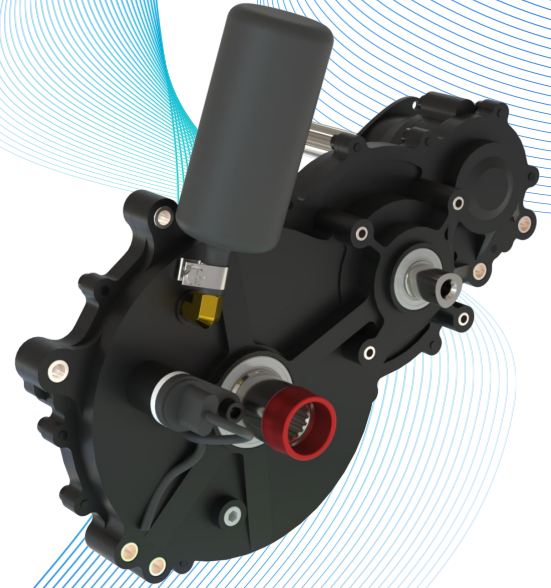


Rear Gearbox Design - RCA & Fatigue Optimized Design

Luis Daniel Weiss Quiroz
2024 & 2025 Seasons



Outline

1. About
2. Problem Statement
3. Constraints
4. Requirements
5. R&D
6. Design
7. Data Collection for Analysis
8. Analysis
9. Testing & Validation
10. Correlation of Analysis & Testing
11. Results
12. Appendix





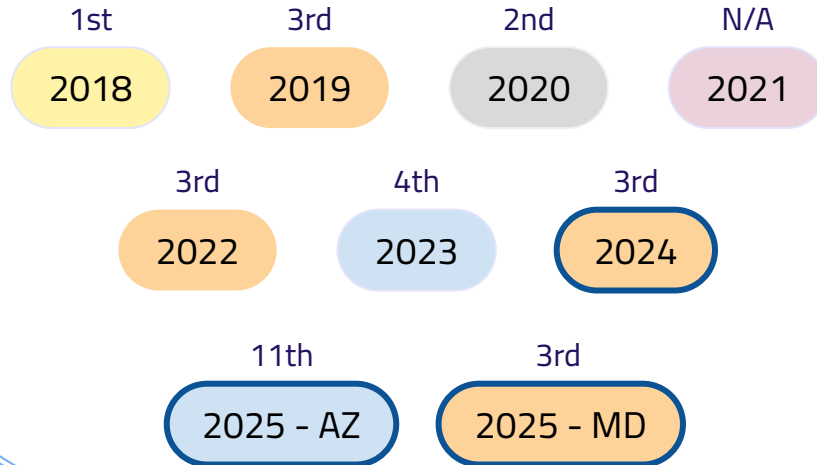
01

About

About RIT BAJA

Baja SAE is a collegiate engineering competition where students design and build an offroad race vehicle competing dynamic short courses, a 4hr Endurance Race, and design presentation all while conforming to the safety regulations of the competition.

Rochester Institute of Technology is one of the oldest Baja teams and has a history of being a top contender.





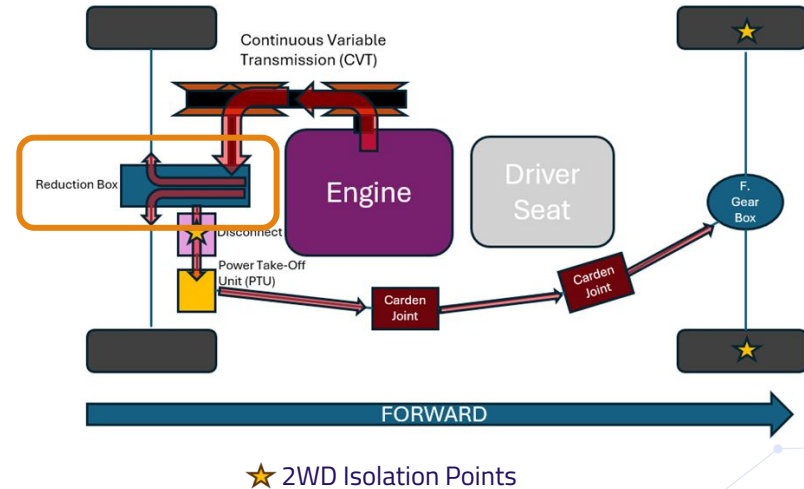
02

Problem Statement

Problem Statement

As the rear gearbox designer for the 2023-2024 & 2024-2025 vehicles, my task was to design a geared reduction box for the rear drivetrain that could withstand the extreme loads experienced during competition while delivering competitive speed and acceleration.

R24 & R25 Driveline Architecture





03

Constraints

Budget

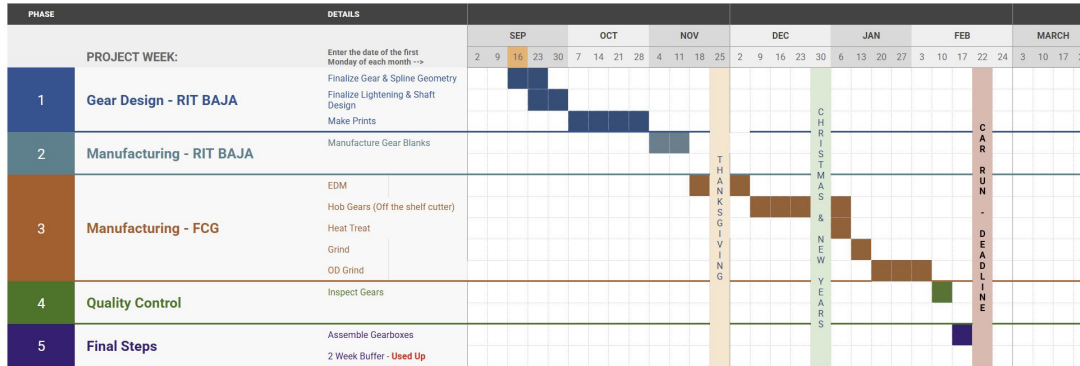
RIT BAJA Budget 2024-2025 Subsystem: Reduction						
Category	Description/Part Number	Vendor	Individual Cost	Quantity	Total Cost	Additional Notes
Fluids	Gear Oil	Redline	\$ 20.00	8	\$ 160.00	
Hardware	Magnetic Pipe Plug	McMaster	\$ 7.00	4	\$ 28.00	
Hardware	Jack Screws	McMaster	\$ 14.55	1	\$ 14.55	
Hardware	1808 SS Locking Inserts	McMaster	\$ 2.50	30	\$ 75.00	
Hardware	Output Shaft Steel	Online Metals	\$ 250.00	1	\$ 250.00	
Hardware	Breather	Amazon	\$ 15.00	5	\$ 75.00	
Other	RTV	Amazon	\$ 10.00	2	\$ 20.00	
Category	Old Reduction Box Repair	Various	\$ 50.00	1	\$ 50.00	
Other	Shipping	Misc	\$ 150.00	1	\$ 150.00	
Hardware	Bearings	123 Bearings	\$ 50.00	30	\$ 1,500.00	
Hardware	Seals	Motion	\$ 10.00	34	\$ 340.00	
Materials	Case Half Blanks	TBD	\$ 200.00	6	\$ 1,200.00	
Total					\$ 3,862.55	

2024-25 Budget, ended up being \$479.80 over budget at the end of the season due to the need for additional gear stock.

Timeline

RIT BAJA Gear Timeline

COMPANY NAME Forest City Gears
DATE 9/19/24



Original R25 gear timeline. Delayed by ~4 weeks due to delays in coordinating EDM sponsors.

FCG Responsibility RIT Responsibility

January 2025

SUN	MON	TUE	WED	THU	FRI	SAT
			1 EDM	2 EDM	3 EDM	4
5	6 EDM	7 EDM	8 EDM	9 EDM	10 EDM	11
12	13 EDM	14 EDM	15 EDM	16 EDM	17 EDM	18 Ship to IL
19 Ship to IL	20 Hob	21 Hob	22 Hob	23 Hob	24 Hob	25
26	27 Hob	28 Hob	29 Hob	30 Ship to RIT	31 Ship to RIT	

February 2025

SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3 HT	4 HT	5 HT	6 HT	7 HT	8 PR
9	10 HT	11 HT	12 Shipping	13 Grind	14 Grind	15
16	17 Grind	18 Grind	19 Grind	20 Grind	21 Grind	22 PR
23	24 Grind	25 Grind	26 Grind	27 Ship to MPI RIT	28 Ship to RIT	

Updated timeline after meeting with gear manufacturing sponsor.



04

Requirements

R24 Goals



Reduce Effective Mass
Moment of Inertia by 15%



Achieve a 40 Hour
Fatigue Life

R25 Goals



REDUCE
SUBSYSTEM
WEIGHT BY 8.3%



REDUCE MASS
MOMENT OF
INERTIA BY 5%



ACHIEVE AN 18 HR
MINIMUM FATIGUE LIFE FOR
ALL COMPONENTS



R24 & R25 Rear Gearbox goals. The goals we designed to help work towards vehicle speed, acceleration, and service-free life goals.



05

R & D

Research

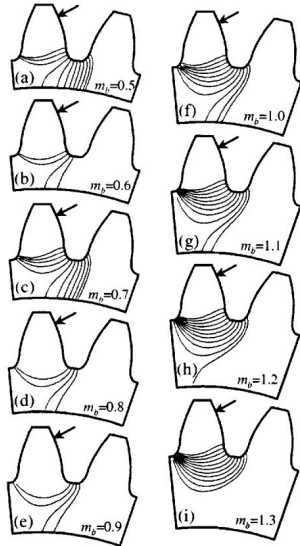


Fig. 7. Effect of backup ratio and initial crack location on propagation path.

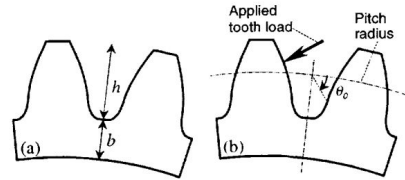


Fig. 4. Definition of terms. (a) backup ratio, $m_b = b/h$, (b) initial crack location angle, θ_o .

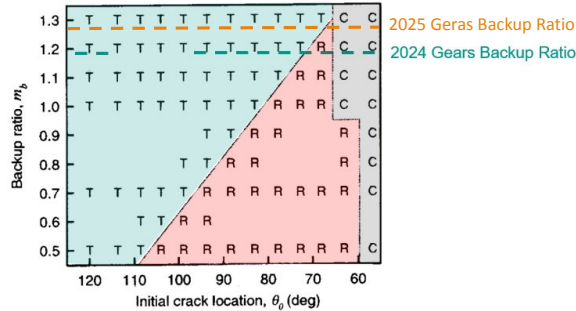
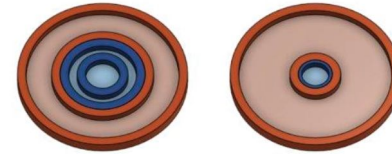


Fig. 9. Effect of backup ratio and initial crack location on crack failure modes, T=tooth fracture, R=risk fracture, C=compression (no crack propagation).



- G2 Required Material
- G2 Lightning
- MS Required Material
- MS Lightning

Comparison of room for gear lightning
*MS = Intermediate Shaft



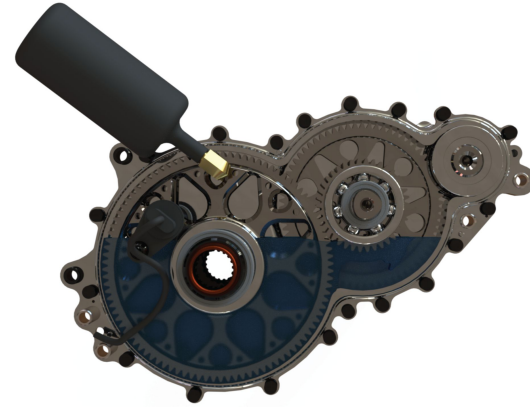
06

Design

Design



R24 Reduction, Outboard, and Hubs Assembly

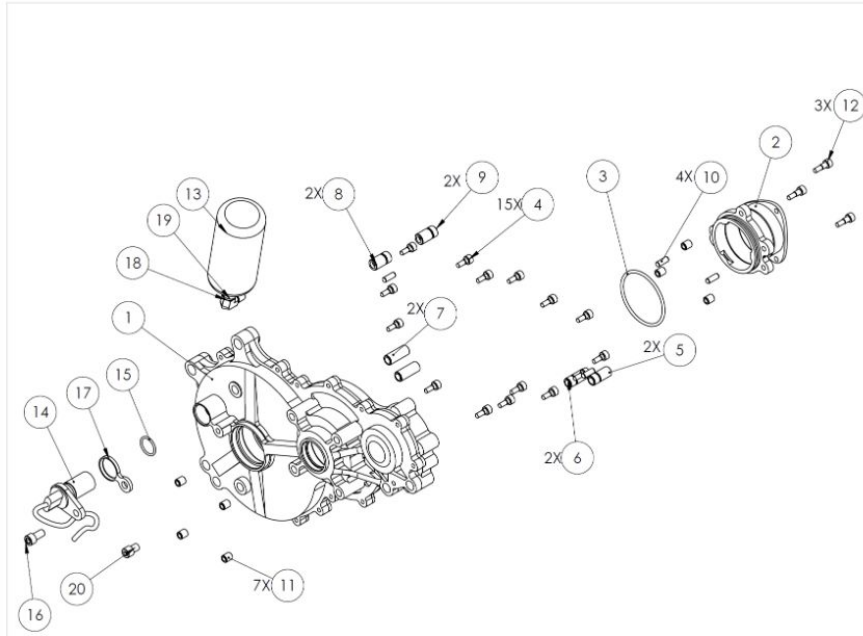


R24 Reduction Box Assembly



Previous Vehicle Intermediate Shaft compared to
R24 Intermediate Shaft

Design



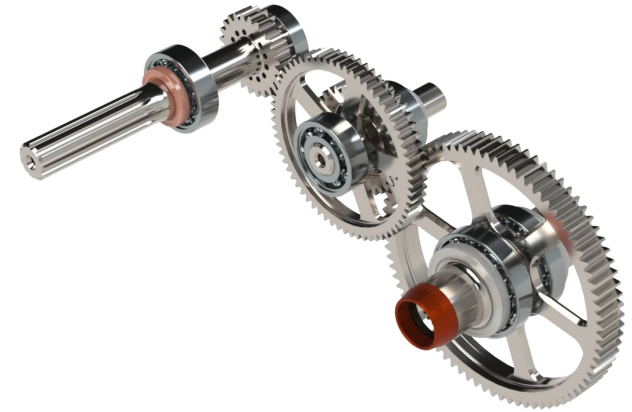
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	R25 Case Halves		1
2	Third Case		1
3	9452K142	Oil-Resistant Buna-N O-Ring	1
4	91251A350	Black-Oxide Alloy Steel Socket Head Screw	15
5	R25 L Mounting Inserts		2
6	R25 R Mounting Inserts		2
7	R25 Rear Mounting Inserts		2
8	R25 Break R Insert		2
9	R25 Break L Insert		2
10	98381A505	Dowel Pin	4
11	93904A612	MIL. Spec. Key-Locking Insert	7
12	91251A356	Black-Oxide Alloy Steel Socket Head Screw	3
13	Breather Dummy CAD		1
14	Gear Tooth Sensor		1
15	9452K6	Oil-Resistant Buna-N O-Ring	1
16	91251A537	Black-Oxide Alloy Steel Socket Head Screw	1
17	Gear Sensor Plastic Spacer		1
18	53525K11	Brass Barbed Hose Fitting for Air and Water	1
19	53175K23	Tight-Seal Bolt Clamps for Soft Hose and Tube	1
20	1457N11	Low-Pressure 316 Stainless Steel Plug with Hex Drive	1

Exploded view & BOM of R25 rear gearbox housing & hardware.

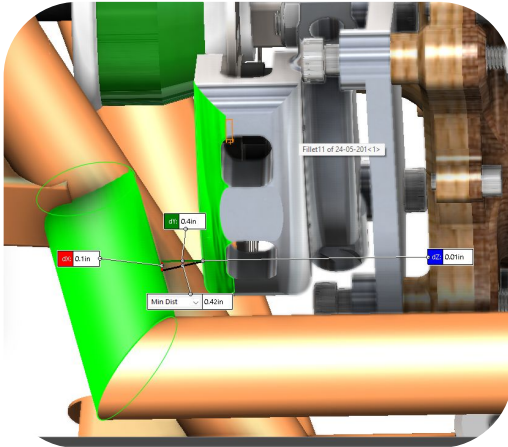
Design

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	25-07-202		1
2	25-07-203		1
3	25-07-204		1
4	25-07-205	Output Shaft	1
5	25-07-206		1
6	25-07-201		1
7	SKF_17X29X5 HMSA10 RG		1
8	SKF_30X42X6 HMSA10 RG		2
9	SKF_20X30X5 HMSA10 V		1
10	skf-6004		1
11	skf-6203		2
12	skf-61904		1
13	skf_bearing_61806_2		2
14	R25 IS R Spacer		1
15	G1 R Spacer		1
16	OS Spacer		2
17	R25 MS L Spacer		1
18	R25 MS R Spacer		1
19	Right OS CV Spacer		1

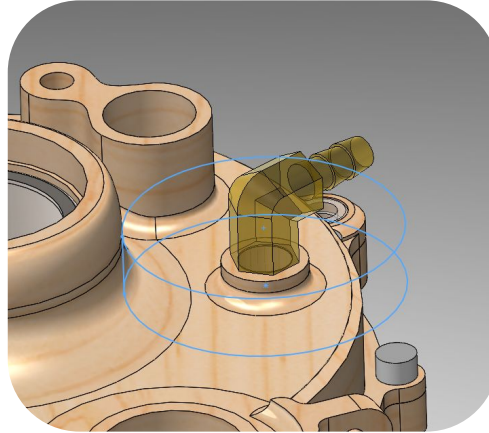
Exploded view & BOM of R25 rear gearbox gears.



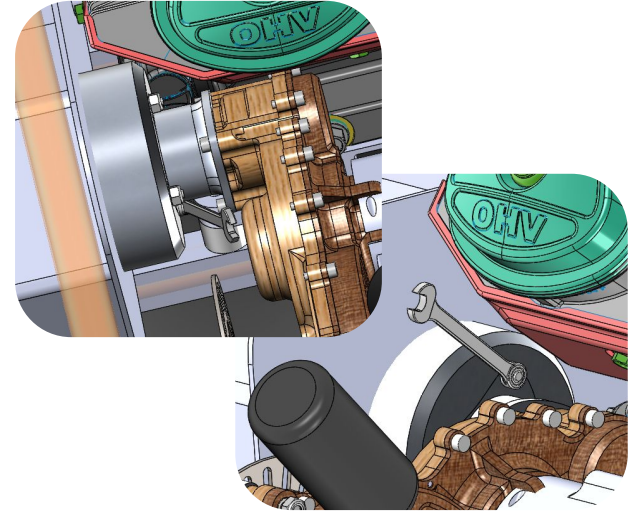
Design - Serviceability



Checking Clearance Between
Rear Brake Caliper and Frame.

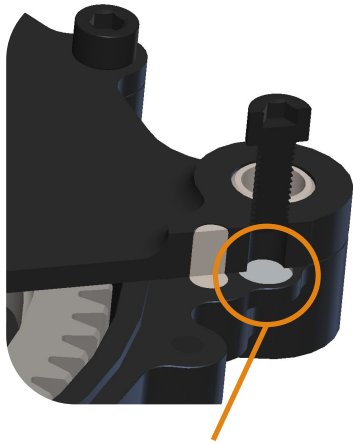


Checking Clearance to Screw
in Breather Adapter.



Checking Clearance for Tool
Access.

Design - Serviceability



Offset face to prevent damage to sealing surface from jack screws.



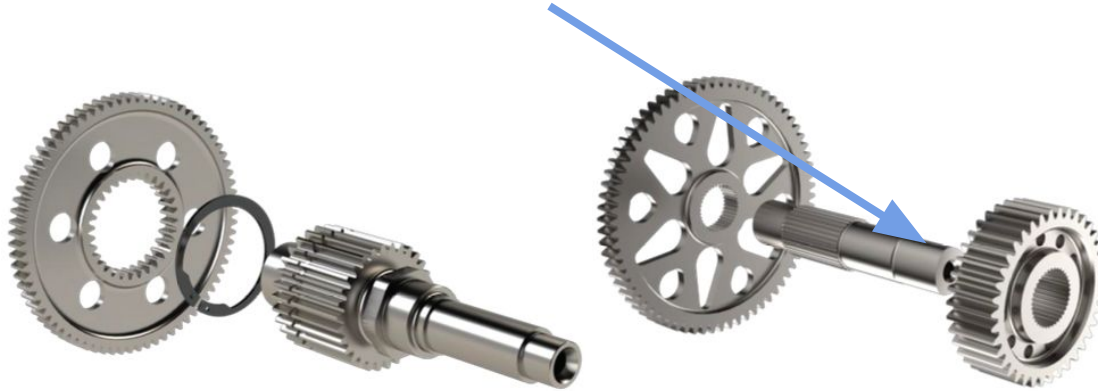
3D Printed Jig to remove third case



Protrusions to press against

Design - Manufacturability

P3 Connection to 4WD Disconnect Allows for In House Manufacturing of Male & Female Profiles

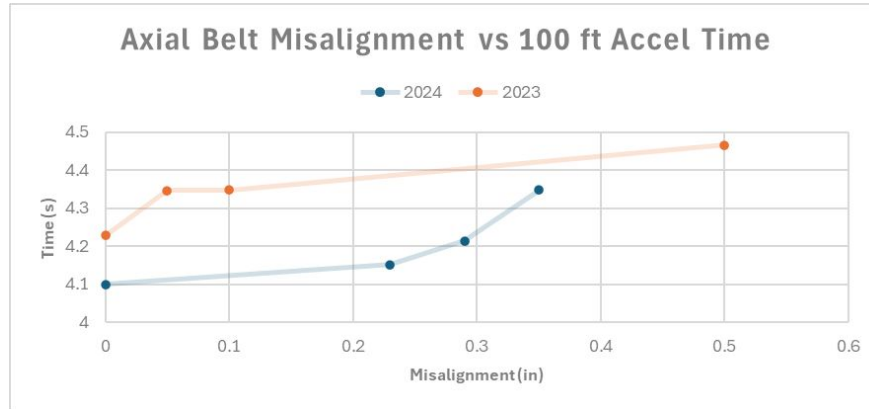


Separation of Gear & Shaft Reduces Material Removal

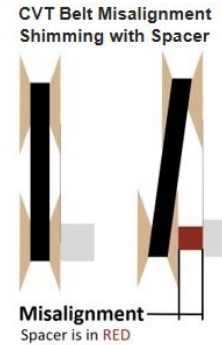
Design - Manufacturability



Spline Selection Allows for in House Manufacturing of the Male Input Shaft Spline



Graph Shows the the Results of Testing Done to Validate the Need for a Sliding Torque Transfer Profile on the Input Shaft.

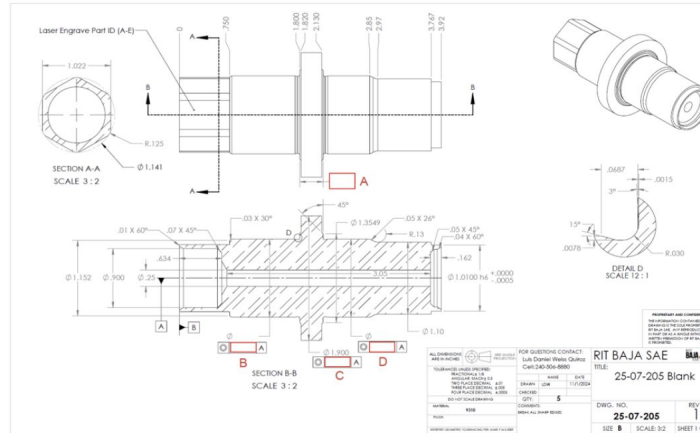


Design - Quality Control

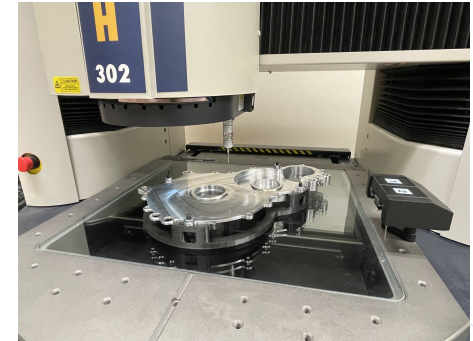
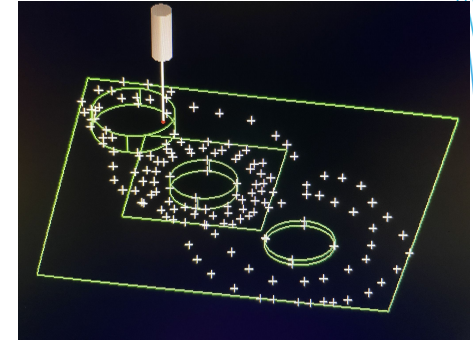
Date of Inspection: _____
Inspector: _____

Part ID	Measurement [in]			
	A	B	C	D
A	✓0.31000	✗1.19085	✗1.90285	✗1.90350
B	✗0.31030	✗1.19085	✗1.90275	✗1.90250
C	✗0.31070	✗1.19085	✗1.90295	✗1.90350
D	✗0.31040	✓1.19080	✗1.90300	✗1.90450
E	✗0.31095	✗1.19085	✗1.90275	✗1.90300
F	✗0.31080	✗1.19095	✗1.90285	✗1.90300

	Measurement [in]			
	A	B	C	D
Nominal	0.3100	1.1908	1.9	1.9
Upper	0.3110	1.1928	1.905	1.905
Lower	0.3100	1.1908	1.90	1.90



Output shaft inspection results.



Housing inside of CMM.

Design - Material Selection

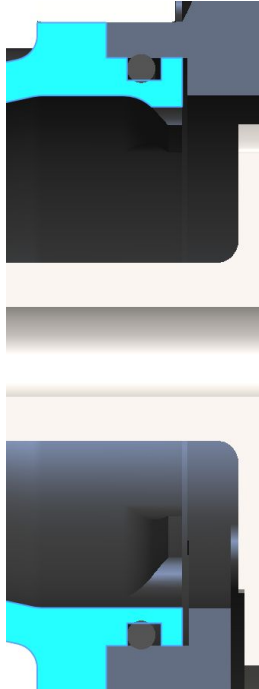
Material	Part(s)	Yield Strength	Ultimate Strength	Young's Modulus	Source
E9310	Gears & Shafts	162767 psi	194349 psi	29000000 psi	Gear Bible

High strength, toughness, & manufacturable.

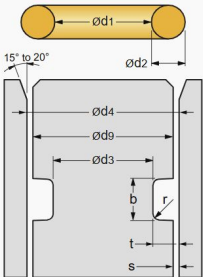
Alternative Materials

Material	Part(s)	Yield Strength	Ultimate Strength	Source	Downside
4320	Gears & Shafts	150100 psi	187800 psi	Matweb	Lower strength & fatigue life.
C64	Gears	199000 psi	229000 psi	Carpenter Technologies	Manufacturability
8620	Gears & Shafts	157400 psi	200000 psi	Matweb	Lower toughness (low Nickel alloy)

Seals - Parker® O-Ring Calculator



Sizing Selection



Back-up Rings
Amount

O-ring Size Code

OR		Nominal	Tolerance	Limit	Min	Max	
ed1	Inner Diameter	1.987	AS 568	± 0.016	1.971	2.003	inch
ed2	Cross section	0.103		± 0.003	0.100	0.106	inch

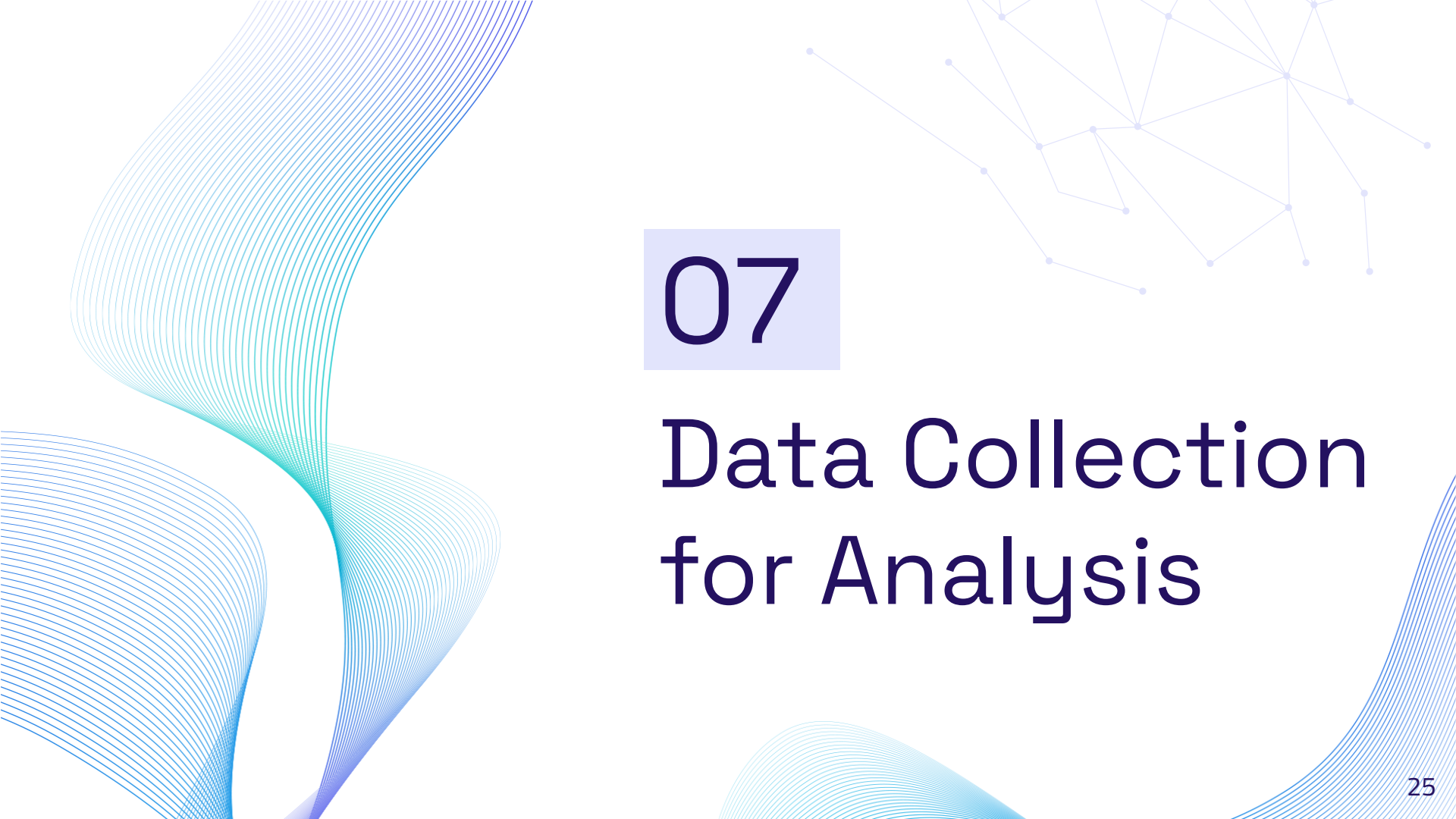
Groove		Nominal	Lower	Upper	Min	Max	
ed4	Bore Diameter	2.1655	0.0000	0.0010	2.1655	2.1665	inch
ed9	Piston	2.1655	-0.0020	-0.0010	2.1635	2.1645	inch
ed3	Groove	2.0050	-0.0020	0.0000	2.0030	2.0050	inch
b	Width	0.1250	0.0000	0.0050	0.1250	0.1300	inch
r	Radius	0.0050	-0.0040	0.0040	0.0010	0.0090	inch

Results

● Recommended ▲ Warning ● Critical

Results	Recommendation	Concentric		Eccentric		
		Min	Max	Min	Max	
t Depth + gap		0.0803	0.0818	0.0793	0.0833	inch
s gap		0.0005	0.0015		0.0030	inch
Stretch of OR inner	0 ... 6	●	● 1.7			%
Compression of OR ed2	17 ... 24	● 17.0	▲ 24.3	● 15.4	▲ 25.2	%
Gland fill	60 ... 90	● 73.4	● 89.3			%
Total deformation force						lbf

Used Parker® O-Ring Calculator to select o-ring & o-ring groove dimensions & tolerances for all o-rings.



07

Data Collection for Analysis

Data Collection for Analysis

Race Box – GPS & IMU

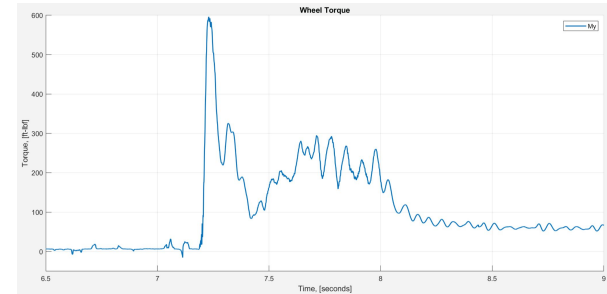
Collecting both GPS & vehicle acceleration in all six degrees of freedom, the Race Box allows RIT BAJA to refine our vehicle models.



Testing of the R24 vehicle at RIT BAJA's testing track.

Wheel Force Transducer

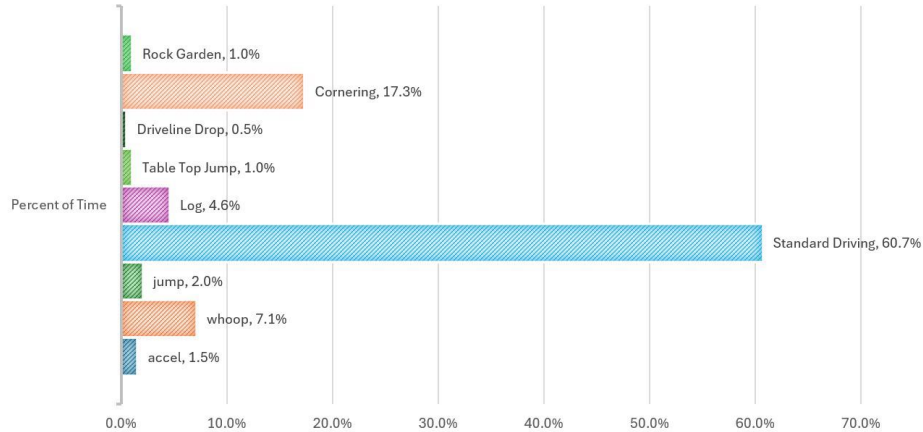
Collecting loads in all six degrees of freedom, the wheel force transducer allows RIT BAJA to design heavily optimized components that can withstand the harsh impacts seen at races.



R23 Wheel Force Transducer Data of the Max 2WD Torque

Duty Cycle Design

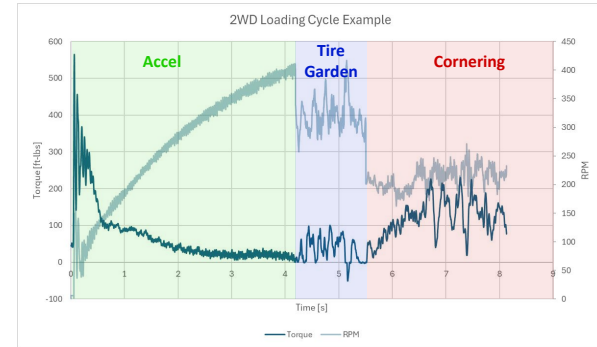
CALI ENDURANCE



Obstacle Breakdown of Worst Race

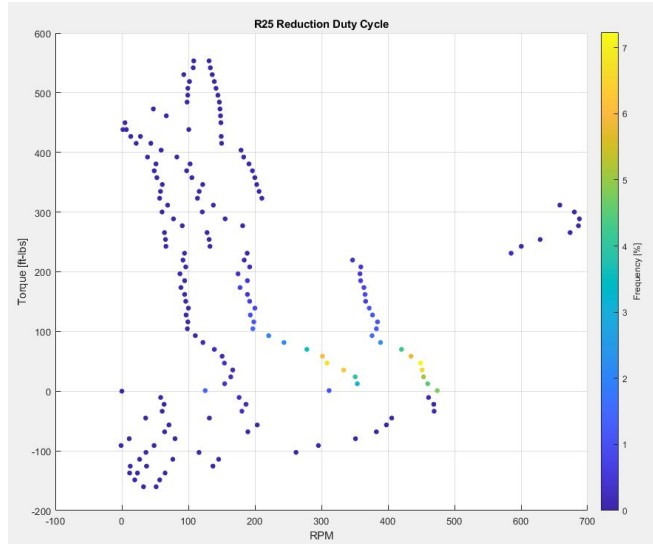


GoPro Footage Used to Count Obstacles



3 WFT data sets combined

Duty Cycle Design



Rainflow Used in KISSsoft Analysis

1.4 FOS R25 Reduction Simplified Duty Cycle				
	Common	Mid	Max	
Frequency [%]	53%	45%	2%	
RPM OS	386	320	165	Sum
Cycles IS #	1,819,703	1,287,078	22,404	3,129,185
Cycles MS #	794,041	561,626	9,776	1,365,443
Cycles OS #	309,870	219,171	3,815	532,856
Torque IS [ft-lbs]	11	61	132	
Torque MS [ft-lbs]	26	139	302	
Torque OS [ft-lbs]	66	356	775	
Belt Tension [lb]	-350	-350	-350	
Run Time [hr]	25.2			

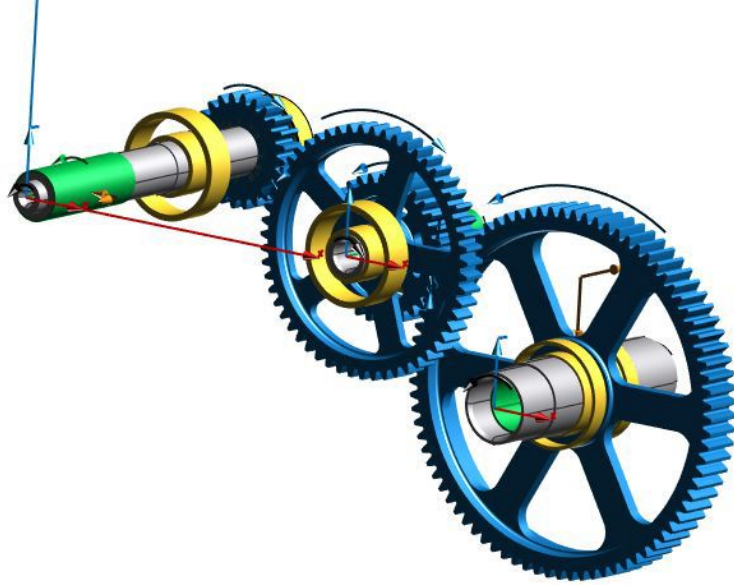
Duty Cycle Used in ANSYS Analysis



08

Analysis

Analysis - Gears - KISSsoft



R25 rear gearbox in KISSsoft's system module.

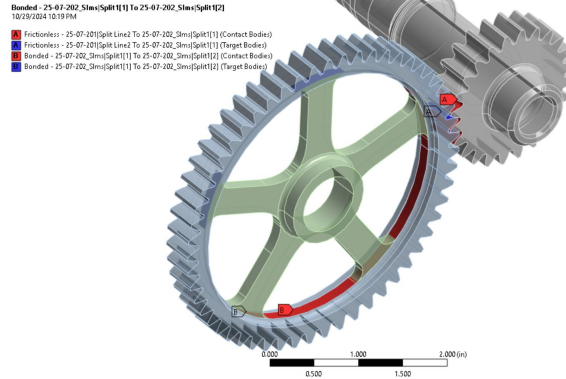
Component	Root Life (hr)	Flank (hr)
G1	71.6	2095.3
G2	71.8	8941.3
G3	136.5	42985.7
G4	141.8	1.412e+5

R25 gear lifetime results from KISSsoft.

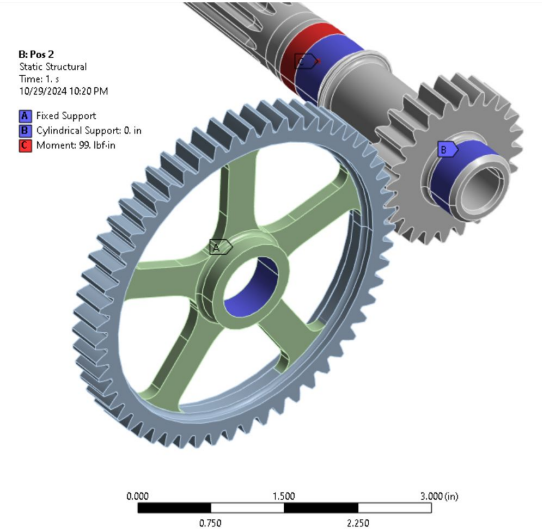
Analysis - Gear Web - Conditions



Mesh



Connections

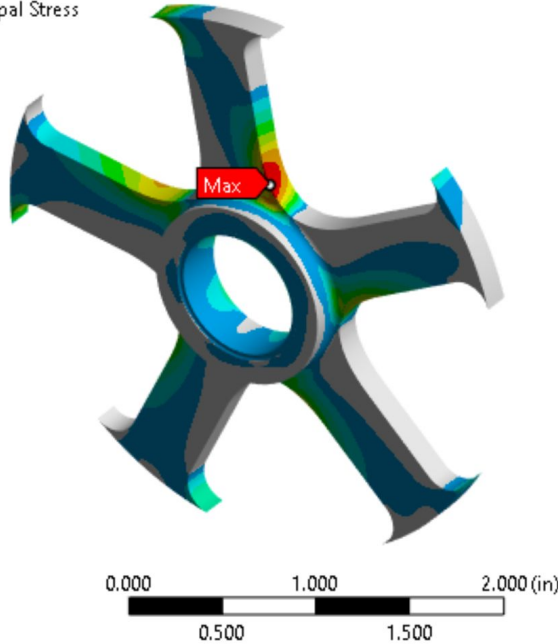
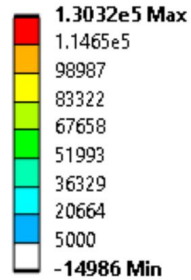


Boundaries

Analysis - Gear Web - Results

B: Pos 2

Maximum Principal Stress
Type: Maximum Principal Stress
Unit: psi
Time: 1 s
10/30/2024 8:38 PM



ANSYS FEA results of G2 web.

RIT Baja Fatigue Calculator			
Total Damage: 76%			
Minimum FOS: 1.02			

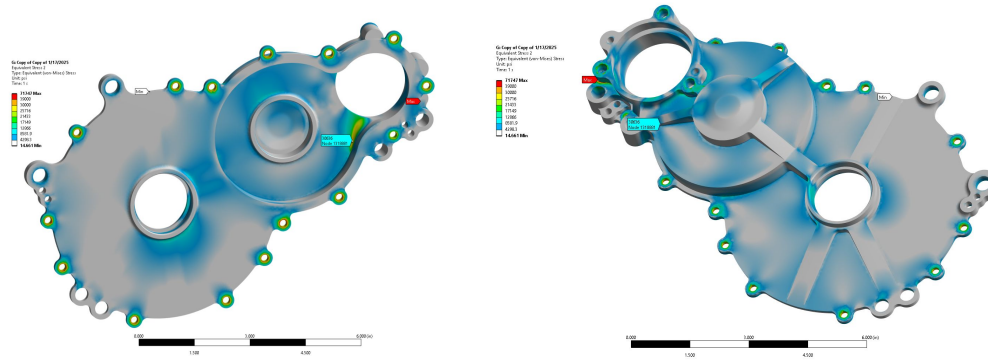
Given Values	Common			Mid	Max	
a. Maximum Stress		11092	59924	130320	[psi]	
b. Minimum Stress		0	0	0	[psi]	
c. Cycles		7.94E+05	5.62E+05	9.78E+03	[cycles]	
d. Stress Conc. Factor, Kt		1.17	1.17	1.17	[factor]	
e. Notch Radius, r		0.275	0.275	0.275	[in]	
f. Surface Finish		Machined	Machined	Machined	List	
g. Material		8620, Carburized, 43HRC Core, 5	8620, Carbu	8620, Carbu	List	

$$\sigma = A + N^B$$

Final	Common			Mid	Max	
FOS		13.83	2.27	1.02	[FOS]	
Survivable Cycles		1.0E+99	1.0E+99	1.3E+04	[cycles]	
Percent Damage Done		0%	0%	76%	[% Damage]	

Fatigue analysis results of G2 web.

Analysis



ANSYS FEA results of R25 housing.

RIT Baja Fatigue Calculator			
Total Damage: 101%			
Minimum FOS: 1.00			Read Below
Common			
a. Maximum Stress	30636	[psi]	Sim uses 1.4x Load
b. Minimum Stress	0	[psi]	
c. Cycles	2.21E+04	[cycles]	
d. Stress Conc. Factor, Kt	1.00	[factor]	Total G1 rotations at max and mid load. 1.4 FOS applied.
e. Notch Radius, r	0.050	[in]	
f. Surface Finish	Machined	List	Kt Online Calculator
g. Material	6061-T6	List	

Fatigue analysis results of R25 housing.

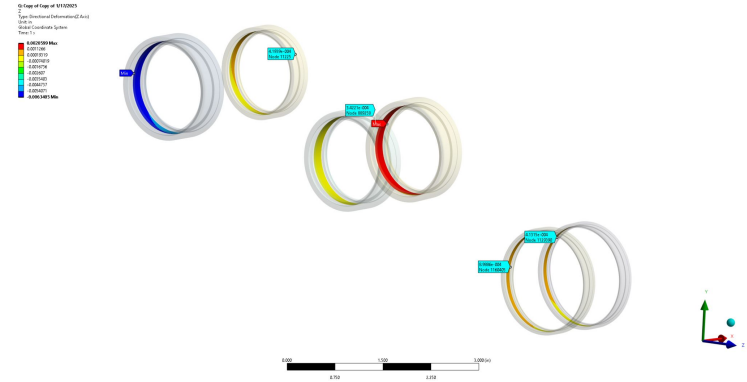
Analysis

Component	L0.03 Life (hr)
ISL	1069
ISR	794
MSL	1095
MSR	1379
OSL	66
OSR	3579
System Life	7.4

Car	System	Reduction Component
99.99%	99.9995%	99.99997%
99.95%	99.998%	99.9999%
99.90%	99.995%	99.9997%
99.00%	99.954%	99.997%
97.50%	99.885%	99.99%
95.00%	99.767%	99.99%
90.00%	99.522%	99.97%
85.00%	99.264%	99.96%
80.00%	98.991%	99.94%
50.00%	96.898%	99.83%

22 Systems 18 Components

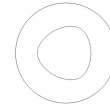
Bearing life KISSsoft analysis.



	IS		MS		OS	
Shaft Length [in]	2.26		1.53		0.83	
	L	R	L	R	L	R
y [in]	-0.00385	0.00112	0.00212	0.00487	-0.00139	0.00070
z [in]	-0.00634	0.00042	0.00034	0.00206	0.00090	0.00041
Δ y [in]	5.0E-03		2.7E-03		2.1E-03	
Δ z [in]	6.8E-03		1.7E-03		4.9E-04	
Δ [in]	8.4E-03		3.2E-03		2.1E-03	
Misalignment [arc min]	12.8		7.3		8.9	

ANSYS misalignment analysis.

Analysis - KISSsoft - P3



Polygon P3G-Profile DIN 32711-1:2009

d_1 [mm]	d_2 [mm]	d_3 [mm]	e [mm]	y
14.0000	14.8800	13.1200	0.4400	1.4400
16.0000	17.0000	15.0000	0.5000	1.4400

Operating data

Calculation method: Niemann/Winter

Type of loading: No alternating torque

Nominal torque T_n : 260.0000 ft*lb

Number of changes of load direction N_v : 100000

Maximum torque T_{max} : 260.0000 ft*lb

Number of load peaks N_L : 2800000

Application factor K_A : 1.0000

Geometry

Supporting length l_b : 0.7500 in

Small outside diameter of hub D_1 : 1.1350 in

Materials

Shaft: Case-hardening steel 18 NiCr 5-4, case-hardened

Hub: Case-hardening steel 18 NiCr 5-4, case-hardened

Results (basic calculation)

	Shaft	Hub
Pressure stress at T_n (lb/in ²)	84799.8322	84799.8322
Pressure stress at T_{max} (lb/in ²)	84799.8322	84799.8322
Safety at T_n	1.90	2.20
Safety at T_{max}	2.20	2.54



09

Testing & Validation

Testing & Validation

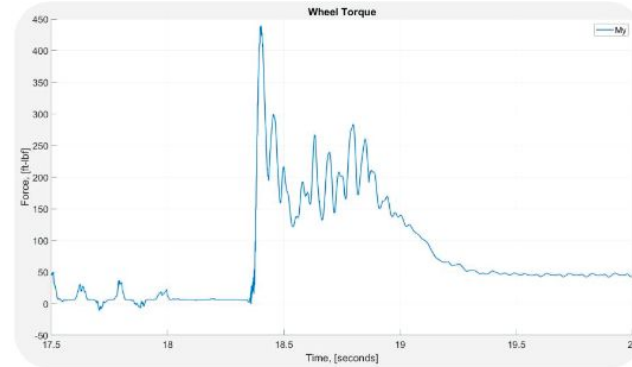


Test Track Overview - Designed to Mimic CA Endurance Race

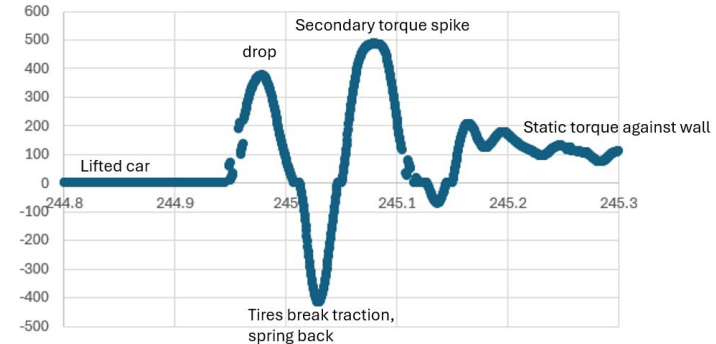
Testing & Validation



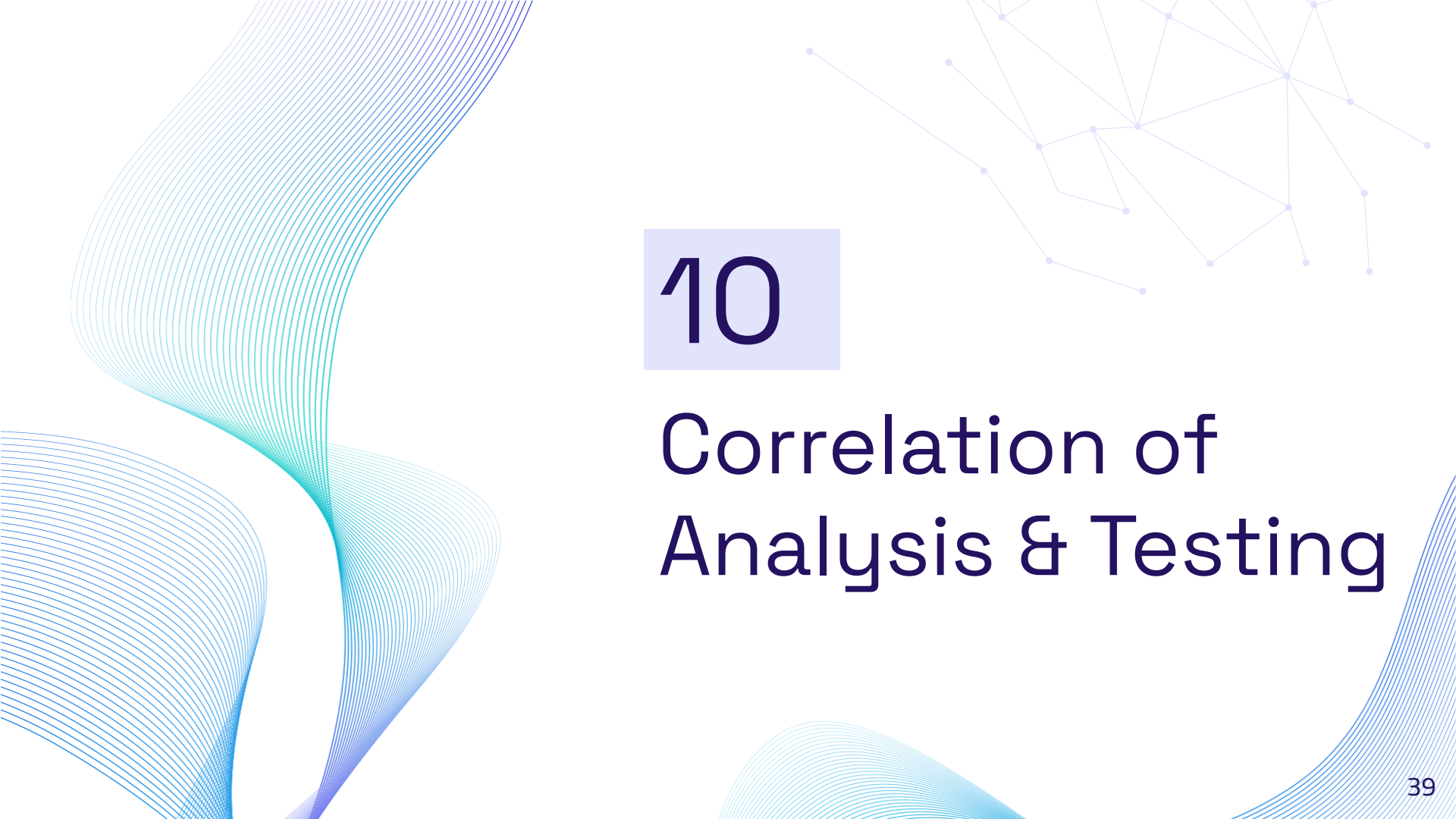
Driveline Drop Test on R24



2024 Wheel Force Transducer Data of the Max 2WD Torque.



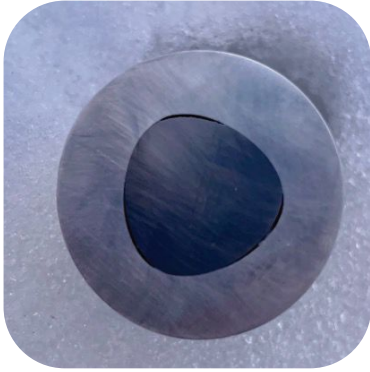
2025 TeCat Data of the Max 2WD Torque.



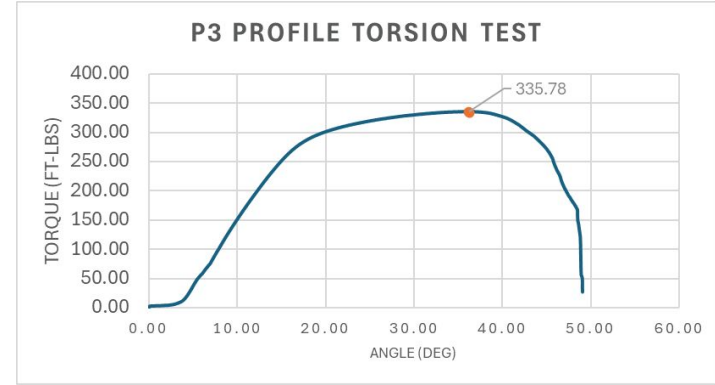
10

Correlation of Analysis & Testing

Correlation of Analysis & Testing



Designed to 330 ft lbs
Broken PC3 After the Torsion Test.

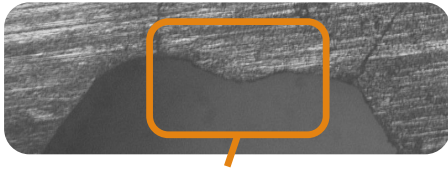


Torsion Test Data.

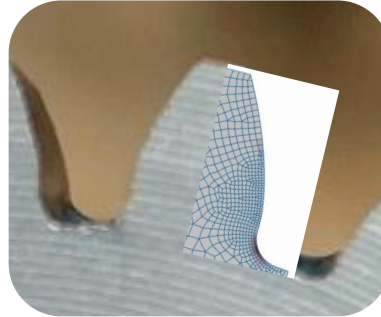


Torsion Test Set-Up.

Correlation of Analysis & Testing



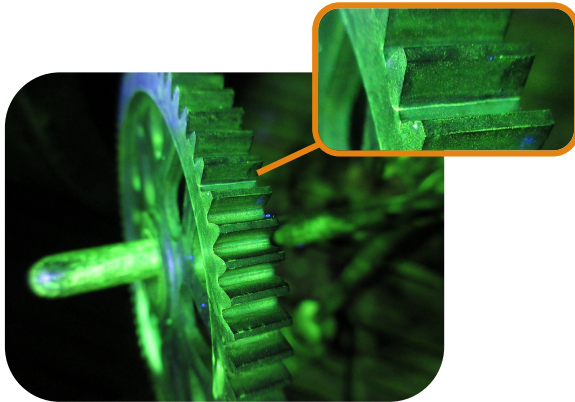
Start & End point of EDM.



KISSsoft FEM result overlaid on gear root failure.



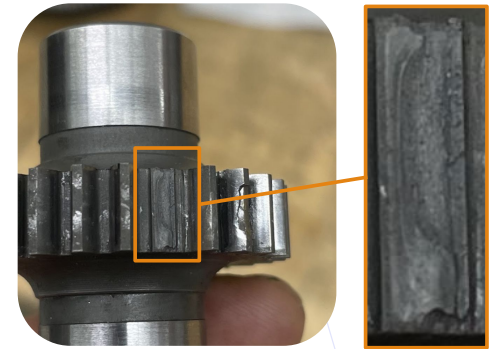
Angled view of gear root failure.



MPI of mating gear.



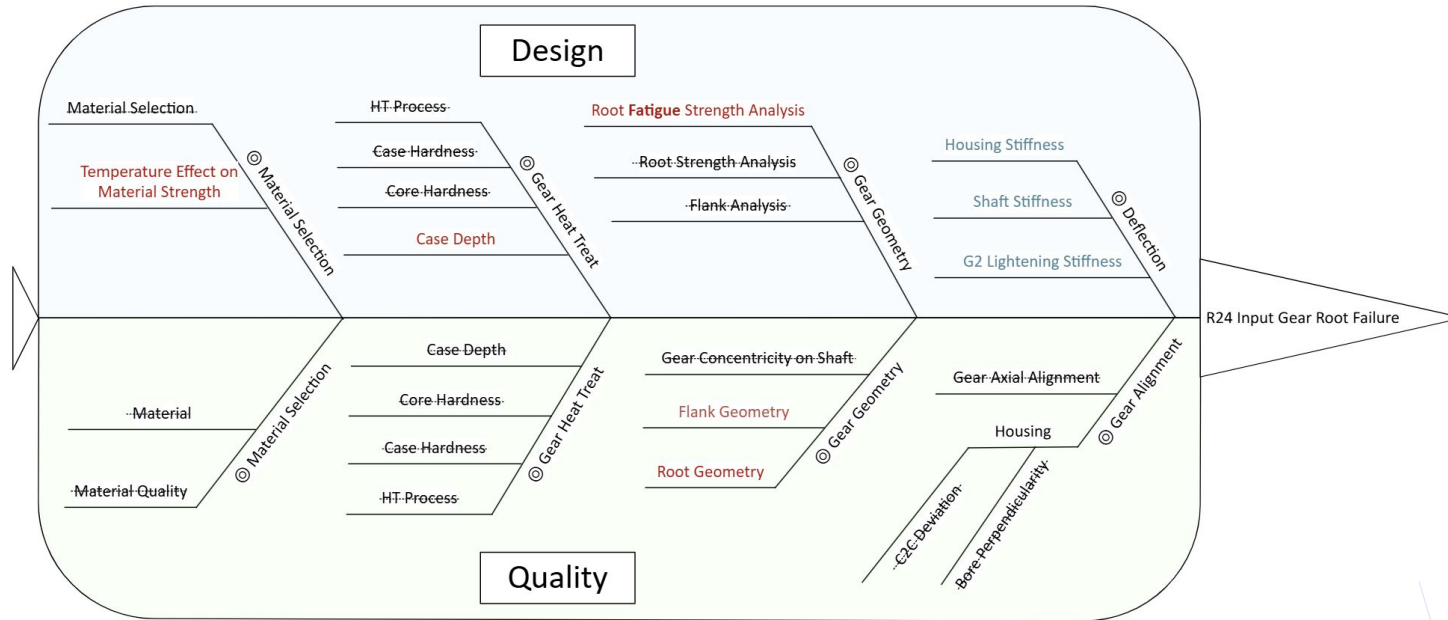
Side profile of gear root failure.



Zoomed in view of gear root failure.

Correlation of Analysis & Testing

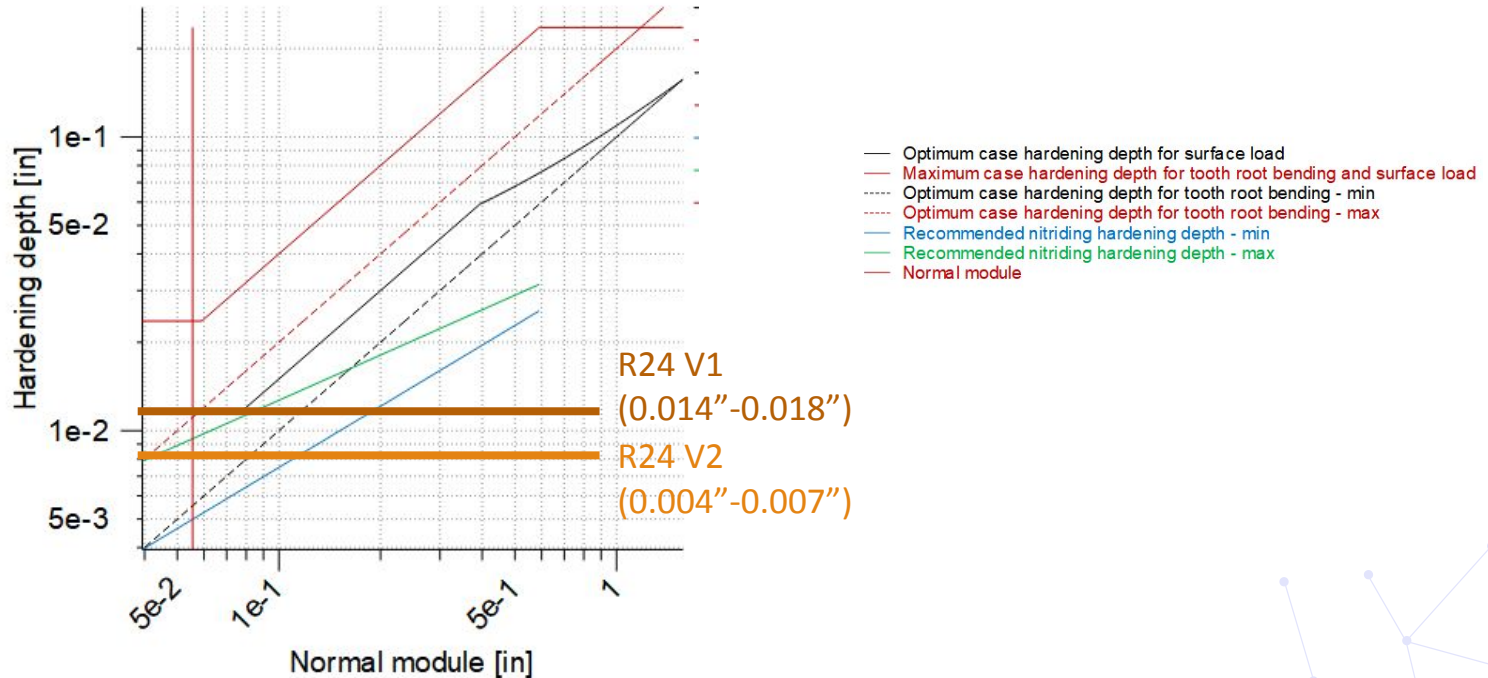
R24 Input Gear Failure Root Cause Analysis



Fishbone diagram of R24 root failure.

Correlation of Analysis & Testing

ISO 6336 Case Depth Recommendation for G1 (Using KISSsoft)



Correlation of Analysis & Testing

Initial Analysis

Max Torque (100 Cycles)	G1	G2
Root Safety	1.016	1.229
Max RPM (40 hr)	G1	G2
Root Safety	1.584	1.796

Corrected Analysis of Rev 1

	G1	G2
Root Lifetime (hr)	18.5	251.1

Analysis of Rev 2

	G1	G2
Root Lifetime (hr)	41.3	636.9

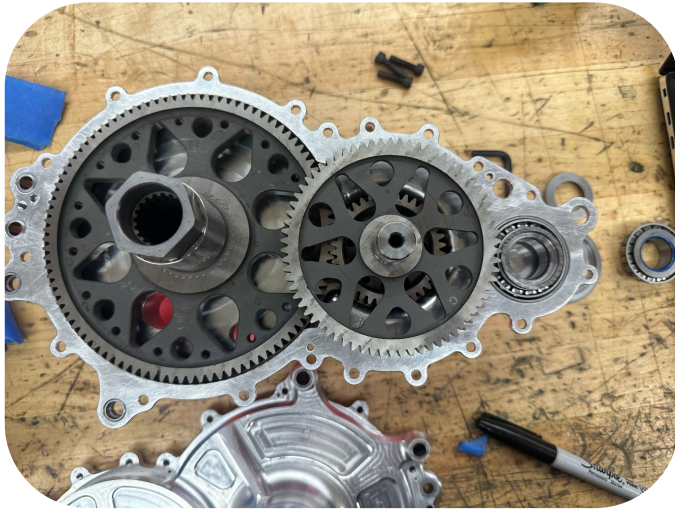
The initial analysis used an incorrect & oversimplified duty cycle. The corrected analysis used a rainflow which encompassed more of the loads seen in the gear's lifetime. A Rev 2 was designed using the new analysis and has not failed since installation.



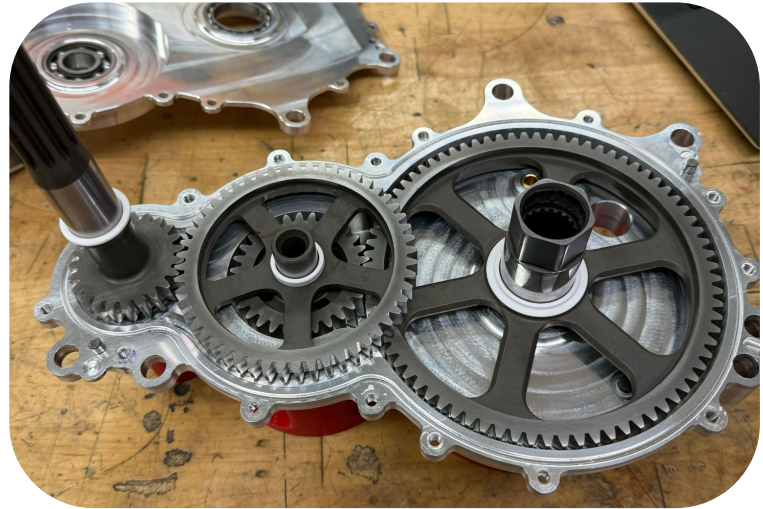
11

Results

Results



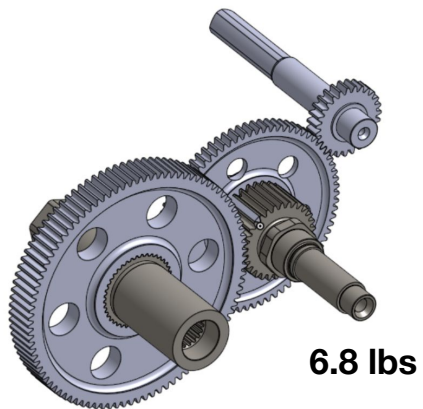
R24 Rear gearbox interior.



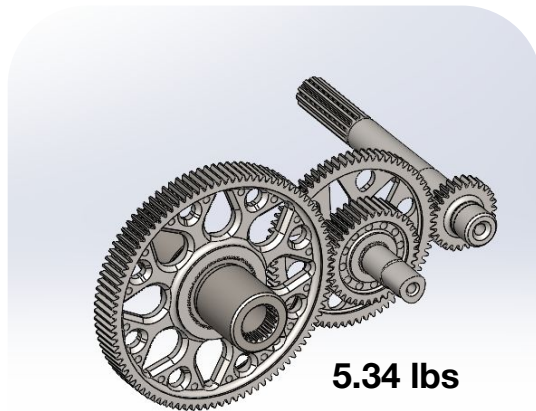
R25 Rear gearbox interior.

Results

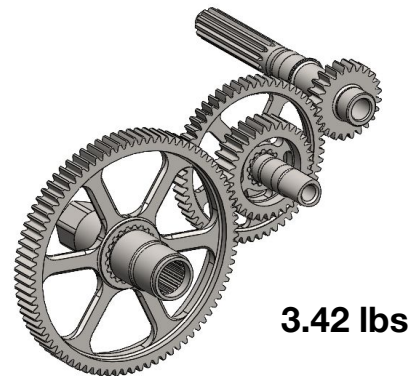
R23



R24

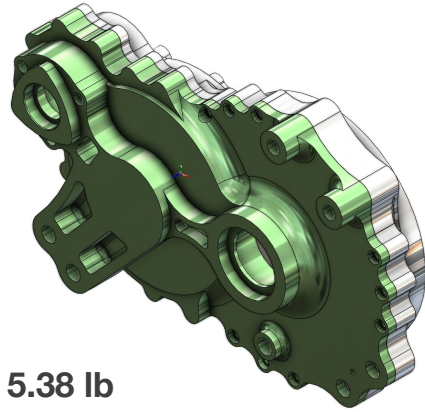


R25

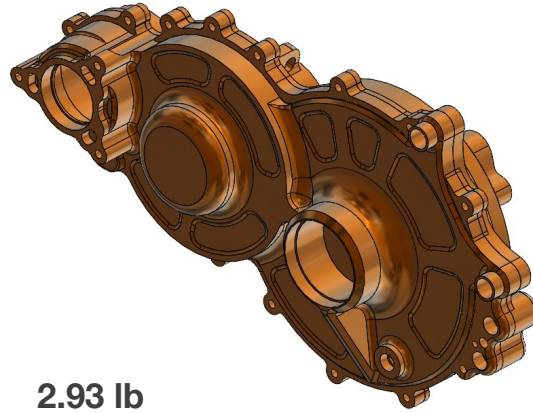


Results

R23



R24



R25





Thanks!





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Appendix

Duty Cycle Design

2WD Loading Overview

*Modified time & impacts is used to find worst case race based off the type of impacts that are seen. Based on max load seen from WFT.

Max Wheel Torque [ft-lbs]	Severity	Event
435	91%	Accel
300	63%	Whoop
294	61%	Jump
65	14%	Max
294	61%	Log
294	61%	Table top jump
348	73%	Drop Turn
313	65%	Brake Check
350	73%	Driveline Drop
380	79%	Curb
16	3%	Dock Drop
323	68%	Tire Garden
300	63%	Barrels
360	75%	Cornering
479	100%	Rock garden
300	63%	Dirt Mound
Total		

AZ S&T			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
6	2	5.5	2
4	4	2.5	3
0	0	0.0	0
56	18	7.6	2
8	16	4.9	10
0	0	0.0	0
2	2	1.5	1
0	0	0.0	0
0	0	0.0	0
10	6	7.9	5
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
22	2	22.0	2
0	0	0.0	0
108	50	51.9	25

TN S&T			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
6	2	5.5	2
20	28	12.5	18
8	4	4.9	2
66	20	9.0	3
12	26	7.4	16
0	0	0.0	0
4	4	2.9	3
0	0	0.0	0
0	0	0.0	0
2	2	1.6	2
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
8	4	8.0	4
0	0	0.0	0
126	90	51.7	49

Oshkosh S&T			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
8	4	7.3	4
2	2	1.3	1
0	0	0.0	0
30	20	4.1	3
12	10	7.4	6
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
12	2	8.1	1
0	0	0.0	0
2	2	1.5	2
4	2	4.0	2
0	0	0.0	0
70	42	33.6	19

Call S&T			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
4	0	3.6	0
28	30	17.6	19
0	0	0.0	0
36	18	4.9	2
16	24	9.8	15
0	0	0.0	0
2	2	1.5	1
0	0	0.0	0
0	0	0.0	0
10	10	7.9	8
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
16	6	12.0	5
12	2	12.0	2
0	0	0.0	0
124	92	69.3	52

PCT S&T			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
14	6	12.7	5
0	0	0.0	0
0	0	0.0	0
38	14	5.2	2
36	40	22.1	25
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
2	2	1.5	1
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
12	4	12.0	4
0	0	0.0	0
106	68	56.5	39

Max Wheel Torque [ft-lbs]	Severity	Event
435	91%	Accel
300	63%	Whoop
294	61%	Jump
65	14%	Max
294	61%	Log
294	61%	Table top jump
348	73%	Drop Turn
313	65%	Brake Check
350	73%	Driveline Drop
380	79%	Curb
16	3%	Dock Drop
323	68%	Tire Garden
300	63%	Barrels
360	75%	Cornering
479	100%	Rock garden
300	63%	Dirt Mound
Total		

TN Endurance			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
124	41	113.2	38
871	996	546.4	624
373	290	229.5	178
12865	913	1747.5	124
0	0	0.0	0
41	41	25.5	25
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
124	41	124.5	41
0	0	0.0	0
14400	2324	2786.6	1032

Oregon Endurance			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
67	67	60.9	61
1607	1273	1007.8	798
2076	1206	1275.7	741
10582	2880	1437.5	391
0	0	0.0	0
67	67	41.2	41
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
14400	5492	3823.1	2032

Ohio Endurance			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
179	60	163.0	54
359	179	224.8	112
1076	717	660.8	441
10397	2330	1412.3	317
598	896	367.1	551
837	657	514.0	404
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
956	359	719.3	270
0	0	0.0	0
0	0	0.0	0
14400	5198	4061.2	2148

Cali endurance			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
220	73	200.4	67
1029	1249	644.9	783
294	294	180.6	181
8743	2424	1187.6	329
661	735	406.3	451
147	147	90.3	90
0	0	0.0	0
0	0	0.0	0
73	73	53.7	54
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
2498	955	1879.3	719
147	220	146.9	220
588	808	368.5	507
14400	6980	5156.5	3401

PCT Endurance			
Total Time Spent	Total Impacts	Modified Time	Modified Impacts
164	55	149.3	50
1040	438	652.2	275
274	164	168.2	101
11334	1478	1539.6	201
55	55	33.6	34
383	219	235.5	135
55	55	39.8	40
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
0	0	0.0	0
986	493	741.5	371
110	55	109.5	55
0	0	0.0	0
14400	3011	3669.3	1260

FOS Determination

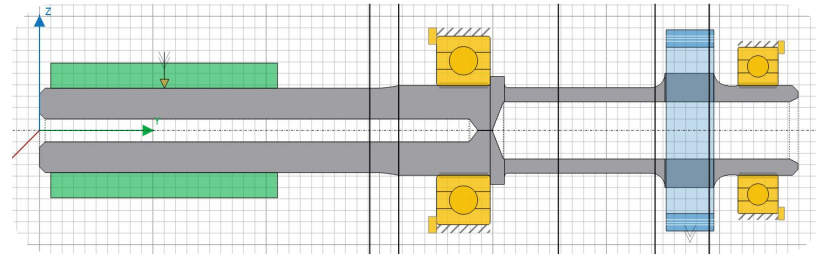
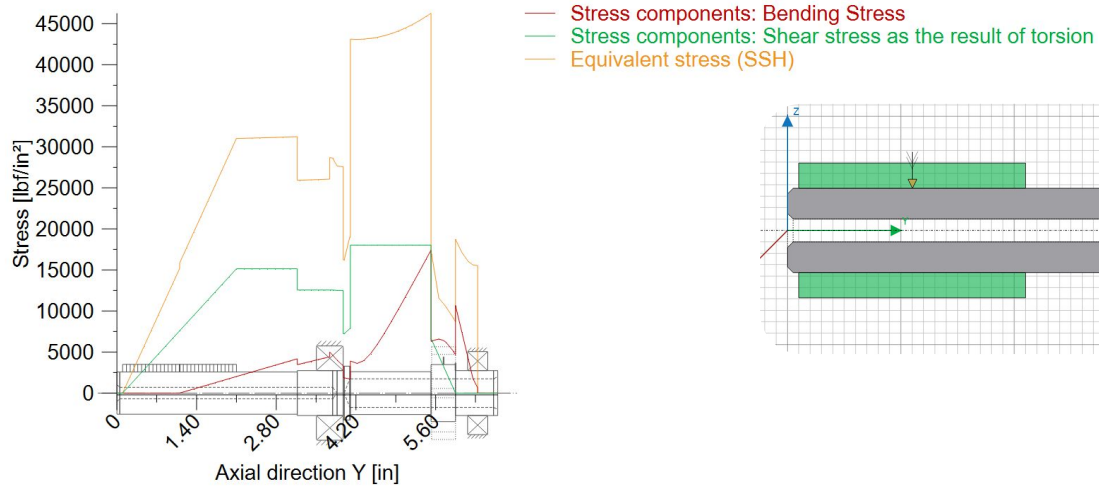
Factor of Safety		Risk Level		
		1	2	3
Load	Proof Loaded	1.2	1.1	1.05
	Confirmed Loading	1.4	1.25	1.15
	Theoretical Loading	1.6	1.4	1.25
	Guessed Loading	3	2.5	1.5

Due to the importance of the rear gearbox and the existed of un-measured loads, the rear gearbox is designed to have an FOS of 1.4.

Shaft Stress Analysis

9310 Endurance Limit = 97.145 ksi

Analysis done at max torque of 560 ft-lbs @ OS



R25 IS resulting stresses within the shaft.

More Detailed Results

Component	R24 Weight (lb)	R25 Weight (lb)	Change (%)
G1	0.93	0.77	-16.3
G2	0.52	0.43	-16.9
G3	0.45	0.38	-16.6
MS	0.36	0.31	-15.7
G4	1.84	1.16	-36.9
OS	1.16	0.89	-12.8
Total	5.25	3.94	-15 (-1.31 lb)

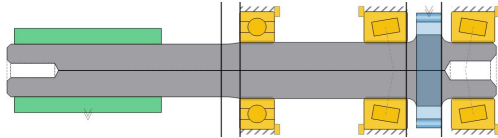
Resulting weight of R25 rear gearbox components.

Component	R24 Weight (lb in^2)	R25 Weight (lb in^2)	Change (%)
G1 (This will change)	0.1	0.13	25.5
G2	1.25	1.05	-16
G3	0.30	0.23	-23
MS	0.02	0.02	-18
G4	7.87	5.99	-14
OS	0.41	0.28	-32

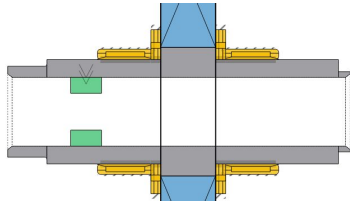
Resulting MMOI of R25 rear gearbox components.

Bearing Selection

R24

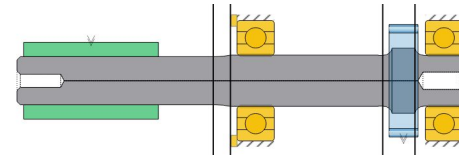


Tapered Rollers Require Precise Pre-Load
3 Bearings = Efficiency Loss & ↑ Cost
Can Withstand Large Axial Loads

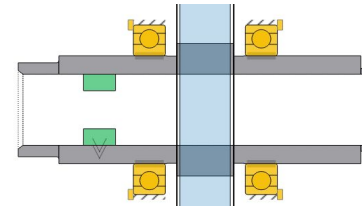


Combo Needle Bearings = Efficiency Loss, ↑ Cost & ↑ Weight
Can Withstand Large Radial & Axial Loads While Maintaining Shaft Alignment

R25

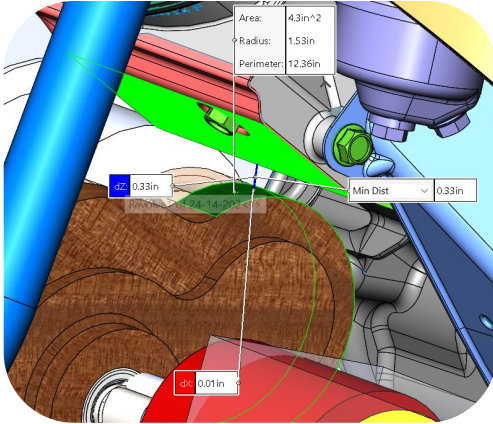


2 Ball Bearings = No Pre-load Requirements
Higher Efficiency
Lower Part Count
Can withstand axial loads up to x amount

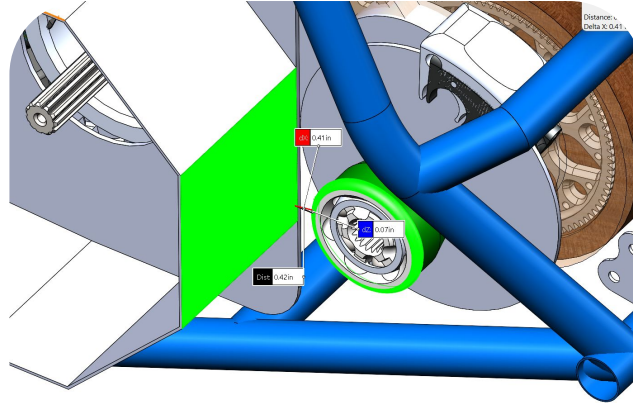


2 Ball Bearings = Lower Cost & Lighter Box
Can withstand axial loads up to x amount

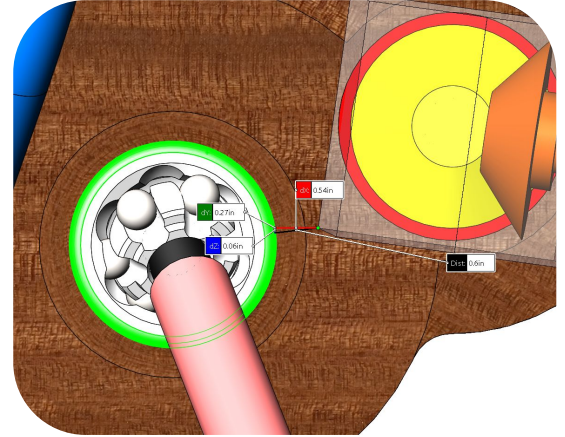
Packaging Constraint



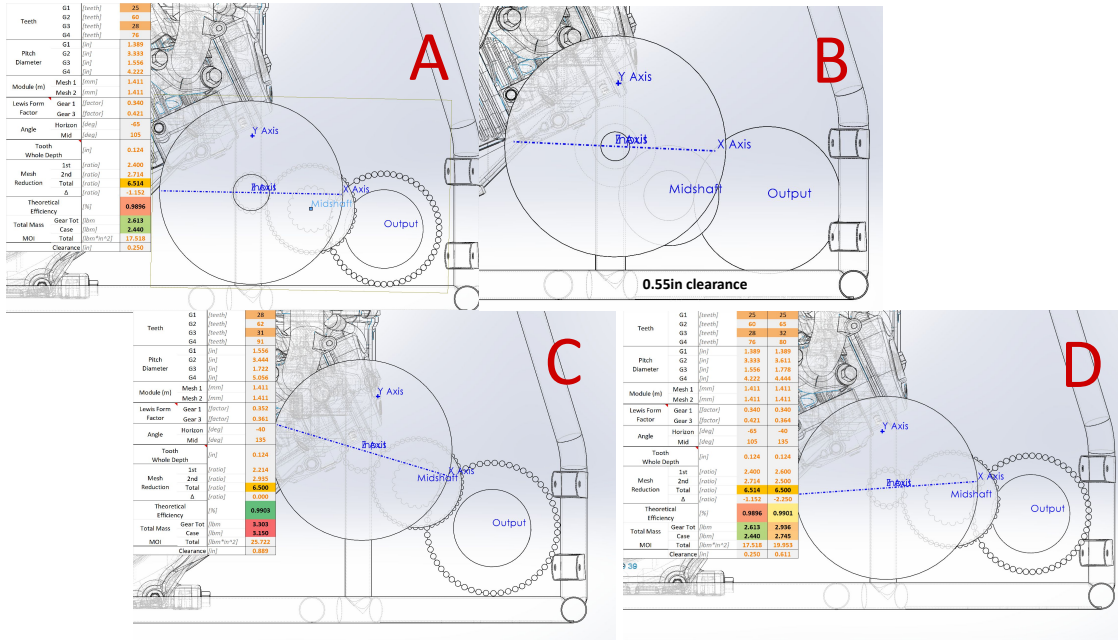
The IS gear diameter is limited by the clearance to the engine.



CVT Cover → CV & 4WD Disconnect → CV Limit the minimum center distance of the MS → OS.

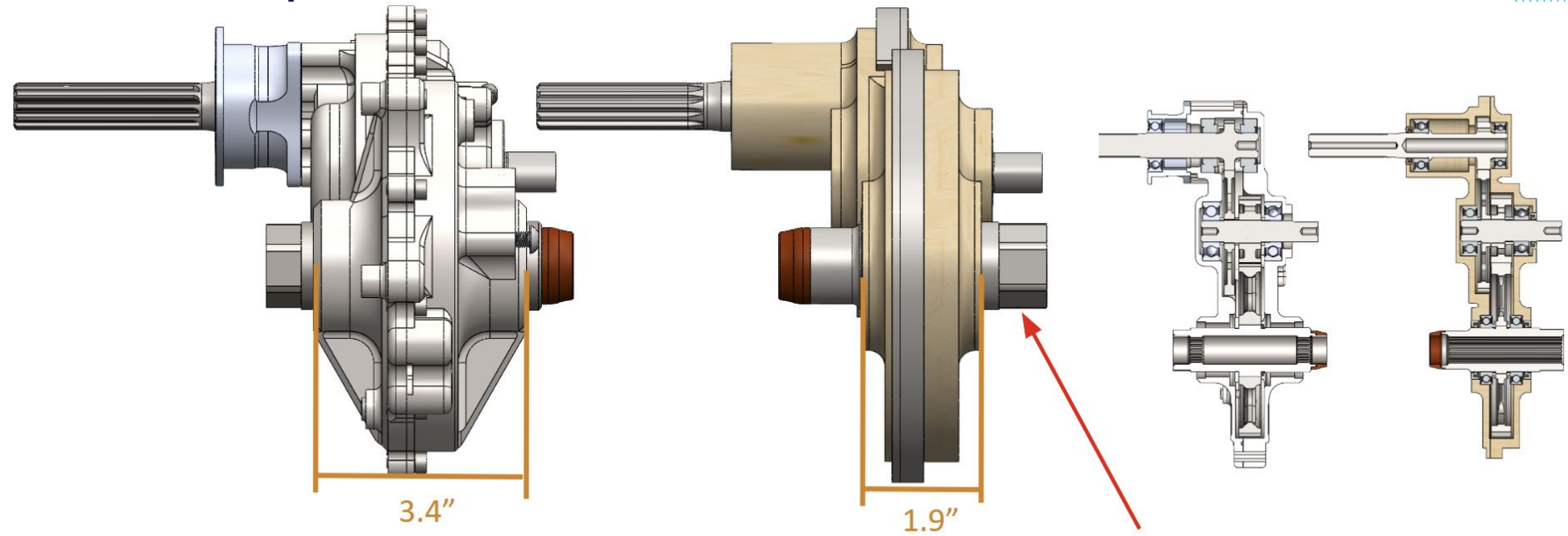


Packaging Constraint



Comparing the CV→CVT cover clearance between multiple gear design options.

Comparison



Brakes will remain on the left side to to clearance with disconnect

Results from clutches tuning between AZ & MD competitions.

R24 Housing Timeline

