Department of
Automotive Engineering

Computational
Design
Lab

SLA suspension design optimization

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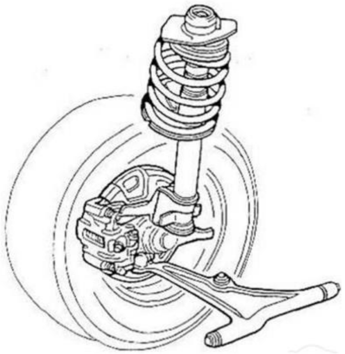
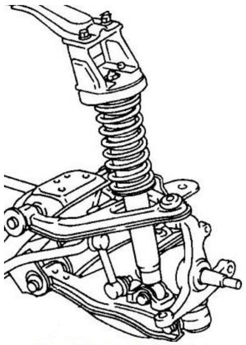
Outline

- Motivation
- Design process
- Simulate system model
- Design optimization
- Conclusion

Motivation - SLA Suspension

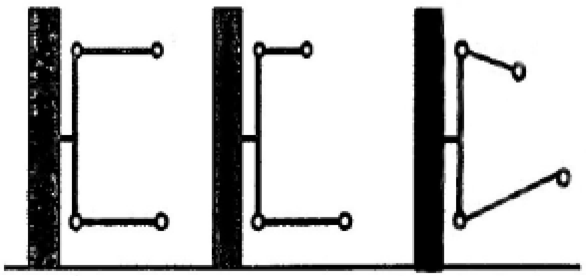
Suspension

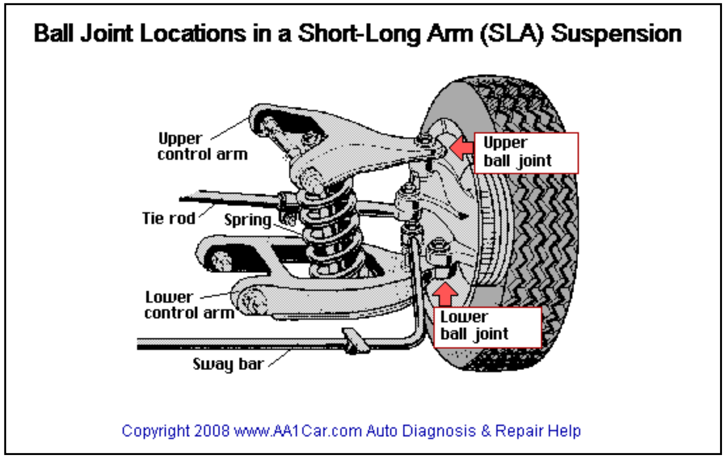




Macpherson   Double wishbone

Double wisebone suspension designs



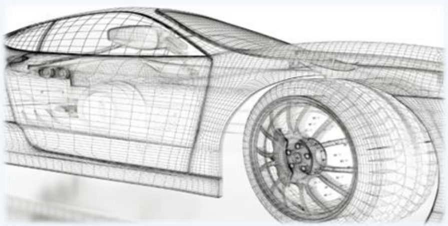


Short and Long arm suspension

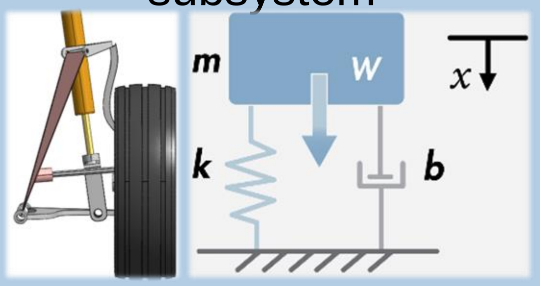
The unequal length double wishbone suspension. The unequal arm length causes a change in the camber of the vehicle as it rolls, which helps to keep the contact patch square on the ground, increasing the ultimate cornering capacity of the vehicle.

Suspension requirement

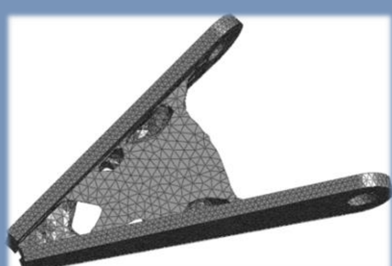
Vehicle system



SLA suspension subsystem



Structural elements



Quarter vehicle model (weight, suspension type)

↓

Suspension simulation model

↓

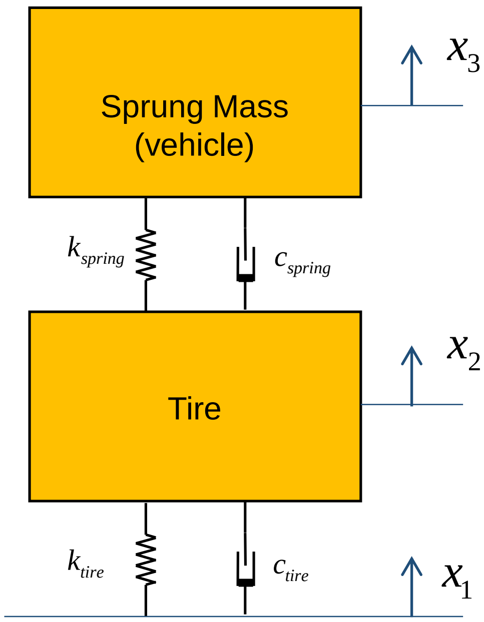
Suspension component model

Suspension

System equation

$$m_{tire}\ddot{x}_2 = k_{tire}\left(x_1 - x_2\right) + c_{tire}\left(\dot{x}_1 - \dot{x}_2\right) - k_{spring}\left(x_2 - x_3\right) + c_{spring}\left(\dot{x}_2 - \dot{x}_3\right)$$

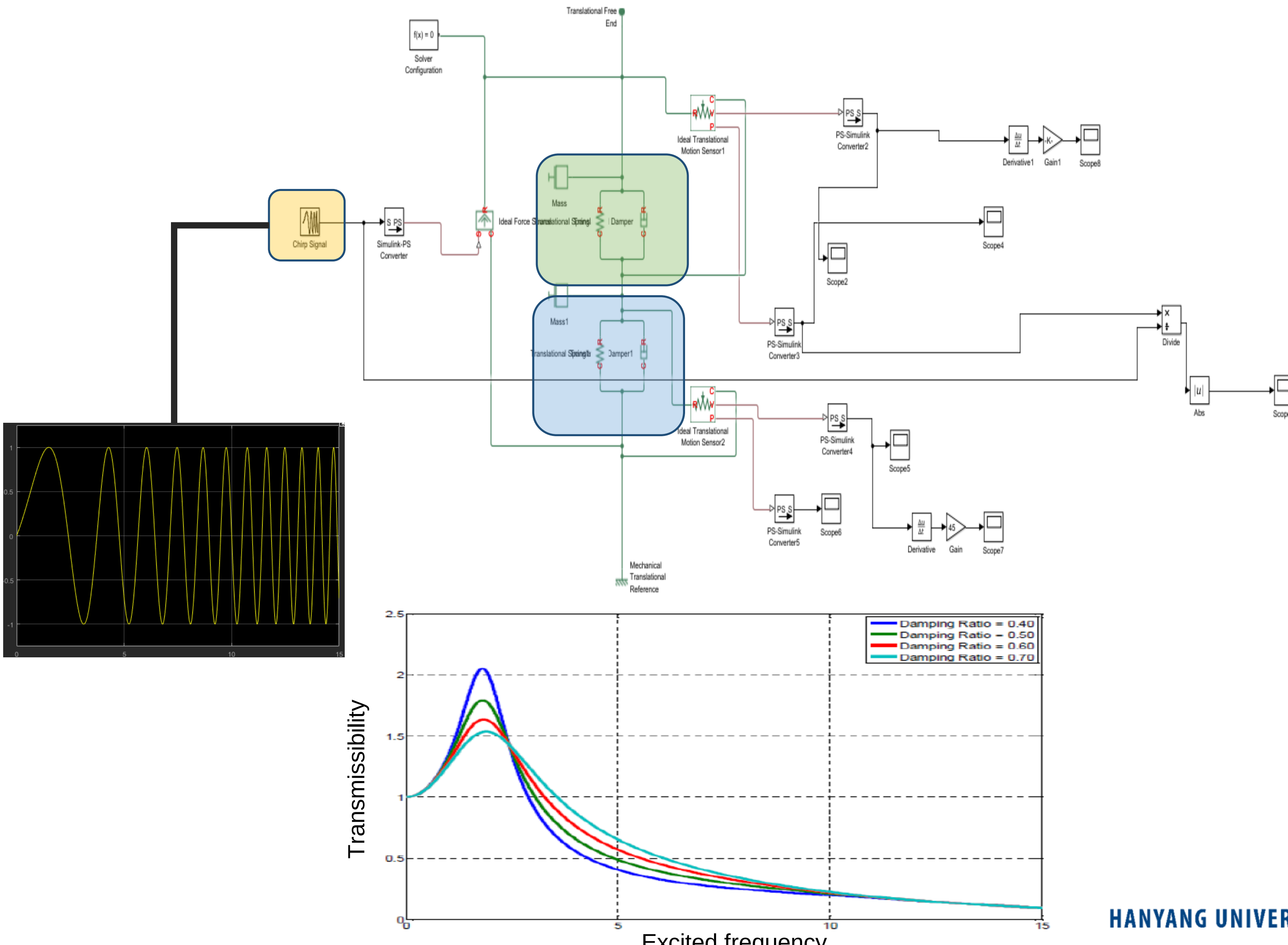
$$m_{car}\ddot{x}_3 = k_{spring}\left(\ddot{x}_2 - \ddot{x}_3\right) + c_{spring}\left(\dot{x}_2 - \dot{x}_3\right)$$



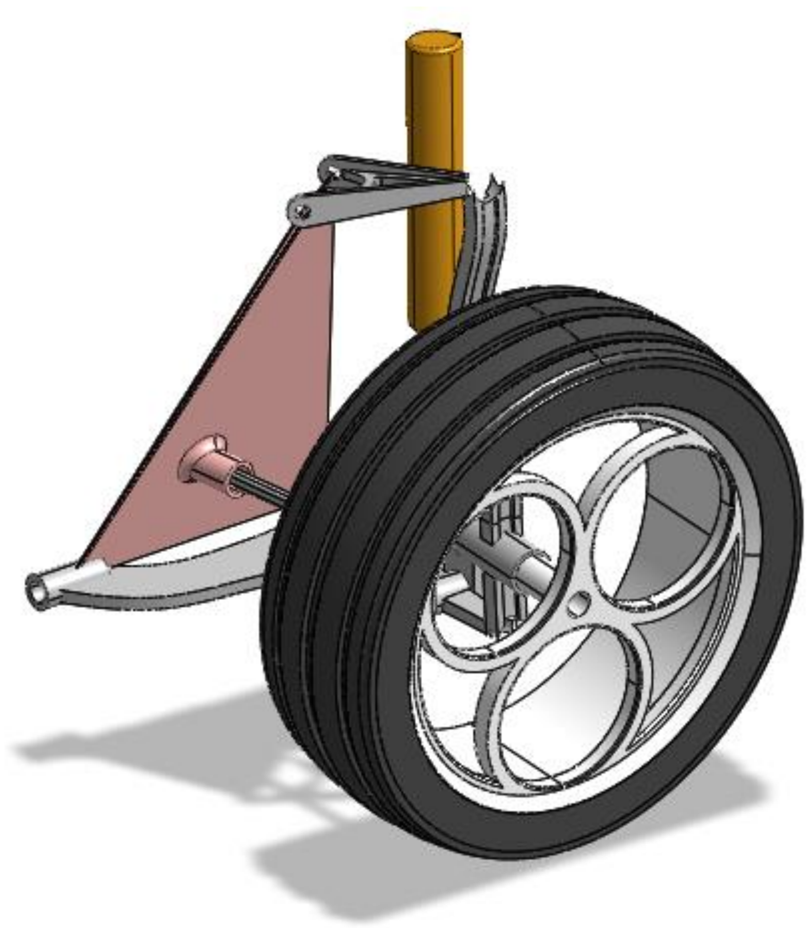
Suspension Parameters of Quarter Car Model

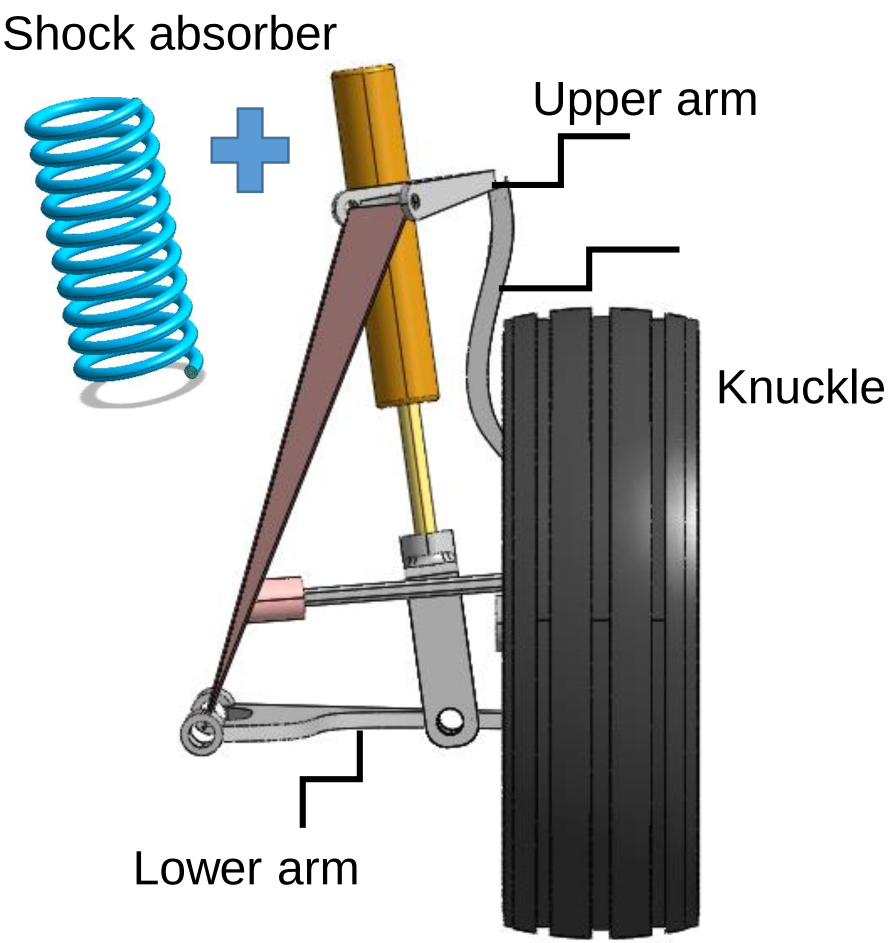
System Parameters	Value
Sprung Mass	450 Kg
Upsprung Mass	45 Kg
Suspension Stiffness	22000 N/m
Passive Suspension Damping	2300 Ns/m
Tire Stiffness	176000 N/m
Tire Damping Coefficient	230 Ns/m

Simscape Suspension model



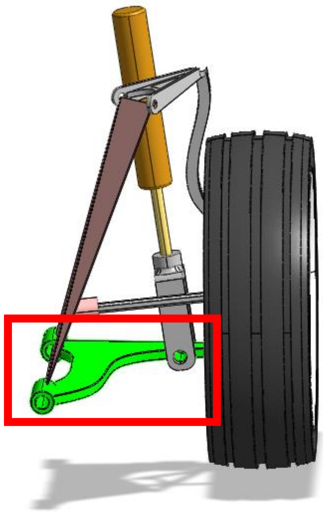
Suspension cad model



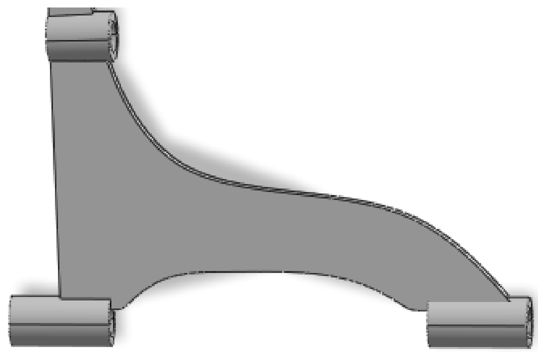


Reference – grabcad

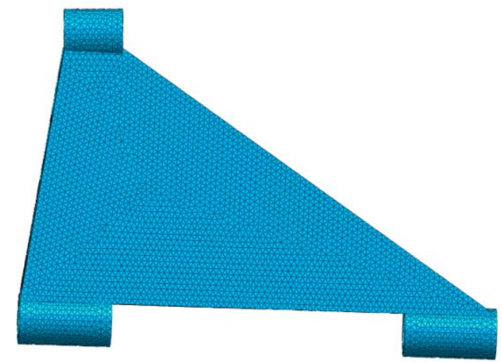
Lower control arm



Original cad model



Modified model
for topology optimization



Boundary Condition

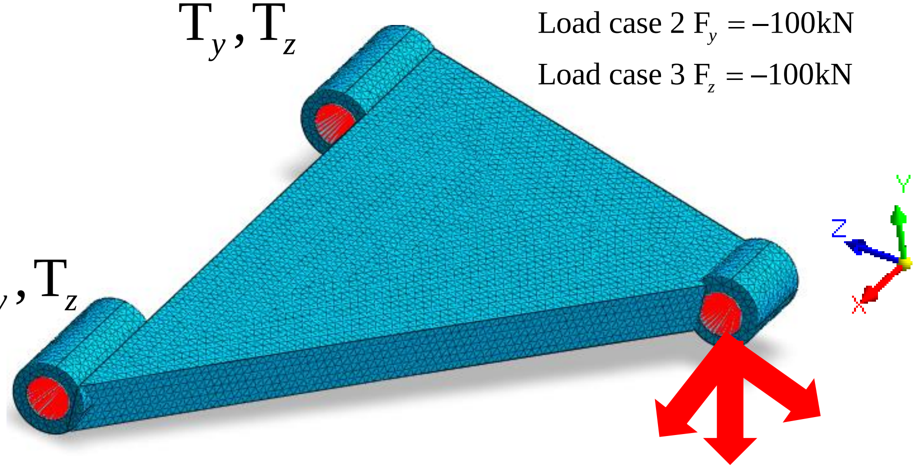
T_y, T_z

T_x, T_y, T_z

Load case 1 $F_x = -100\text{kN}$

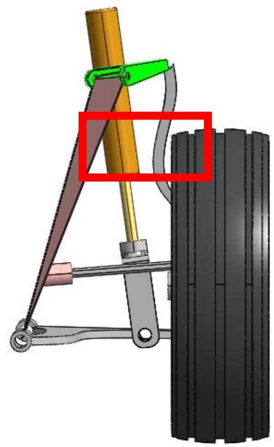
Load case 2 $F_y = -100\text{kN}$

Load case 3 $F_z = -100\text{kN}$

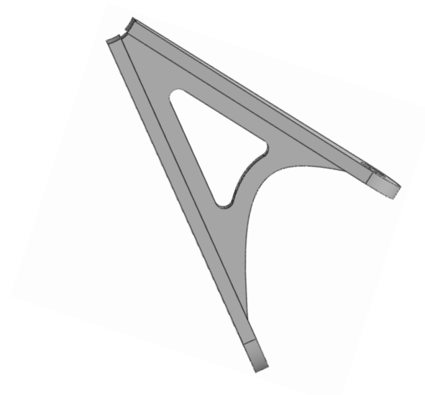


Optimum solution
Minimize Compliance
Subject to Volume fraction 50%

Upper control arm

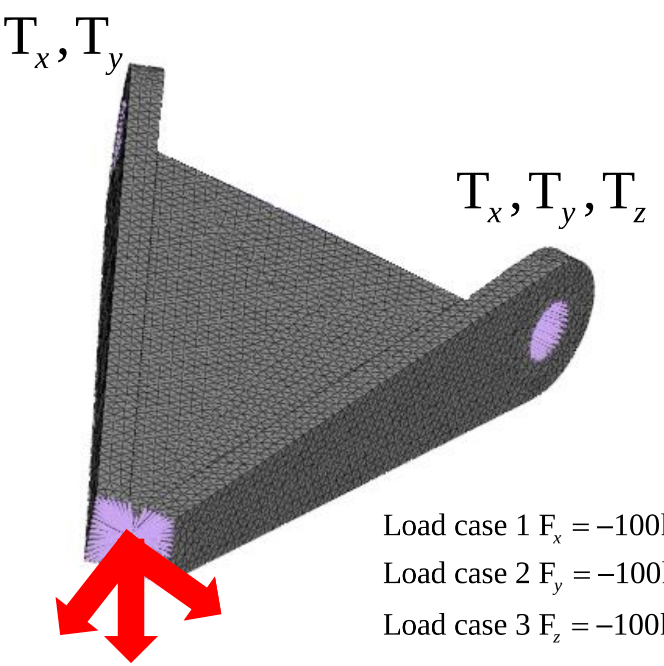


Original CAD model



Modified model
for topology optimization

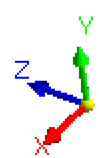
Boundary Condition



Load case 1 $F_x = -100\text{kN}$

Load case 2 $F_y = -100\text{kN}$

Load case 3 $F_z = -100\text{kN}$



Optimum solution
Minimize Compliance
Subject to Volume fraction 40%

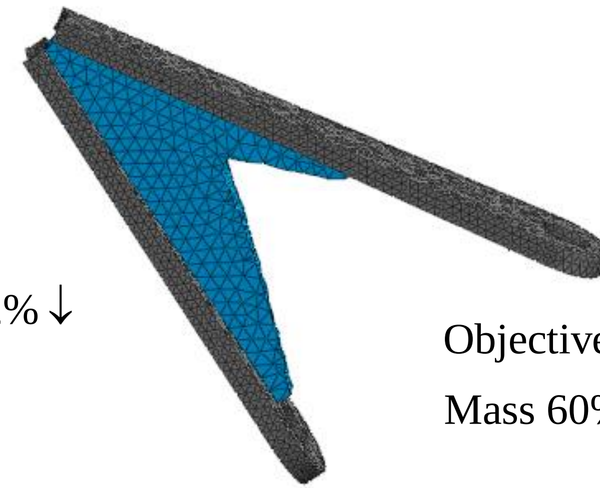
Optimization results

Lower control arm

Objective function 52%↓

Mass 50% ↓

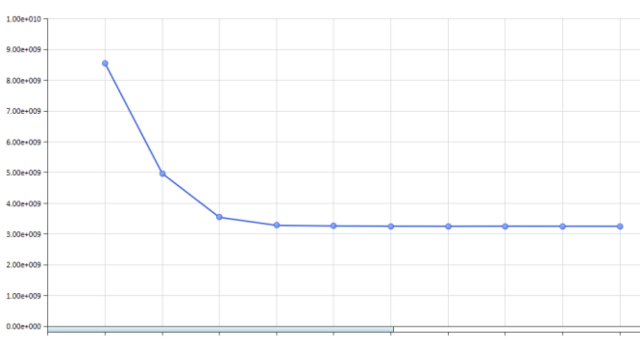
Upper control arm

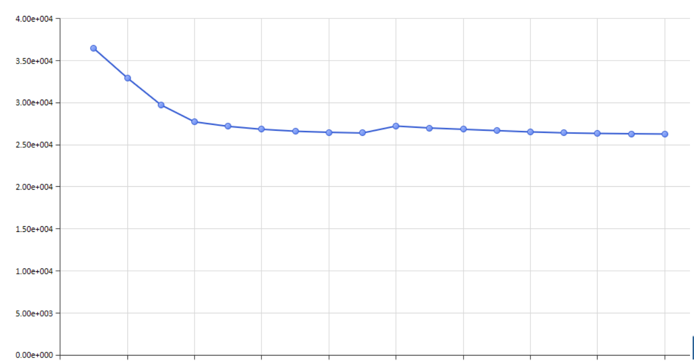


Objective function 28%↓

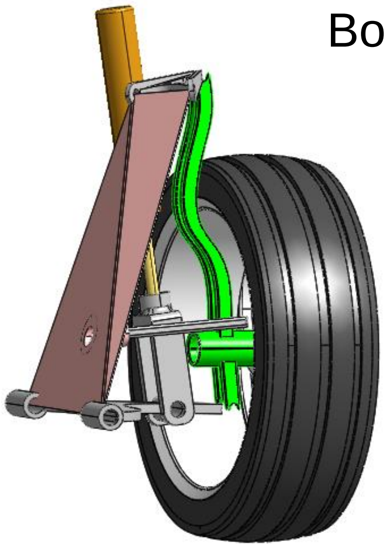
Mass 60% ↓

History of topology optimization process



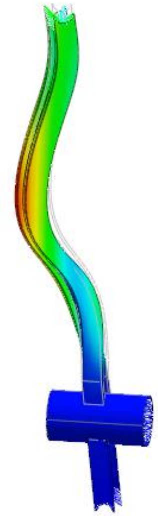


Knuckle Buckling



Boundary Condition

$\mathrm{T}_x, \mathrm{T}_y, \mathrm{T}_z$



Buckling critical load

$$P_{CR} = \lambda_1 \times P = 41395 \times 1\mathrm{N}$$

$$= 41395\mathrm{N} \gg 4900\mathrm{N}\left(500\mathrm{kg} \times 9.8\mathrm{m/s}^2\right)$$

MODE NUMBER	EIGENVALUE	RADIANS	CYCLES	PERIOD	GENERALIZED MASS	GENERALIZED STIFFNESS	ORTHOGONALITY LOSS	ERROR MEASURE
1	4.139516e+004	2.034580e+002	3.238135e+001	3.088197e-002	2.856865e-003	1.182604e+002	0.000000e+000	8.110991e-007
2	4.457239e+005	6.676255e+002	1.062559e+002	9.411242e-003	6.976600e-003	3.109637e+003	4.365019e-008	5.805730e-007
3	9.826840e+005	9.913042e+002	1.577710e+002	6.338300e-003	1.864009e-002	1.831732e+004	3.006508e-008	1.008825e-006
4	2.136294e+006	1.461607e+003	2.326219e+002	4.298821e-003	4.287182e-002	9.158681e+004	5.562087e-009	1.093380e-006
5	3.233952e+006	1.798319e+003	2.862114e+002	3.493921e-003	5.734149e-002	1.854396e+005	2.731026e-009	1.226047e-006
6	4.283163e+006	2.069580e+003	3.293840e+002	3.035970e-003	2.425383e-001	1.038831e+006	4.226700e-010	1.045108e-004
7	4.334293e+006	2.081896e+003	3.313441e+002	3.018011e-003	4.517459e-001	1.957999e+006	9.896330e-011	1.857164e-003
8	4.419908e+006	2.102358e+003	3.346006e+002	2.988638e-003	4.824325e-001	2.132308e+006	1.063839e-010	1.699417e-002
9	4.439901e+006	2.107107e+003	3.353565e+002	2.981901e-003	1.353718e-001	6.010375e+005	7.687307e-011	2.506434e-003
10	4.456696e+006	2.111089e+003	3.359902e+002	2.976277e-003	3.483564e-001	1.552518e+006	1.267671e-009	5.083981e-003

Conclusion

- 2-DOF quarter car suspension simulation is applied.
But It has difficult to use analyzed data on 3d FEM model.

- Multi-objective topology optimization is used on Suspension components.

- Buckling analysis is applied on knuckle component.

Reference

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MASS REDUCTION FOR STEERING KNUCKLE ARM IN A SUSPENSION SYSTEM THROUGH TOPOLOGY OPTIMIZATION IN CAE

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Static Analysis and Topology Optimization of Upper Control Arm

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Finite Element Analysis and Topology Optimization of Lower Arm of Double Wishbone Suspensionusing RADIOSS and Optistruct

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Analysis of Vehicle Suspension System Subjected to forced vibration using MAT LAB/Simulink

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