Solar Car Suspension Design
Considerations for achieving an efficient and stable vehicle

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About the Presenter

- **Education: Iowa State University**
  - Mechanical Engineering B.S.
- **Solar Car: Team PrISUm**
  - 2009-2011: Media Director
  - 2011-2012: Project Director
  - Solar Car Driver for ASC 2010, FSGP 2011, and ASC 2012
- **Event Volunteer: IEF**
  - 2012-2017: Webmaster
  - 2014-Present: Team Coordinator
  - Event Staff since 2013 including ADSC 2015
- **Employment: Caterpillar**
  - 2012-Present: Electric Drive Systems Engineer in Peoria, IL
- **Current Vehicle: 2018 Tesla Model 3**
Why have a suspension system?

- Serves to always keep your tires in contact with the ground
  - Acceleration, steering, and braking forces act on the tire contact patches
  - You want traction on all tires to remain in control!
- Protects the vehicle and onboard cargo from damage
- Lots of tradeoffs between comfort and efficiency
Common Suspension Types

- Double Wishbone
- Macpherson Strut
- Trailing Arm
The goal of camber is to keep the tire oriented perpendicular to the ground (maximize grip) during turning.

Lateral tire scrub is increased when you try to optimize camber angle in your suspension.

- For solar cars, minimizing lateral scrub is arguably more important than optimizing camber for efficiency reasons.
- Solar cars typically don’t need to have great cornering capability at race car speeds.
Positive caster helps with straight line tracking if the driver lets go of the steering wheel.

Adding caster also increases tire scrub when steering.
Toe Angle

- Most efficient is zero toe
- Some toe in can help improve stability of vehicle at the cost of increased tire scrub
Scrub Radius

- True zero scrub radius is most efficient but can result in less stable steering feel.
- On rear wheel drive cars, a positive scrub radius in the rear suspension can help improve straight line tracking when the steering wheel is released.
- On the front, a slight negative scrub radius can help with maintaining stability in scenarios like sudden tire deflation or hitting standing water.
Free Body Diagrams

- Draw free body diagrams for your various suspension components to calculate input loads
- Consider brake, bump, and steering loads

Fc & W given, F1, 2, 3 found geometrically.
Fasteners

- Friction is not an acceptable method of constraining structural members
- Loctite is not allowed to restrain fasteners
- Make sure your frame can support suspension loads
  - Try to put suspension/shock mount locations near structural nodes on the frame
    - Minimize frame tube bending loads!
- No unrestrained fasteners are allowed in structural applications
  - Flex lock nuts are OK
  - Cotter/Spring Pins are OK
  - Safety wire is OK
Rod Ends vs. Spherical Bearings

- Rod ends should not be put in bending
- If you do have to put the in bending, there is a rod end sizing calculation sheet on the ASC website that must be used!
- Consider spherical joints instead of rods ends
Suspension Adjustability

- The goal is to enable adjustability without resulting in binding or inefficient force path
- What to do with frame mounts to enable adjustability/account for manufacturing tolerances
- If you put a slot in the frame, make it perpendicular to the control arm link
Loads Into Nodes

- Efficient mechanical design can be used to minimize the weight components
- Minimize bending loads and if they must be used try to put them into components that can have a rectangular/oval cross section or ribs/gussets with extra bending strength
Eliminate Binding

- Don’t over-constrain your suspension such that binding is possible
  - What should stop vertical motion? - Rubber bump stops are built into shocks
- What should stop steering motion? - Steering bump stops
  - ASC doesn’t allow use of the pinion gear as the steering stop
  - Must implement external steering stops that prevent the pinion gear from colliding
- Rubber steering stop is recommended
- Ensure your suspension system has interference free travel through it’s full range of vertical and steering motion
  - To test this, take your spring off your shock absorber and manually move your suspension through it’s extremes of vertical and steering travel
  - The shock or steering bump stops should be the only things that ever interfere
  - If you notice any other interference points that don’t allow the bump stops to be engaged this interference needs to be eliminated by modifying your suspension components (grinding/redesign)
- Why does it matter?
  - If you have hard metal to metal interference in your suspension travel this will result in grinding/wear stress concentrations and can put parts in bending that were not intended to be in bending resulting in premature failure
Other Notes

- Lower A-arms should be either the same length as or longer than uppers, and should have a nearly horizontal resting position. The upper arm should never be longer.
- Verify that your wheels spin freely
  - Try to use retracting brake calipers
  - Consider turning brake rotors on hub to be flat
- Steering shaft connections should be splined with a spring pin holding the tube on.
- In general, mountain bike components (shocks, brakes, etc.) are not sufficient for components for solar cars
Steering

- Ackermann steering
  - https://www.youtube.com/watch?v=TBwa1HvpHMY
- Steering ratio
  - Get a rack and pinion with a reasonable steering ratio - too sensitive to steering wheel movement will be difficult to control and not sensitive enough will make it difficult to complete the Scrutineering figure 8 test
- Ensure stable, reliable control of your vehicle
  - Eliminate sources of steering slop
  - Bump Steer
    - Bump steer is where the front wheels turn when going over a bump
    - To eliminate bump steer ensure your steering tie rod locations are lined up between your upper and lower suspension pivots as shown below
Open Discussion