COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

REDUCED TURNING-RADIUS SOLUTION

SPONSOR
BAJA RACING

SECTION INSTRUCTOR
Professor Jun Ni

ME 450 TEAM 22
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PROBLEM

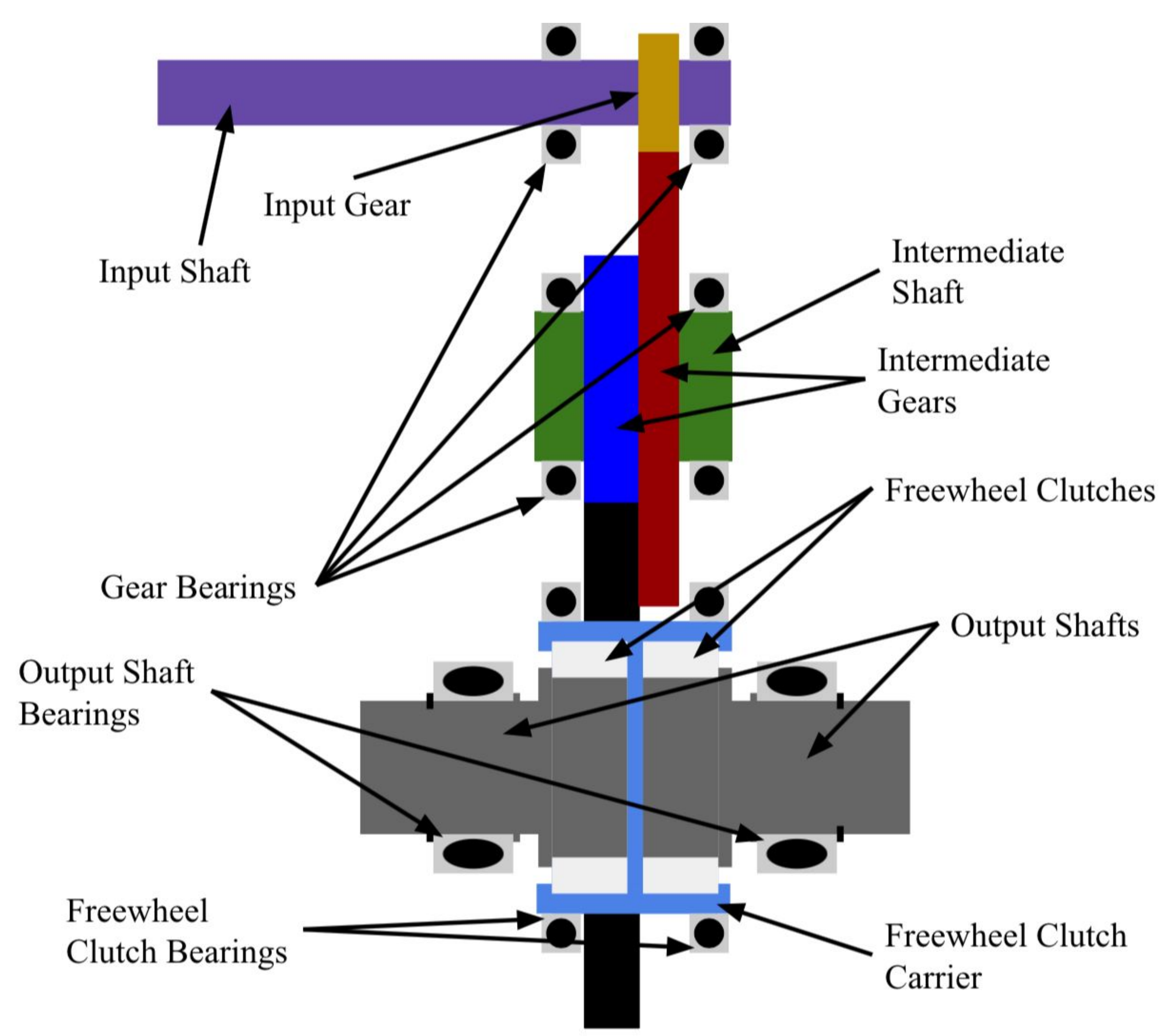
The ME450 Baja Team is serving the needs of the Michigan Baja Racing Team by providing our sponsor with a solution that reduces the low-speed turning radius of their 2018-2019 vehicle. Our sponsor participates annually in three national competitions in which their vehicle competes in dynamic and static events. The team forfeited 150 of the 3,000 total points during their last competition series due to a large low-speed turning radius that disqualified them in two of their six dynamic events. Consequently, our sponsor has requested our team develop a solution that will reduce the 2018-2019 vehicle's low-speed turning radius.

USER REQUIREMENTS AND SPECIFICATIONS

User Requirements	Relative Priority	Specifications	Rationale
Decrease low-speed turning radius	High	15% decrease	Decreasing the low-speed turning radius maximizes competition points
Minimal effect on suspension geometry	High	Less than 2" width addition to both side of gearbox	Changes to suspension cannibalize other competition points
Low rotational inertia	High	Less than 50% addition of rotational inertia	Higher rotational inertia negatively impacts acceleration
Low mass	Medium	Less than 10 pound overall mass increase	Higher weight negatively impacts all performance aspects
Cannot distract driver from operating car	Medium	Necessary controls must be mounted at steering wheel	Distractions could cause crashes, or negatively affect performance
No loss in rear-wheel traction	High	Solution must apply full torque to both wheels	If vehicle loses rear-wheel traction, it becomes prone to getting stuck
Durability	High	Must withstand 3 drop tests/4 hours of testing	Points are lost if the vehicle breaks down unexpectedly
Reverse compatibility	Medium	Must be compatible with chassis tabs	Allows for spare gearbox to be implemented
Manufacturable	Medium	Designed for 3-axis CNC mill and 2-axis CNC lathe	Our sponsor must be able to manufacture our gearbox in-house with relative ease
Low Cost	Medium	Must be less than $1000	Our sponsor cannot allocate further resources

DESIGN CONCEPT

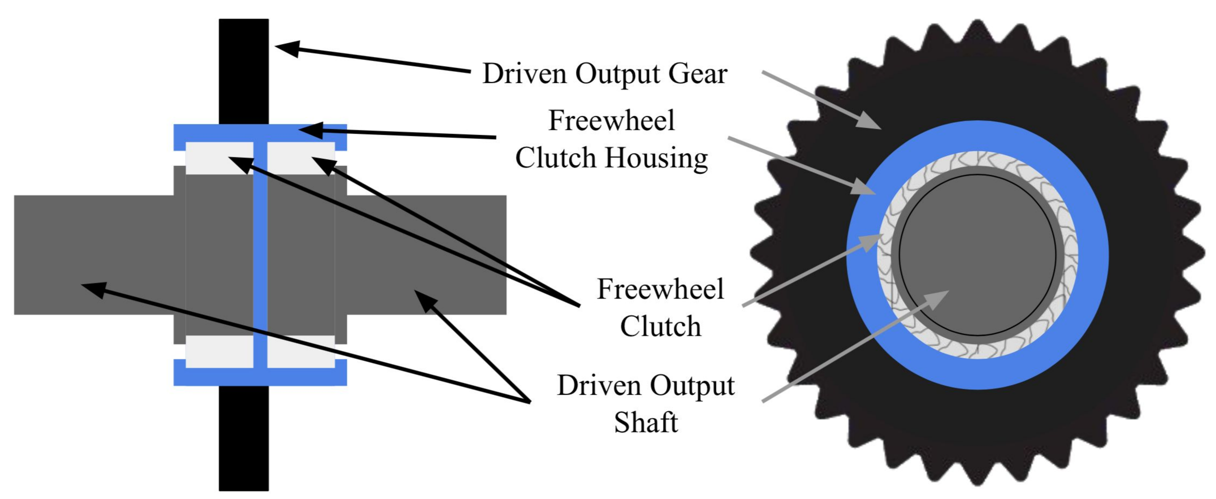
Gearbox Cross-Section Schematic



Freewheel Housing and Output Schematic

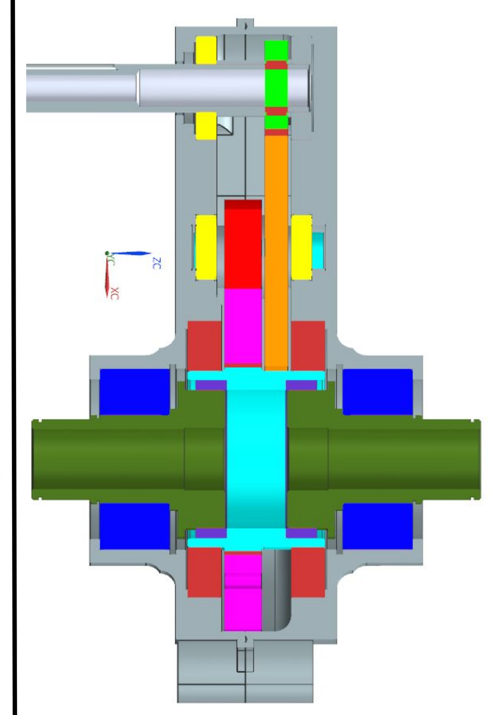
Cross-Section View

Side View

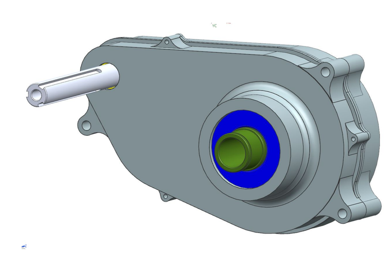


Gearbox CAD

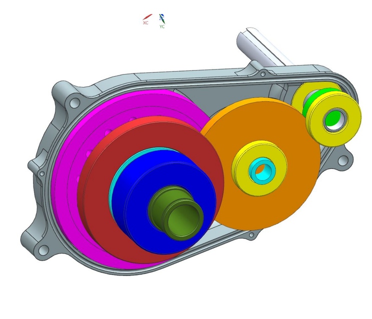
Cross-Section



Isometric View



Isometric View



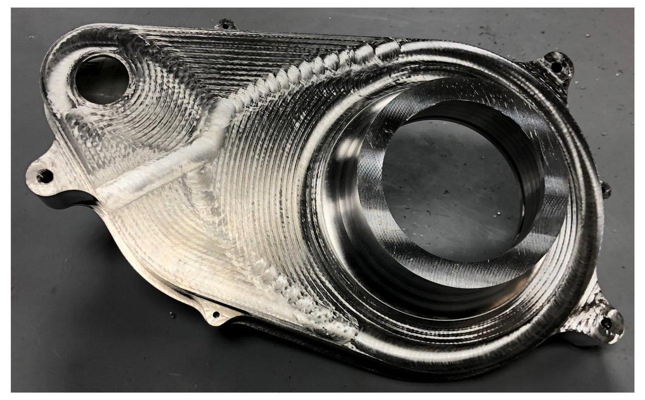
Gearbox Component Pictures

Input Shaft, Gear, and Bearing Assembly

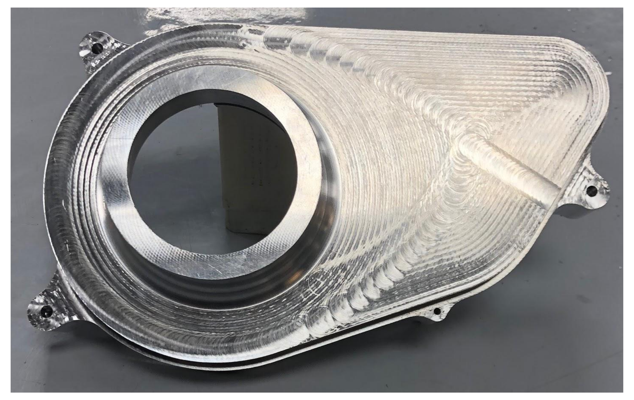
Intermediate Shaft, Gears, and Bearing Assembly

Driven Output Gear and Freewheel Casing Assembly

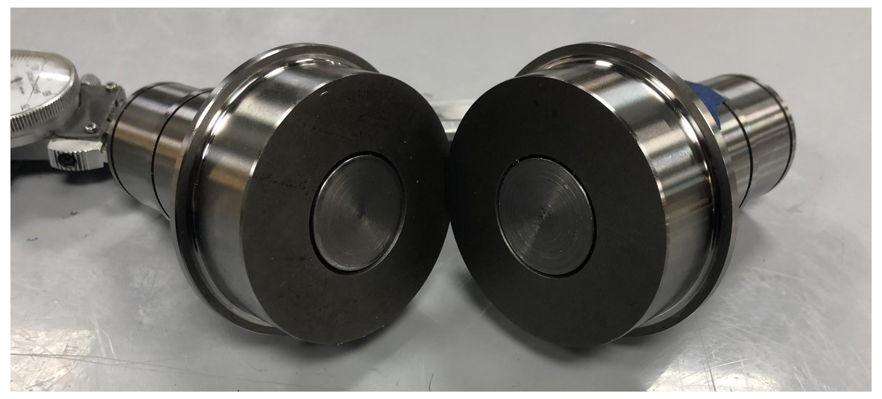
Left Gearbox Casing



Right Gearbox Casing



Left and Right Driven Output Shafts



The gearbox receives input torque from the CVT secondary pulley. Then, the input shaft rotational speed is reduced using an input gear, two intermediate gears on an intermediate shaft, and an output gear. Whereas the driven output gear used to spin on a single output shaft that linked rear wheels to each other, our gearbox's driven output gear rotates with an internal freewheel clutch housing that is constrained via two large outer bearings. This housing rotates the outer diameters of left and right freewheel clutches, which are suspended by left and right driven output shafts inserted into their inner diameters. The driven output shafts are constrained radially via bearings and axially via snap rings. The freewheel clutches are designed and implemented such that they lock when forward torque is applied and unlock when reverse torque is applied. During a left turn, this will result in all CVT torque going to the left wheel and the right wheel freely overrunning the left wheel. In a low-friction scenario, the gearbox will send equal torque to both wheels, and the wheels will spin at the same rate.

VALIDATION

Empirical Testing

We conducted empirical testing to determine the maximum load that our gearbox would experience. First, we strain gauged and calibrated a joint axle to collect torque and force measurements. Then, we installed the joint axle on last year's car and replicated its maximum load case to find maximum force and torque applied to the component. The maximum load case occurs during a drop test, where the car's rear wheels are lifted 3 feet in the air, the driver hits the gas pedal, and the rear tires are suddenly dropped on the ground. This test replicates landing a jump while on-throttle.

Joint Axle Calibrations

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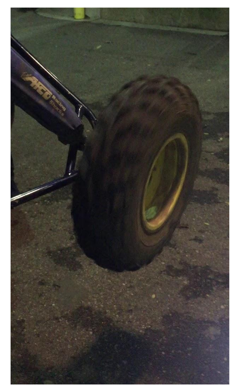
Drop Test



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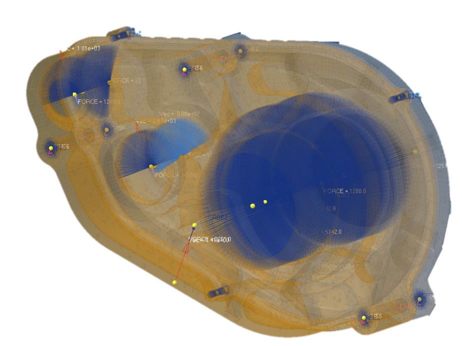
Maximum Load Case

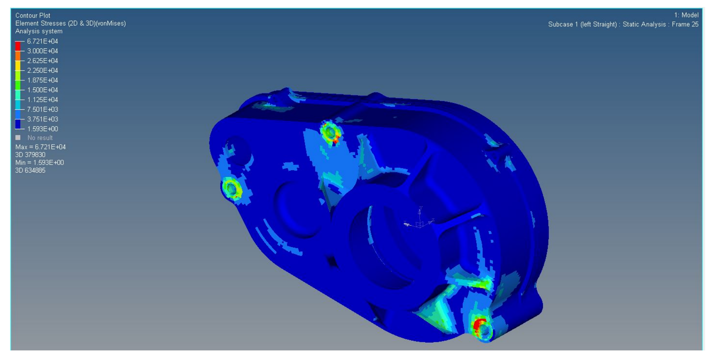
Analytical Testing

With our load cases experimentally derived, we developed free body diagrams to determine forces applied on shafts, bearings, and snap rings. Shaft thicknesses were designed for these load cases, while shaft outer diameters were unchanged due to the need for reverse-compatibility with previous gearboxes. Then, bearing sizes were selected such that they fit shafts and they could withstand our maximum load case for one million cycles. Next, snap rings were sized such that they could withstand the axial forces from the joint axles. Lastly, a finite element model was created containing the case geometry, constraints, and loads. Finite element analysis was then run to verify that the casing could withstand its maximum loadcase.

Finite Element Model



FEA Results



CONCLUSIONS

We designed and built the first ever gearbox with an integrated freewheel differential in the Baja SAE series. While we have not yet tested the performance and durability of our gearbox, our project has been successful in laying the groundwork for freewheel differential design and manufacturing. We have demonstrated that the freewheel differential is the best solution for the Baja team and that its integration into the gearbox is feasible.

FUTURE WORK

We will install this gearbox on the Baja car and perform maximum load and durability testing. Specifically, we want this gearbox to withstand three drop tests as well as four hours of obstacle-dense testing.

ACKNOWLEDGMENTS

- NSK Bearings
- Modified Gear and Spline Inc.
- Temp-Rite Steel Treating Inc.
- Michigan Baja Racing