dr
R = Ds/2 = 0.5025 Dr + 0.0015 **A** = $35^\circ+\frac{60^\circ}{N}$	**W** = $1.4\ Dr\ \cos\frac{180^\circ}{N}$
B = $18^\circ-\frac{56^\circ}{N}$	**V** = $1.4\ Dr\ \sin\frac{180^\circ}{N}$
ac = 0.8 x Dr	**F** = $Dr\left[0.8\cos(18^\circ-\frac{56^\circ}{N})+1.4\cos(17^\circ-\frac{64^\circ}{N})-1.3025\right]-.0015$
M = $0.8 \times Dr\cos(35^\circ+\frac{60^\circ}{N})$	**H** = $\sqrt{F^2-(1.4Dr-\frac{P}{2})^2}$
T = $0.8 \times Dr\sin(35^\circ+\frac{60^\circ}{N})$ **E** = 1.3025 Dr + 0.0015	**S** = $\frac{P}{2}\cos\frac{180^\circ}{N}+H\sin\frac{180^\circ}{N}$
Chordal Length of Arc xy = (2.605 Dr + 0.003) $\sin(9^\circ-\frac{28^\circ}{N})$	**PD** = $\frac{P}{\sin\left[\frac{180^\circ}{N}\right]}$

Note that Chain Pitch (P) and Roller Diameter (Dr) are found from looking at the chain that we tend to use or rather that would be used (520 Roller Chain).

Lap Sim Quick How-To:

The info below is only enough to describe how to change the final drive ratio and run the lap sim. I'm not going to go into detail of how to use MATLAB FYI.

- Set current folder to Quasi-Static_lap_sim_v2 and open up pf20_12.m
- Go to drivetrain section

```
%% Drivetrain

% array of gear ratios multiplied by primary drive and final drive ratios
NET_RATIO = [2.583, 2.000, 1.667, 1.444, 1.286, 1.150] .* 28 ./ 11 .* 2.073;
%NET_RATIO = [2.583, 2.000, 1.667] .* 3.0909 .* 2.073; % artificially remove 4th
% , 1.286, 1.150 these are 5th and 6th. currently unused

% time required for each shift - how long between end of acceleration in
% one gear and start of acceleration in the next
shift_time = 0.2;

% coefficient representing all drivetrain losses. SET TO 1.0 IF USING
% CHASSIS DYNO TORQUE CURVE as opposed to engine dyno
drivetrain_efficiency = 1.0;
```

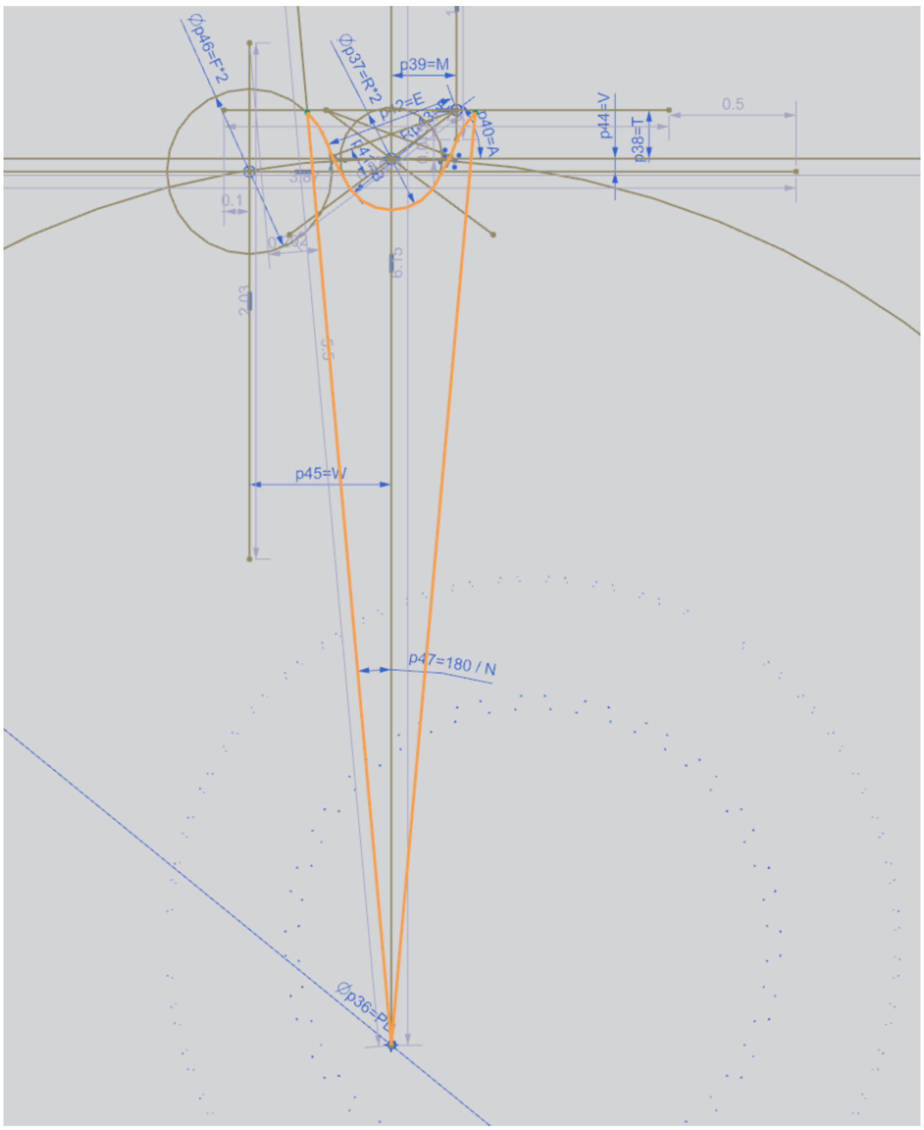
- The 28 ./ 11 is the ratio of the rear to the front sprocket. The rear sprocket tooth count is what you will be changing for this exercise. I would recommend starting out with 28/11 or 29/11.
- Run virtual_competition_29a
- Copy points results and number of shifts for each event. Points are in order: Total, accel, skidpad, autocross, endurance, efficiency

```
Running Acceleration
Total Time: 4.538 s
Accel Points: 60.5
Avg on throttle (>95%) rpm: 8582.316829
Upshifts: 1


Running Skidpad
Skidpad Points: 43.7
Total Time: 5.300 s
Avg on throttle (>95%) rpm: NaN


Running Autocross
Total Time: 87.416 s
Autocross Points: 70.8
Avg on throttle (>95%) rpm: 8624.725940
Per lap upshifts / downshifts: 7 / 7


Running Endurance and Efficiency
Total endurance distance (mi): 15.924
Total Time: 1480.170 s
Endurance Points: 133.4

Total fuel used (gallons): 1.086
Total CO2 output (kg): 9.498
Efficiency Points: 66.9
Avg on throttle (>95%) rpm: 9149.158382
Per lap upshifts / downshifts: 13 / 13

Congragulations, you got 375.4 dynamic event points. (If only it were that easy)

375.3782
60.5442
43.7358
70.7671
133.4070
66.9241
```

- Put into trade-offs excel sheet in the folder

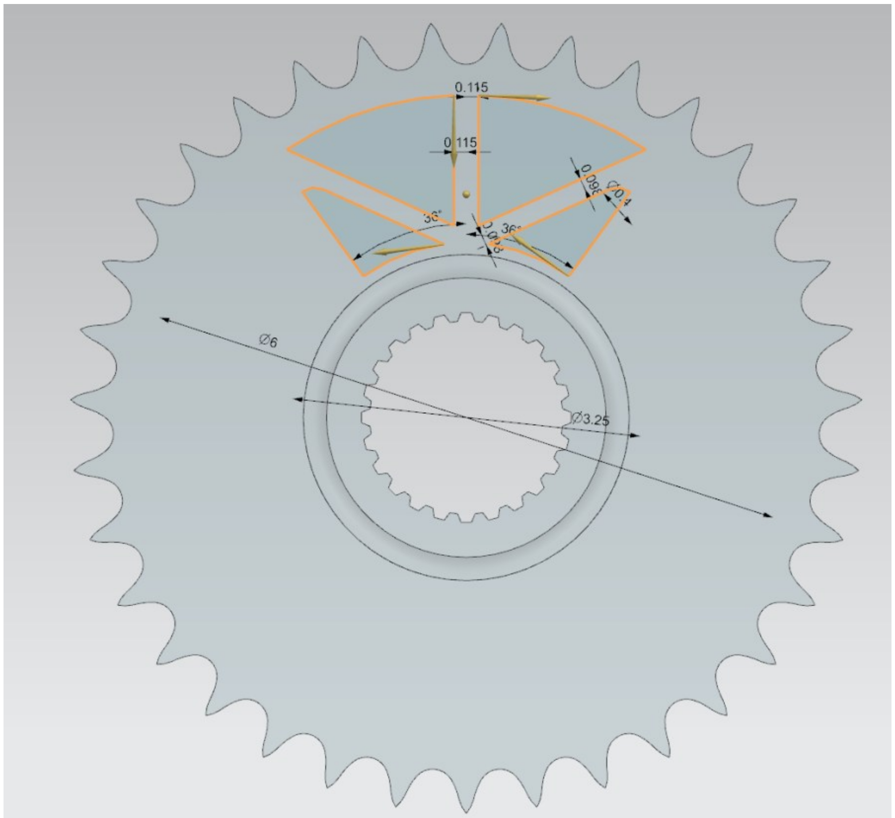
- Using the results, determine the optimal final drive ratio with your reasoning, balancing out the points gained vs the additional shifts that occurred
- To make this part easier, I recommend the following:
    - Pick a number for the number of front sprocket teeth (11, 12, or 13)
    - Pick a number of rear sprocket teeth (start from 26 and go up until you have passed the maximum number of points.
    - Repeat for the other two front sprocket teeth combos
- I expect values to converge, but they can be slightly different from person to person. As long as you can soundly justify your choice, you are correct.

How to model sprocket in CAD? Follow [this tutorial] until step 15.



Other considerations:

- This tooth profile can be patterned and extruded to create the sprocket. Generally, you want around 90% of the chain width as the sprocket width. A 520 chain has a width of 0.25 inches, so the tooth width was made to be 0.227 inches, or 90.8% of the chain width. This ensures that the chain won't bind under any slight misalignment and will reduce any friction due to the sliding action between the sprocket and the chain.
- The center spline is obtained by projecting the spline of the differential onto the sprocket and extruding the cutout. I used the intersection curve in the sketching tools to accomplish this. Differential model is in folder.
- The cutouts are designed to be bi-directional, meaning that the sprocket can be used in two orientations. This is simpler to model and based on experience with making a uni-directional sprocket for PF19, the uni-directional design does not net you any meaningful weight savings. The cutout geometry is iterated upon in ANSYS until the structural design criteria is met.
- **For FEA, you will only be running ONE load case (i.e. orientation of sprocket). For actual purposes, you will have to test different orientations (which is something I can show you at some point, but I do not expect you to do this, but you are more than welcome to).**
- The sprocket has a lip on either end to produce a larger area for the splines. This increases the effective shear area and reduces the stress on each spline. Generate your own lip thickness but be able to defend your choice of thickness.
- When designing the pattern, only model a single slice and utilize the pattern tool to wrap the cutouts around the sprocket. Example below:


0.115
0.115
0.095
∅0.4
36°
36°
∅6
∅3.25

Titanium Halfshaft "Design" Project

Project Description: The team has additional space for budget and after discussing heavily, the best way to utilize that budget is to invest in making Ti halfshafts. The issue is that now the team does not have a clear path to making them and needs the research to be done to see if it is worth it.

Goals:

- Leverage knowledge of materials and material science to determine how much of a benefit Ti is over steel.
- Leverage knowledge of material testing to come up with a good material testing plan to ensure that the halfshaft will not cause damage.
- Economically feasible to buy components such as CVs, snap rings, etc that a company like Drexel sells, so it is best to implement that into your "design"

Considerations:

- You have to be cognizant of hardness and metallurgical compatibility. When purchasing halfshafts and CVs, you have a scenario where you are only dealing with steel on steel contact, but in this scenario, you are dealing with Ti on steel, which may have different hardnesses. I can talk through material testing if you need any input on this.
- Come up with a few metrics that can be used to make a quick decision on whether this is economically feasible or not. An example of such a metric is $/lb reduced.

Deliverables:

- A report and/or presentation that includes the following:
    - Research into what benefits of Ti are over steel, including a bit about metallurgical compatibility
    - Research into other alternatives that other FSAE teams or other motorsports teams run (if applicable)
    - Material testing plan
    - Metrics
    - etc.