

INERTIA RELIEF ANALYSIS OF AUTOMOTIVE CONTROL ARM

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Abstract - To carry out inertia relief analysis of automotive control arm using Optistruct finite element solver to evaluate displacement and stress characteristic. Inertia relief allows the simulation of unconstrained structures. Typical applications are an airplane in flight, suspension parts of a car, or a satellite in space. With inertia relief, the applied loads are balanced by a set of translational and rotational accelerations. These accelerations provide body forces, distributed over the structure in such a way that the sum total of the applied forces on the structure is zero. This provides the steady-state stress and deformed shape in the structure as if it were freely accelerating due to the applied loads. Boundary conditions are applied only to restrain rigid body motion. Because the external loads are balanced by the accelerations, the reaction forces corresponding to these boundary conditions are zero.

Key Words: Inertia relief, Optistruct, Unconstrained structures, Boundary conditions, Reaction forces, Steady-state stress.

1. INTRODUCTION

In automotive suspension, a control arm, also known as an A-arm, is a hinged suspension link between the chassis and the suspension upright or hub that carries the wheel.

The inboard (chassis) end of a control arm is attached by a single pivot, usually a rubber bushing. It can thus control the position of the outboard end in only a single degree of freedom, maintaining the radial distance from the inboard mount. Although not deliberately free to move, the single bushing does not control the arm from moving back and forth; this motion is constrained by a separate link or radius rod.

This is in contrast to the wishbone. Wishbones are triangular and have two widely-spaced inboard bearings. These constrain the outboard end of the wishbone from moving back and forth, controlling two degrees of freedom, and without requiring additional links.

Most control arms form the lower link of a suspension. A few designs use them as the upper link, usually with a lower wishbone. The additional radius rod is then attached to the upper arm. So here we carried inertia relief analysis of control arm to evaluate displacement and stress characteristic.

1.1 History of Vehicle Suspension System

Pioneering vehicle manufacturers were faced early on with the challenges of enhancing driver control and passenger comfort. The early 1900's, cars still rode on carriage springs. Early drivers had bigger things to worry about than the quality of their ride like keeping their cars rolling over the rocks and ruts that often passed for roads. These early suspension designs found the front wheels attached to the axle using steering spindles and kingpins. This allowed the wheels to pivot while the axle remained stationary. Suspension systems have been widely applied to vehicles from the horse-drawn carriage with flexible leaf springs fixed in the four corners, to the modern automobile with complex control algorithms. The vehicle design typically represents a trade-off between performance and safety since durability especially of safety components is important. This means that the design of the components must be adapted as accurately as possible to the operating conditions (AA, 2004).

2. TYPES OF VEHICLE SUSPENSIONS SYSTEM

Suspension systems from one key subsystem of an automobile that are used to isolate the occupants from shocks and vibrations induced due to road surface irregularities. It is also used as a wheel locating and guiding mechanism when the vehicle is in motion.

2.1 Front Suspensions

Front suspensions are classified as dependent and independent suspensions. The most common dependent front suspension is the beam axle, which is used less and less in recent vehicles because of numerous disadvantages like large unsprung mass, packaging space, and considerable caster change. However, some off-road application vehicles tend use still to the beam axle dependent front suspension as they offer high articulation and high ground clearance. The most common types of front independent suspensions are the double wishbone suspension and the Macpherson strut. The double wishbone suspension also known as the double A-arm suspension has parallel lower and upper lateral control arms. The main advantage of the double wishbone is that the camber can be adjusted easily by varying the length of the lateral upper control arm such that it has a negative

camber in bounce. The coil spring and the shock absorber are combined into a single unit extending vertically making it more compact. Over the years, many types of independent front suspension have been tried. Many of them have been discarded for a variety of reasons, with only two basic concepts, the double wishbone and the McPherson strut, finding widespread success in many varying forms.

The McPherson strut type suspension consists of a single lower wishbone arm which controls the lateral and longitudinal location of the wheel Figure 2.2. The McPherson suspension providing the suspension can be combined into one assembly and the disadvantage set as less favorable kinematic characteristics. The friction between piston rod and guide impairs the springing effect. Much space needed above the wheel for spring and strut, connection between the upper strut mount and frame unstiff and expensive, clamping of a strut to steering knuckle very difficult for the axle loads of truck and expensive spare part.

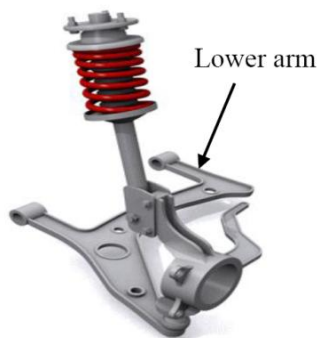


Figure 2.2: McPherson suspension strut

Double wishbone suspension type suspension consists of pairs of parallel arms can be arranged to control suspension geometry (Figure 2.3). Giancarlo and Lorenzo (2009) sighted of the initial design double wishbone suspension and concluded the independent double wishbone front suspension adopted in the automobile manufactures. Most advantages for double wishbone suspensions are space saving, attenuate of road noise, decreasing steering vibration and good kinematic possibilities. The disadvantage set as more space needed besides the frame in a lateral direction, king pin inclination high, and less favorable ratio of spring rate and damper rate. A few disadvantages of this type of suspension are that it requires sufficient vertical space and a strong top mount (Jack, 2005).

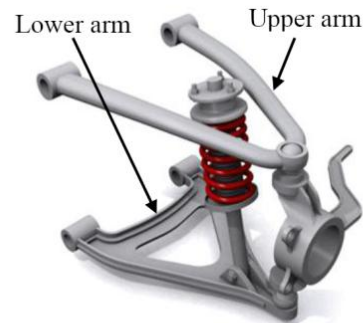


Figure 2.3: Double wishbone suspension arm

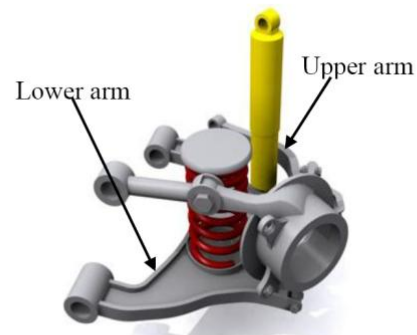


Figure 2.4: Multi link suspension arm

3. DESIGN & MODELLING PROCEDURE

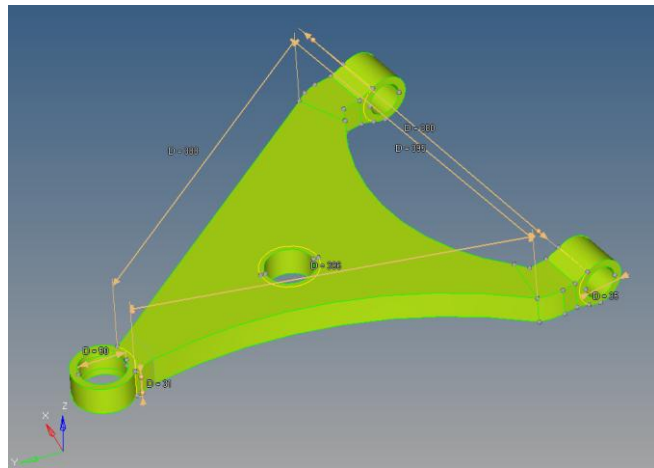
Tools used for CAD modelling & analysis: Hypermesh , OptiStruct & Hyperview.

1. Preprocessing using Hypermesh

HyperMesh is a high-performance finite element pre-and post-processor for major finite element solvers, which allows engineers to analyze design conditions in a highly interactive and visual environment. Hypermesh user-interface is easy to learn and supports the direct use of CAD geometry and existing finite element models, providing robust interoperability and efficiency. Advanced automation tools within Hypermesh allow users to optimize meshes from a set of quality criteria, change existing meshes through morphing, and generate mid-surfaces from models of varying thickness.

Since Basic design shape was very simple. Tool used for Cad creation was Hypermesh. Though Hypermesh is finite element preprocessor but it also offers some Cad creation and cleanup tools. Hence Hypermesh has been used for Cad creation.

We referred some basic control arm design from web and finally arrived at below design using Hypermesh Cad creation and cleanup tools. Dimensions was measured using dimensioning tools in geometry page.



Basic design dimension in mm & Mass 15 Kg

Table 1: Material used for control Arm:

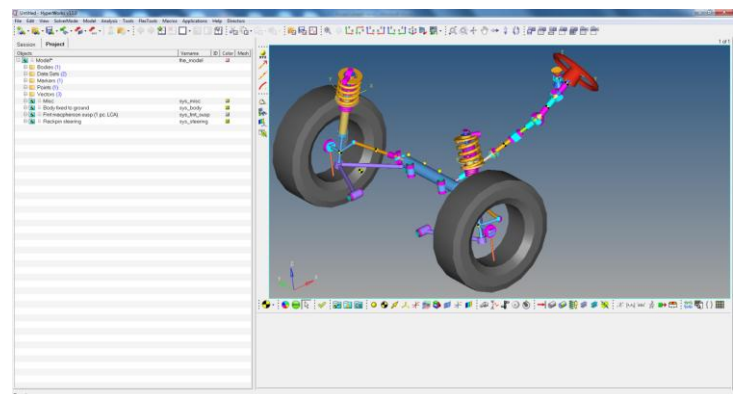
Material Name	Youngs modulus(Mpa)	Poissons ratio	Density(tonnes/mm3)
Steel	2.1e05	0.3	7.89e-09

4. Load for Automotive control arm:

Motionsolve(multibody dynamics) have been used for extracting Static forces acting on the control arm.

MotionSolve is an integrated solution to analyze and optimize multi-body system performance. Through extensive customer partnership, MotionSolve is thoroughly validated for quality, robustness and speed.

Based on superior numerical methods and scalable formulations, MotionSolve offers powerful modeling, analysis, visualization and optimization capabilities for multi-disciplinary simulations that include kinematics and dynamics, statics and quasi-statics, linear and vibration studies, stress and durability, loads extraction, co-simulation, effort estimation and packaging synthesis.



Motionview is the preprocessor for modelling multibody. Assembly wizard have been used for loading half vehicle library for extracting static forces on control arm. As an input we need to provide initial design control arm parameter and type of suspension used for force extraction.

Following force have been exported in txt format from motionsolve after static load analysis:

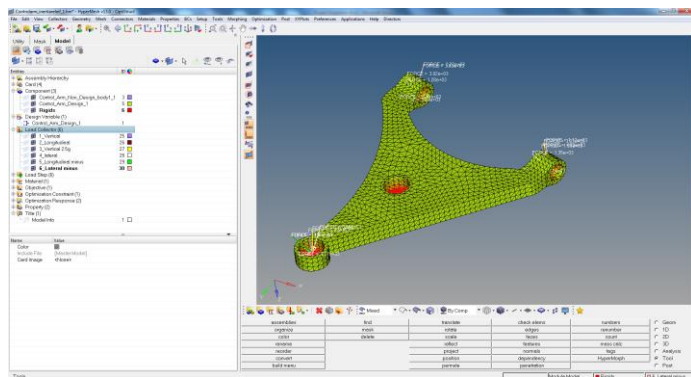
MotionView Version = Altair		r HyperWorks					
ADAMS Request File Name =		Load.mdl					
Units = NEWTON/MILLIMETER/		KILOGRAM ND					
=====		=====					
Lwr control arm-right		Fx	Fy	Fz	Tx	Ty	Tz
Vertical Time = 1.0							
Lwr ball jt-right (Load)	1.88E+02	2.57E+02	2.11E+03	0.00E+00	0.00E+00	0.00E+00	2129.496
LCA frnt bush-right (Load)	3.76E+01	-6.16E+02	1.12E+03	5.76E+03	1.55E+03	5.58E+01	1277.198
LCA rear bush-right (Load)	1.27E+02	-2.62E+00	1.09E+03	5.76E+03	1.54E+03	5.45E+01	1093.586
Coil spring-right (Load)	9.85E+01	3.59E+02	-4.29E+03	0.00E+00	0.00E+00	0.00E+00	4306.741
Gravity	0.00E+00	0.00E+00	-1.96E+01	0.00E+00	0.00E+00	0.00E+00	19.62
Sum of Forces	5	3.10E-03	-1.88E+00	-9.00E-02	1.15E+04	3.08E+03	1.10E+02
Longitudinal Time = 3.0							
Lwr ball jt-right (Load)	3.53E+03	5.14E+02	1.88E+03	0.00E+00	0.00E+00	0.00E+00	4029.745
LCA frnt bush-right (Load)	5.39E+02	-4.86E+03	1.24E+03	6.65E+03	1.91E+03	1.88E+03	5043.869
LCA rear bush-right (Load)	2.94E+03	3.96E+03	7.76E+02	6.70E+03	1.69E+03	1.85E+03	4991.807
Coil spring-right (Load)	4.92E+01	3.85E+02	-3.87E+03	0.00E+00	0.00E+00	0.00E+00	3892.126
Gravity	0.00E+00	0.00E+00	-1.96E+01	0.00E+00	0.00E+00	0.00E+00	
Sum of Forces	5	9.69E-02	-2.17E+00	-1.23E-01	1.33E+04	3.60E+03	3.73E+03
Vertical 2.5g Time = 5.0							
Lwr ball jt-right (Load)	1.07E+02	1.96E+03	5.74E+03	0.00E+00	0.00E+00	0.00E+00	6067.779
LCA frnt bush-right (Load)	1.73E+02	-7.63E+02	2.92E+03	-1.02E+04	-2.71E+03	5.16E+02	3018.991
LCA rear bush-right (Load)	6.18E+02	8.93E+02	2.83E+03	-1.02E+04	-2.65E+03	4.96E+02	3029.811
Coil spring-right (Load)	6.82E+02	-2.08E+03	-1.15E+04	0.00E+00	0.00E+00	0.00E+00	11675.58
Gravity	0.00E+00	0.00E+00	-1.96E+01	0.00E+00	0.00E+00	0.00E+00	
Sum of Forces	-8	9.10E-02	3.31E+00	-2.70E-01	-2.04E+04	-5.36E+03	1.01E+03

Load extracted after static load analysis

Since constrain are not available we have performed Inertia relief analysis of control arm to evaluate displacement and stress characteristic of control arm.

5. Steps to carryout Finite element analysis using OptiStruct finite element solver for control arm:

- 1.Import / Create Cad model in Hypermesh.
- 2.Mesh control arm with 3d tetrahedral element.
- 3.Assign material property to element.
- 4.Apply loads & boundary condition.
- 5.Define type of analysis and request output format.



Meshed model with multiple loads

Since no constraint applied we performed inertia relief analysis.

Inertia relief boundary conditions may be generated automatically by using PARAM INREL, -2.

With control cards > Global output request > We requested stress and displacement as output for all nodes.

6. Solver used OptiStruct

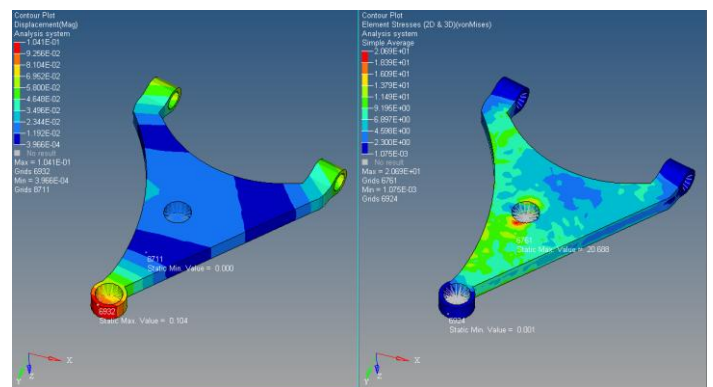
Altair OptiStruct is an industry proven, modern structural analysis solver for linear and nonlinear structural problems under static and dynamic loadings. It is the market-leading solution for structural design and optimization. Based on finite element and multi-body dynamics technology, and through advanced analysis and optimization algorithms, OptiStruct helps designers and engineers rapidly develop innovative, lightweight and structurally efficient designs. OptiStruct is used by thousands of companies worldwide to analyze and Optimize structures for their strength, durability and NVH (noise, vibration and harshness) characteristics.

7. Post Processing using Hyperview

HyperView is a complete post-processing and visualization environment for finite element analysis (FEA), CFD, multi-body system simulation, digital video, and engineering data. HyperView combines advanced animation and XY plotting features with window syncing to enhance results visualization. HyperView also saves 3-D animation results in Altair's compact H3D format so you can visualize and share CAE results within a 3-D web environment using HyperView Player.

Output of static analysis (Displacement in mm & Stress in mpa)

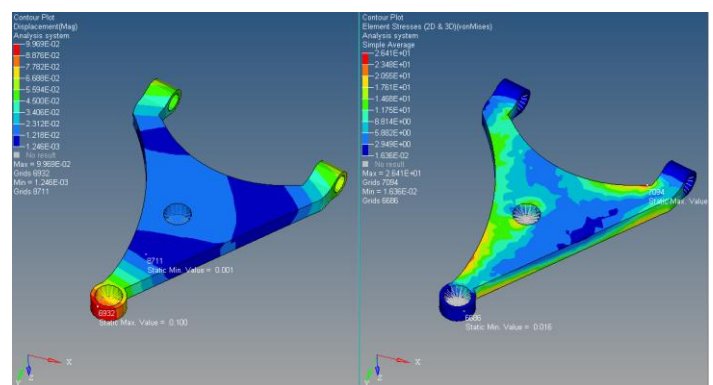
Loadcase1 : Vertical



Displacement:0.104mm

Stress:20.6 Mpa

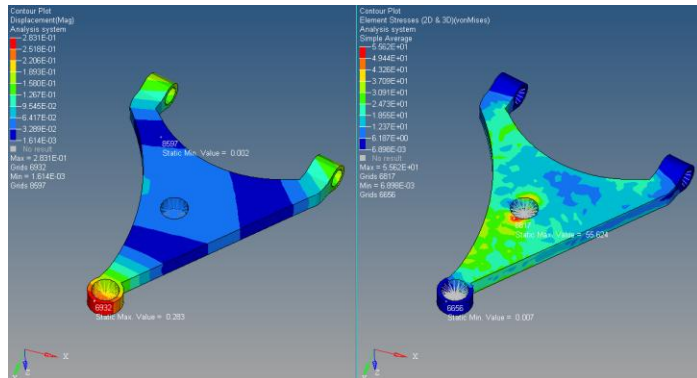
Loadcase2 : Longitudinal



Displacement:0.099mm

Stress:26.4 Mpa

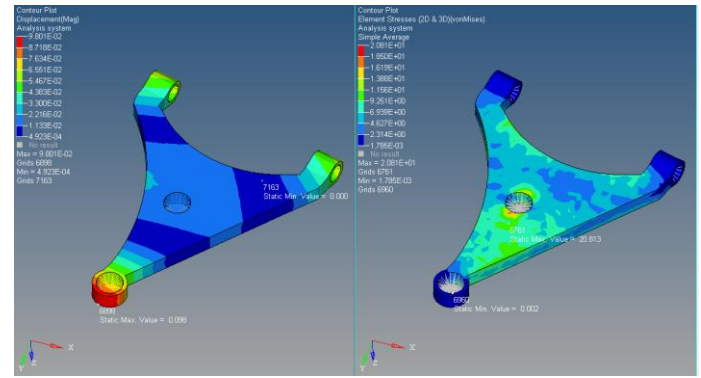
Loadcase3: Vertical 2.5g



Displacement:0.283mm

Stress:55.6 Mpa

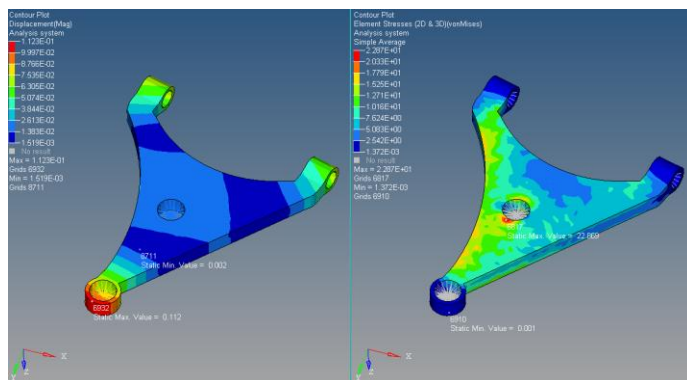
Loadcase6: Lateral minus



Displacement:0.098mm

Stress:20.8 Mpa

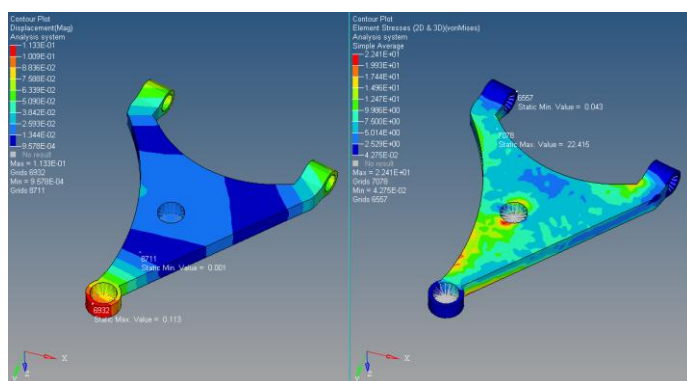
Loadcase4: Lateral



Displacement:0.112mm

Stress:22.1 Mpa

Loadcase5:Longitudinal minus



Displacement:0.113mm

Stress:22.4 Mpa

8. CONCLUSIONS

Linear static analysis will not run if constraint is not available. Hence such option for automatic constraining structure using inertia relief is useful. With inertia relief, the applied loads are balanced by a set of translational and rotational accelerations. These accelerations provide body forces, distributed over the structure in such a way that the sum total of the applied forces on the structure is zero. This provides the steady-state stress and deformed shape in the structure as if it were freely accelerating due to the applied loads. Boundary conditions are applied only to restrain rigid body motion. Because the external loads are balanced by the accelerations, the reaction forces corresponding to these boundary conditions are zero.

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- 2) Altair Optistruct userguide
- 3) Altair Hyperview userguide
- 4) Practical Finite element analysis by Nitin Gokhale