2017 SAE Baja - Brakes

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in Mechanical Engineering Technology

by

Kyle Cobbs

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Thesis Advisor:
Allen Arthur

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ABSTRACT

The purpose of this project is to design and build a braking system for the SAE Baja car. The car must come to a safe and controlled stop and be as light as possible. The budget, timeline, rules, and testing will also be shown in this report.

INTRO

SAE Baja is a collegian competition where students design, build, test, and compete with a vehicle within the limitations of the rules set by SAE Baja. Competitions are in endurance format lasting around 4 hours on an off-road course designed to test all aspects of the vehicle. The braking system is very important to any vehicle and to the safety of the operator. In competition vehicles attain speeds of around 25 mile per hour weaving in and out of trees on a slim track with lots of other vehicles all around. A good braking system can not only keep a driver, it can also give drivers the upper hand in competition.

Problem Statement

My mission is to design and build a braking system for the SAE Baja car. The braking system will be within the rules set by SAE Baja and will being the car to a safe, controlled, and quick stop.

RESEARCH

Rules

B11.1 Foot Brake
The vehicle must have hydraulic braking system that acts on all wheels and is operated by a single foot pedal. The pedal must directly actuate the master cylinder through a rigid link (i.e., cables are not allowed). The brake system must be capable of locking ALL FOUR wheels, both in a static condition as well as from speed on pavement AND on unpaved surfaces.

B11.2 Independent Brake Circuits
The braking system must be segregated into at least two (2) independent hydraulic circuits such that in case of a leak or failure at any point in the system, effective braking power shall be maintained on at least two wheels. Each hydraulic circuit must have its own fluid reserve either through separate reservoirs or by the use of a dammed, OEM-style reservoir.

B11.3 Brake(s) Location
The brake(s) on the driven axle must operate through the final drive. Inboard braking through universal joints is permitted.

B11.4 Cutting Brakes
Hand or feet operated “cutting brakes” are permitted provided the section (B11.1) on “foot brakes” is also satisfied. A primary brake must be able to lock all four wheels with a single foot. If using two separate pedals to lock 2 wheels apiece; the pedals must be close enough to use one foot to lock all four wheels. No brake, including cutting brakes, may operate without lighting the brake light.

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B11.5 Brake Lines (UPDATED)

- All brake lines must be securely mounted and not fall below any portion of the vehicle (frame, swing arm, A-arms, etc.)
- Ensure they do not rub on any sharp edges.
- Avoid being pinched by suspension parts
- Have full range of motion in steering and suspension motion.
- Never loaded in tension at the extremes of the steering angle.
- Plastic brake lines are strictly prohibited.

BRAKING SYSTEM

The braking system on the vehicle works as follows: A force on the pedal becomes a force into the master cylinder. The master cylinder transfers the force into a pressure that travels through the brake lines and into the caliper. The caliper then turns the pressure back into a force where the piston squeezes the rotor that is connected to the hub of the car and slows the car down.

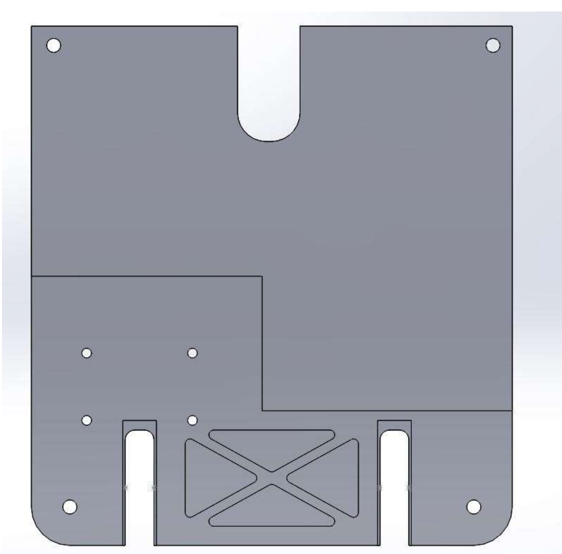
Pedals: As we know Torque=Force*Distance therefore a longer pedal will increase the amount of force the will be input into the master cylinder. The pedals that were chosen are 10in from the foot pad to the pivot point. The pedal from the previous year were only 7in from foot pad to pivot point which means there is a 30% increase of input force.

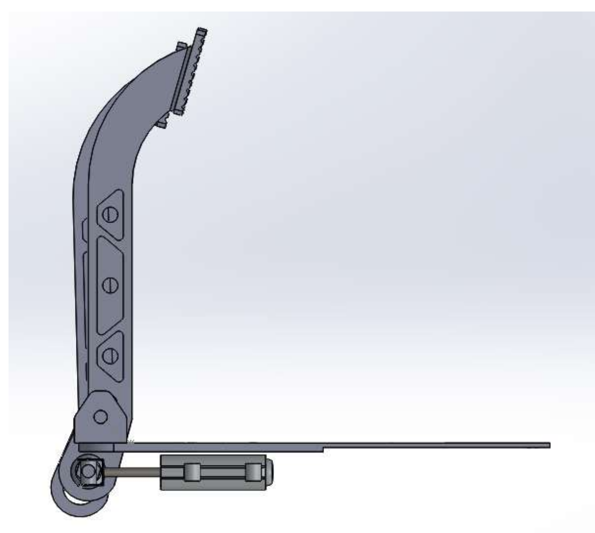
Master Cylinder: Knowing Pressure=Force/Area shows that a smaller area in the master cylinder will produce a higher pressure traveling through the brake lines. The master cylinders that were chosen have a 1/2in diameter compared to last year's 5/8in diameter. That results in a 12.5% increase in braking pressure.

Caliper: Rearranging results in the equation Force=Pressure*Area. This equation shows that a bigger area on the caliper piston will result in a higher force applied to the rotor. The caliper chose has a piston diameter of 1.12in compared to 1in diameter last year. This is a 12% increase in braking force.

Rotor: Looking back to Torque=Force*Distance this also shows that a bigger rotor will output a higher braking torque. To maximize braking torque diameters of 7.5in and 8.25in were chosen for the front and rear respectively.

Floor Board: The only part of my project that I personally manufactured was the floor board. This product holds the pedals and the master cylinders and is where the braking force is generated. Pictured below is the floorboard by itself as well as the final assembly form. The floorboard is attached to the car by the four corners which are bolted to four tabs that were welded onto the frame. The two main considerations for the floor board are that first it must fit within the dimensions of the frame and second there must be adequate spacing for full range of pedal travel and room to access the master cylinders underneath the floor board in case of failure or if an adjustment needs to be made. 1/8in thick 6061 aluminum scrap in the shop was plasma cut to make the floor board and a reinforcement was also plasma cut to strengthen the floor board primarily on the brake pedal side.

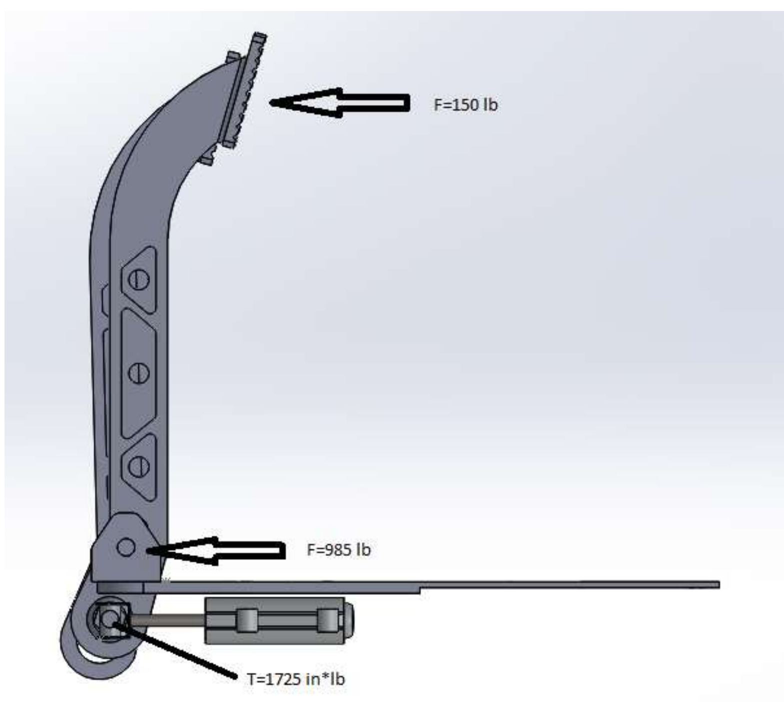




FEA

One improvement that needed to be made was that the floor board from the previous year was bent where the brake pedal was attached. This was a result of a large force being input into the brake pedal. As noted in the previous section reinforcement was added to the floorboard to strengthen the product and to reduce bending due to stress. The force expected was calculated as follows: Once the brake pedal is fully depressed the pivot point then becomes the point where the master cylinder connects to the pedal which creates a force acting on the tabs that connect the pedal to the floor board. An estimated initial force of 150lbs applied to the pedal at a distance of 11.5in. The equation Torque=Force*Distances provides that a torque of 1725in*lbs is at the pivot point. Since the tabs are 1.5in from the pivot point the force acting on them using the same equation comes out to be 985lbs. A safety factor of 2 was applied to the force this was input into SolidWorks to analyze. The results showed that without reinforcement (figure B) the max displacement is .49in. With the reinforcement added (figure C) the max displacement was .08in which is an 84% decrease in displacement.

(A)



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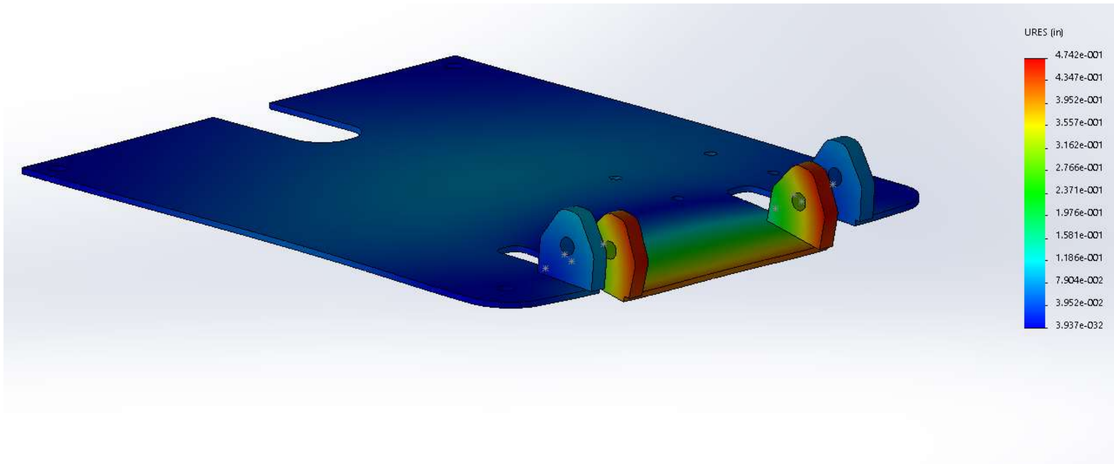
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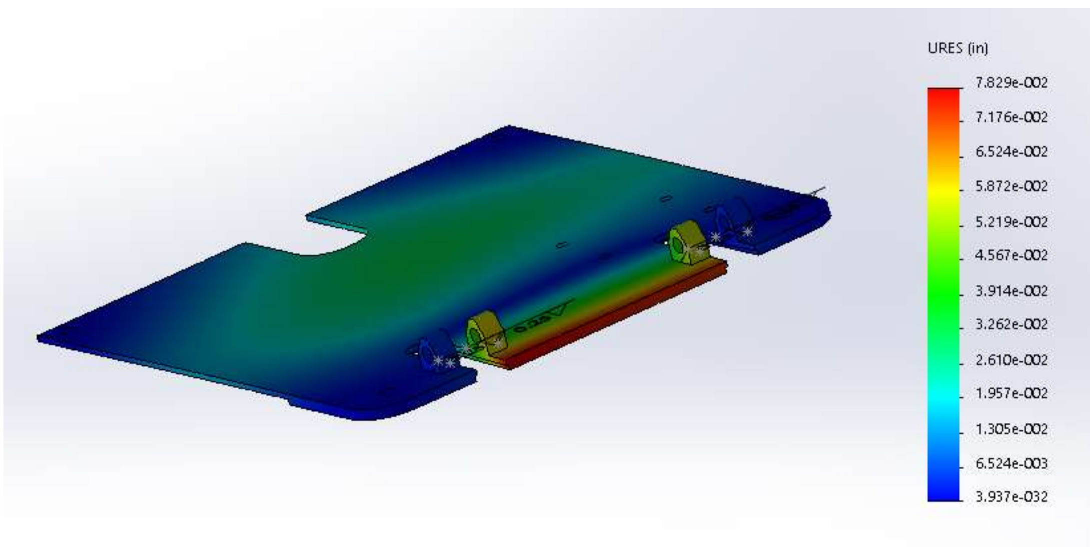
(C)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TESTING

Once the car was fully assembled and ready to drive the very first test of the brakes was to simply get the car to move and then press the brakes to make sure they work. After that the car was accelerated to increasing speeds and the brakes were pressed increasingly hard to ensure they were safe. Next the brakes were tested similarly to how they would be tested in competition. The car was accelerated to top speed and when the car reached a set of cones the brakes were applied at full pressure to see if the tires locked up. This test was observed on a paved and an unpaved surface (shown in pictures below). The stopping distance of the vehicle was calculated to be 8.5ft

The vehicle was also taken to Haspen Off-Road Park in Indiana. This off-road park offers terrain similar to what the car will experience in competition. Although this is mostly meant to test the suspension of the car, a benefit of this test for the braking system was seeing how it operates under high repetition. No failures occurred to the braking system on any testing. The 2013 car was also brought to our testing day at Haspen and the braking systems on the two vehicles were able to be compared. The results were that the 2013 required a significant amount of more force to stop compared to the current car.

COST

Part	Cost	Quantity
Rear Calipers	$205.00	2
Front Calipers	$205.00	2
Master Cylinder	$85.00	2
Front Rotors	previous car	2
Rear Rotors	$51.00	2
Pedals	previous car	2
Floor Board	scrap	1
Brake Lines	$160.00	
Hardware	$367.00	
Total	**$1,619.00**	
Budget	**$2,000.00**	

WEIGHT

Part	Weight (lbs)	Quantity
Rear Calipers	1.5	2
Front Calipers	1.5	2
Master Cylinder	0.25	2
Front Rotors	1.75	2
Rear Rotors	2.25	2
Pedals	1	2
Floor Board	2	1
Brake Lines	1	
Hardware	1	
Total	**20.5 lbs**	

A SPECIAL THANKS TO ALL OUR SPONSORS

REFRENCES

1. **International, SAE.** 2017 Collegiate Design Series SAE Baja Rules. [Online]