# Design And Analysis of Air Suspension System of Bharat Benz 914 & 917

**S.Philip Jesmen , T.Jeyapoovan, M. Ramakrishnan,S.C.Rajasekar**

***Abstract; In response to the short comings of the leaf spring suspension, the four link suspension has evolved as the suspension of choice in recent years for large passenger vehicles that have solid drive axles. The geometric design of four link suspension allows for better control of roll centre location, anti-squat, anti-drive performance and roll steer properties.The main purpose of Suspension system is to provide good ride comfort and provide good vehicle handling techniques. And the Suspension which best serves this purpose is Air-Suspensin system. This is because it provides good ride comfort in Variable load conditions. In this project a Bus having semi-elliptical leaf-spring type rear suspension is taken and is replaced by Air-Suspension to increase the Ride comfort, Vehicle braking and Handling Techniques. One type of four link type suspension called Sub frame type suspension is chosen. In this project, dimensions of the vehicle is taken manually and the design is created to fit air suspension.Then Analysis is done and then the customized model is sent for manufacturing. The Bus chosen is Bharat Benz 914 & 917. Both have similar rear suspension.***

***Keywords; Air suspension, Semi-elliptical leaf spring suspension, Subframe type Air suspension, Ride Comfort, Vehicle Handling.***

## I. INTRODUCTION

All vehicles do not have the luxury of having Air-Suspensionsystem.HencecustomerspreferringAir-suspension look towards Original Equipement Manufacturers(OEMs) for customising their vehicle.There are Tier 1 companies towhom this request is sent with the customer's specifications. These companies design, analyseand manufacture based on the customer's specifications and send it to OEMs, who delieverit to the customer. There are very few tier 1 companies in India that manufactures Air-Suspensionsystem.

The main purpose of Suspension system is to provide good ride comfort to thepassengersinside.The Roll and Bounce damping play an important role in providing ride comfort.

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The Air-springhouses hould have a Natural Frequencybetween1– 1.4 Hz. The rate at which the air-springs get adjusted due to extension and retraction of the wheels due to defect in roads gives us an estimation as to how much load a spring can carry. Thus depending upon the loads , the air-spring is chosen. Another purpose that the Air-suspension system serves is to provide good vehicle handling comfort to the driver. Ride comfort, Vehicle handling, cornering, braking is explained in detail in Fundamentals of vehicle dynamics.

Peter Holen& Boris Thorvald [1] have performed analytical and 3D stimulation studies to determine the roll andbounce damping of heavy vehicles and have illustrated the limits inperformanceresultingfromthechoiceofdampersand mounting positions. [2] Els, P. S et al have suggested a control strategy to switch between a ride comfort mode and a handling mode in a safe and predictable way to improve significantly bothridecomfortandhandling.[3]Gillespie,T.Dhasexplained inhisbook,fundamentalsofVehicleDynamics,indetailabout the acceleration and braking performance, Road loads, Ride, Steadt state cornering, uspensions, Steering system, Roll over andtires.Thisbookenablesustogetanin-deothknowlegdeon all the factors considered while designing a suspension system.[4] UysPE et al have suggested certain suspension settings,suchasdampingbeinglowerthanthestandardsetting, the rear spring as soft as possible, the front spring either soft or stiffer depending on the road and speed conditions, to provide optimal ride comfort.[5]. Chang, F. and Lu, Z have suggested the stiffness frequency technique that enables the design of air springoflowerstiffnessforlowerfrequenciesandthatofhigher stiffness for higher frequencies which will improve handling and ride comfort at the frequencies near the sprung mass frequency. [6] Khajepour, A et al have suggested a new air suspension system which has two air chambers. In this suspension system, the stiffness and ride height of the vehicle canbealteredsimultaneouslyfordifferentdrivingconditionsbycontrolling the air pressure in the two chambers. [7] Lee, S. J developed a general analytic mode of an air spring which has stiffness and hysteresis and can be connected to pneumatic systemdesignedtocontrolairspringheight.[8] Jianwen Zhang etalhaveperformedstimulationandtoanalyzetheridecomfort of air suspension in bus.[9] Sreedhar B and Deshmukh C designed a vehicle model with front and rear suspension systems, steering system and power train and then performed stimulations with and without levellimgvalves to compare the vehicle perfromance. There are many types of Suspension systems. Two types arediscussedinthisproject. Theyare Semi-ellipticalleafspring type suspension system and Sub-Frame type Air-Suspension.

The semi elliptical leaf spring type suspension is a suspension which uses leaf springs of semi elliptical shape to power the vehicle. The Sub Frame type air suspension system is a suspensionwhichhasanextraframecalledsubframetoconnectboth LH and RH of the vehicle and uses compressed airto power the vehicle. The Leaf springs in semi-elliptical typesuspension are designed to withstand only a particular load. Above which there is no ride comfort. Whereas, the sub-frame type Air suspension provides ride comfort for variable loading conditions. Hence Air-suspension is preferred more.

In this project, first measurement of the vehicle is taken. Then based on the measurements taken, the air-suspension system to be fitted in has to be modified in order to fit in perfectly. Articulation Studieshavetobedoneinordertoknow if there will be contact between the parts while bouncing. Then Calculations are done in order to determine the load acting at each parts of the vehicle. The design is then analyzed under certain loading conditions to check if the design can withstand certain amount of load. On no error being found, the model is sent formanufacturing

## II. MATERIAL SELECTION

The Material chosen is Structural steel.

| PROPERTY | VALUES |
|---|---|
| DENSITY | 7850 kg/m3 |
| YOUNGS MODULUS | 2E+11 Pa |
| SHEAR MODULUS | 0.3 |
| BULK MODULUS | 1.6667E+11 Pa |
| POISSON'S RATIO | 7.6923E+11 Pa |
| TENSILE YIELD STRENGTH | 2.5E+08 Pa |
| COMPRESSIVEYIELD STRENGTH | 2.5E+08 Pa |
| TENSILE ULTIMATE STRENGTH | 4.6E+08 Pa |
| COMPRESSIVEULTIMATE STRENGTH | 0 |

## III. DESIGN

The Chasisand axle assembly are designed as per the dimensionsinthesemi-ellipticalleafspringsuspensionsystem. The other components that are designed are parts of Air suspension system. They are subframe assembly, air spring assembly, Levelling valve assembly, Parallel link assembly,Radius rod assembly, antiroll bar assembly, U bolt, Airspringbracket, Shock absorber, Rear axle top pad, Parallel link Bracket.

TheSubframeisastructuralcomponentofavehicle,which connects both the LH and RH of the vehicle. It also gives the vehicle the extra support required. This is used in heavy commercial vehicles.TheAir spring assembly consists of Air spring and Air spring bracket. The Air spring is a spring that uses compressed air instead of metal springs to control the up and down movement of the wheels of the vehicle. Four Air springs are used. They are designed based on the load of the vehicle. The Levelling valve is used for suspension control. It precisely modulates compressed air in suspension bellows as a ratio of vehicle's load. The Levelling Valve ensures a constant ride height, charging the air suspension during loading and venting when unloading. The Parallel and Compound link are the control arm of the vehicle. The Parallel link controls the brakingloadwhereasthecompoundlinkcontrolscorneringand braking. Theanti roll bar also known as Sway bar is used to avoidrollingofthevehiclewhilecornering. TheShockabsorber acts as the rebound controller and damping controller in a vehicle.

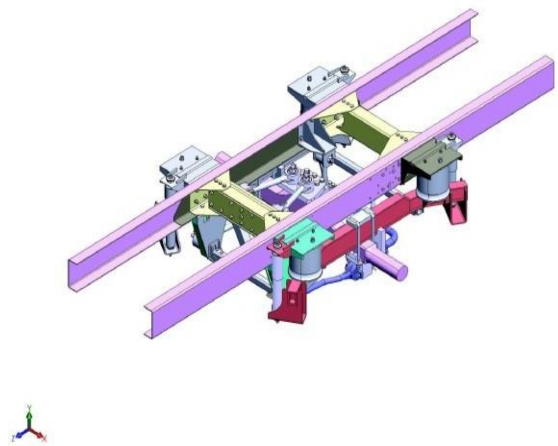

**Fig 3.1. Assembly of Air Suspension**

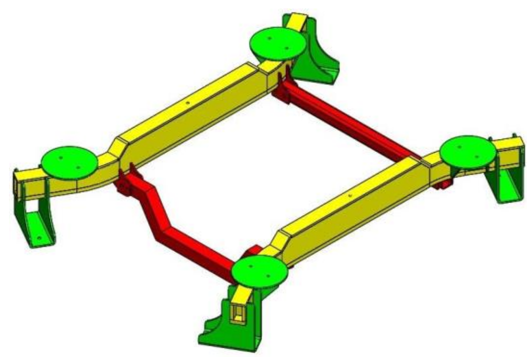

**Fig 3.2. Subframe Assembly**

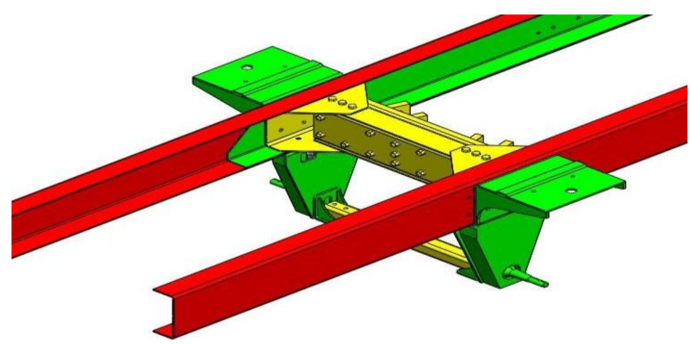

**Fig 3.3. Parallel and Compound link assembly**



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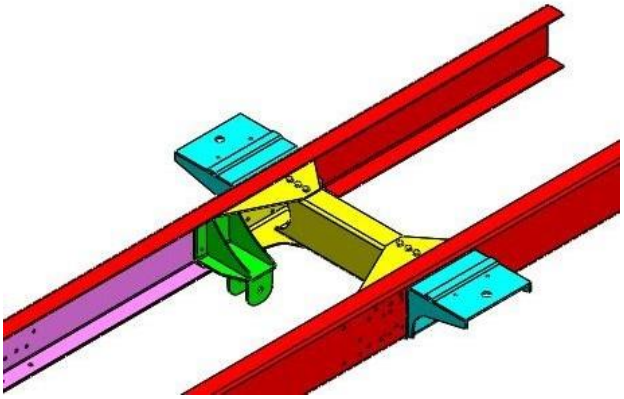

**Fig 3.4. Rear crossmember with Air spring bracket Assembly**

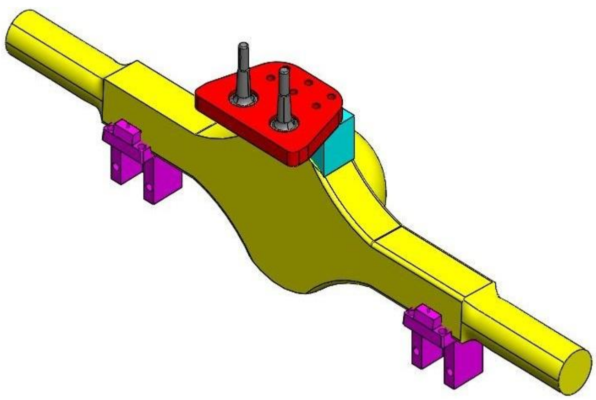

**Fig 3.5. Axle end link Assembly**

Fig 3.1 is Air suspension assembly. Fig 3.2,3.3,3.4,3.5 are the sub-assemblies. Load calculations are done for the sub-assemblies. The designs are designed using SOLIDWORKS software.

## IV. LOADCALCULATIONS

*a. ParallelLink*

Theparallellinkisusetocontrolthebrakingloadofthevehicle. ThisisdeterminedbyusingtheBrakingforceofthevehicle.For Parallellink,BRAKINGFORCE=0.8*6000=4800Kg.Where 6 tonnesis the Rear Axle Weight of the vehicle. The X,Y,Z values should also be determined in order to determine the Parallel link force due to braking. Here X is the distance between compound link axle end pivot point and axle centre,Y is the distance between parallel link axle end pivot point and axle centre and Z is the distance between axle centre and ground. The solution comes in terms of parallel linkforce due tobrakingfortwo links. Whendividedbytwo,theParallellink force due to braking for a single link is determined. Thus the parallel link force due to braking for a single link is fond to be 2619Kg. This solution is used for ouranalysis.

*b. Compound Link*

Thecompoundlink isusetocontrolbothbrakingandcornering load of the vehicle. This is determined by using the Braking forceofthevehicle.Forcompoundlink,BRAKINGFORCE= 0.6*6000 = 3600Kg. Where 6 tonnesis the Rear Axle Weight of the vehicle. The X,Y,Z values should also be determined in ordertodeterminethecompoundlinkforceduetobraking.Here X is the distance between compound link axle end pivot point andaxle centre,Yisthedistancebetweenparallellinkaxle end pivot point and axle centre and Z is the distance between axle centre and ground. The solution comes in terms of compound link force due to braking for two links. When divided by two, the compound link force due to braking for a single link is determined.Thus the compound link force due to braking for a single link is found to be 438Kg. To determine the force dueto cornoring for two links , CORNORING FORCE = (CF/SINβ). It is divided by two in order to determine the cornering force acting in one link. Thus the compound link force due to cornering is found to be 2768Kg. This solutions are used for ouranalysis.

*c. Subframe*

The Subframe is the frame which connects both LH and RH of the vehicle. The force acting on each plate of the subframe is given by, FORCE ACTING ON EACH PLATE = (R.A.W –UNSPRUNG MASS)/4. Here unsprung mass is the weight of the components mounted on the axle. R.A.W is the rear axle weight of the vehicle. The rear axle weight of the vehicle is 6 tonnes.The subframe has four plates. Hence the force is shared between the four plates. Thus, the force acting on the subframe is found to be 1312.5 Kg.

## V. ANALYSIS

a. *Subframe*

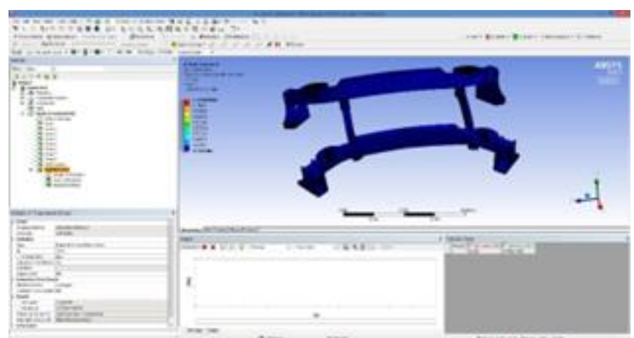

**Fig 5.1.1. EquivalentStress**

**Fig 5.1.2. TotalDeformation**


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InSubframeassembly,thecentreregionofbothLHandRHof the frame is kept fixed. The loads are applied on the fourplates of the subframe and also in the four shock absorber holding brackets. Fine meshing is carried out for better results. The material selected is structural steel. The yield strength of this material is about 250 Mpa. This is entered in the engineering datacolumn.ThentheTotaldeformationandEquilibriumstress is found out. The equilibrium stress should not be greater than the yeildofthe material. The equilibrium stress is found to be237.9 Mpa. The factor of safety is determined in order to determineifthecomponentwillwithstandtheloadapplied.The factor of safety is given by, n = yield stress/maximum stress. The factor of safety calculation is givenbelow.

From Analysis,

Maximum Stress = 237.9 MPa

Material used = StructuralSteel

Yield Strength =250Mpa

FOS (n) = yield strength / Maximumstress

n =250/237.9

n = 1.05

*5.2 Parallel & Compound LinkBracket*

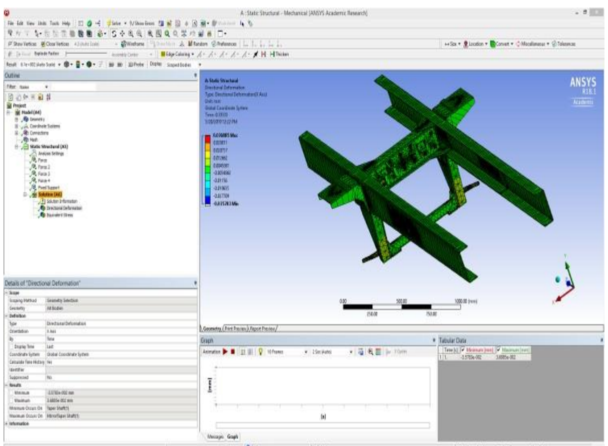

**Fig 5.2.1. EquivalentStress**

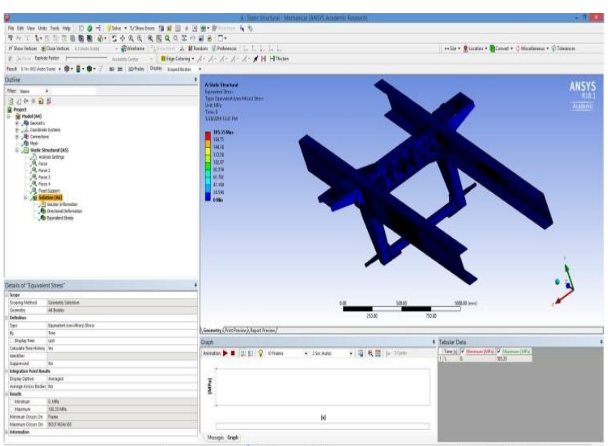

**Fig 5.2.2. TotalDeformation**

Inparallelandcompoundlinkbracket,thechassisiskeptfixed. In this assembly, the loads due to cornoringand braking are applied in their respective links. The force due to braking for a single parallel link is found to be 2619 kg. The force due to corneringincompoundlinkisfoundtobe2768kg.Thebraking force in compound link is found to be 438 Kg. The loads are applied in the respective directions. Fine meshing is done in order to get better results. The Total deformation and Equilibrium stress of the component is determined. The equilibrium stress should not be greater than the yeild of the material.Theequilibriumstressisfoundtobe185.35Mpa.The factor of safety is determined in order to determine if the componentwillwithstandtheloadapplied. Thefactorofsafetyis given by, n = yield strength/maximum stress. The factor of safety calculation is given below.

From Analysis,

Maximum Stress = 185.35 Mpa

Material used = Structural Steel

Yield Strength = 250 MPa

FOS (n) = yield strength / Maximumstress

n =250/185.35

n = 1.35

*5.2 Rear Crossmember BracketAssembly*

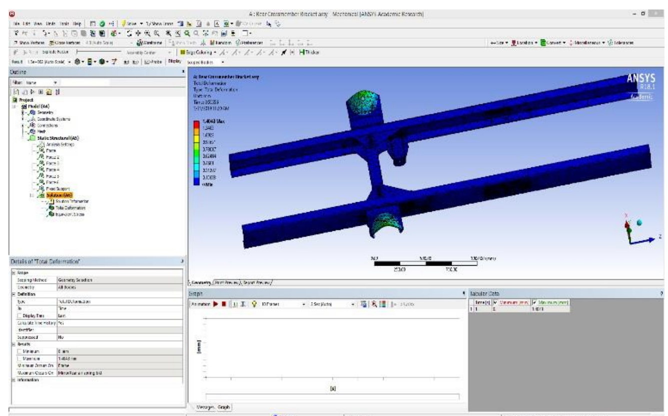

**Fig 5.3.1. TotalDeformation**

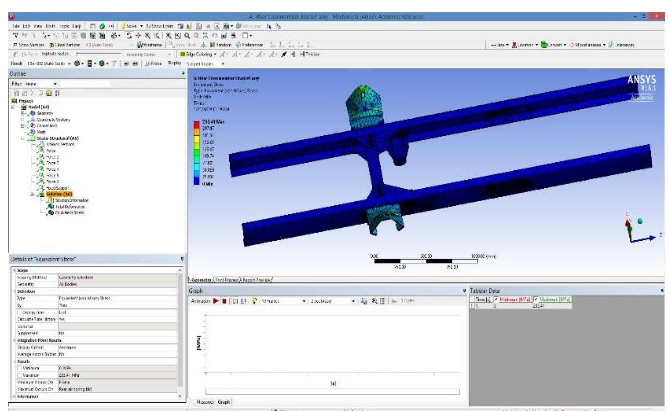

**Fig 5.3.2. EquivalentStress**


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In rear crossmember bracket assembly, the chassis is kept fixed. TheLoadactingontherear crossmemberbracket is determined by subtracting the Rear axle weight of the vehicle and the unsprung mass. The unsprungmass is the weight of the components mounted on the axle. The force is found to be 1312.5 Kg. Fine meshing is done in order to get better results. TheTotaldeformationandEquilibriumstressofthecomponent isdetermined.Theequilibriumstressshouldnotbegreaterthanthe yeild of the material. The equilibrium stress is found to be233.41 MPa. The factor of safety is determined in order to determineifthecomponentwillwithstandtheloadapplied.The factor of safety is given by, n = yield strength/maximumstress. The factor of safety calculation is givenbelow.

From Analysis,
Maximum Stress = 233.41MPa
Material used = Structural Steel
Yield Strength = 250 MPa
FOS (n) = yield strength / Maximum stress
n = 250/233.41
n = 1.07

*5.4 Axle End Link Assembly*

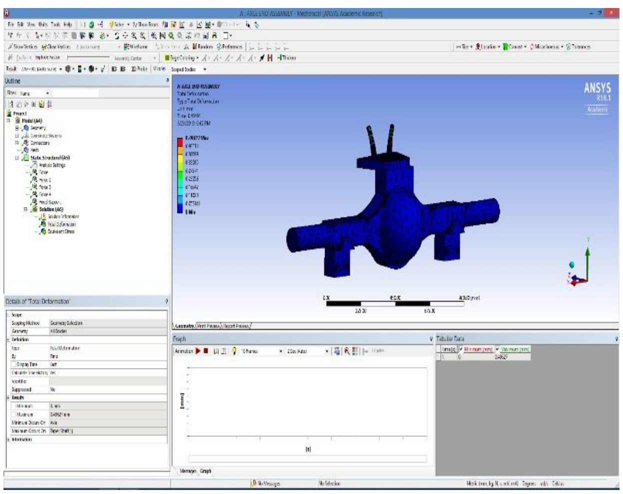


Fig 5.4.1. TotalDeformation

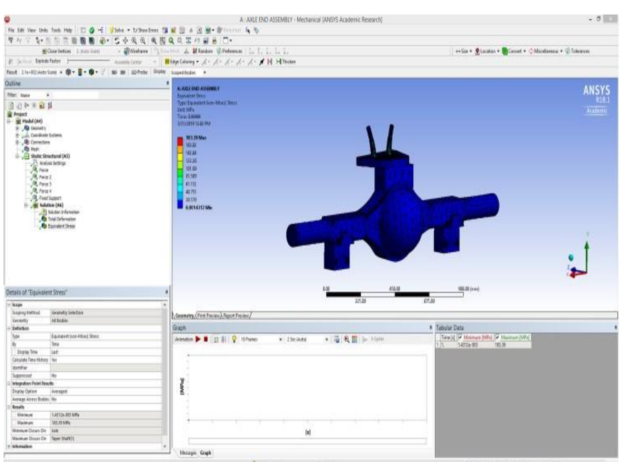


Fig 5.4.2. EquivalentStress

In Axle end assembly, both the ends of the axle are kept fixed. The fine meshing is done to the assembly to get better results. The force due to braking and cornering of a compound link is determined. The braking force is found to be 438 kg. thecorneringforceisfoundtobe2768Kg.Theloadsareappliedto the compound link in the respective directions. The Total deformation and Equilibrium stress of the component is determined. The equilibrium stress should not be greater than the yeildofthe material. The equilibrium stress is found to be231.15 MPa. The factor of safety is determined in order to determineifthecomponentwillwithstandtheloadapplied.The factor of safety is given by, n = yield strength/maximumstress. The factor of safety calculation is givenbelow.

From Analysis,
Maximum Stress = 231.15 MPa
Material used = Structural Steel
Yield Strength = 250 MPa
FOS (n) = yield strength / Maximum stress
n = 250/183.39
n = 1.4

## 6.RESULTS ANDDISCUSSION

| S.NO | SUB ASSEMBLIES | DEFORMATION (mm) | VON-MOISES STRESS (MPa) | FACTOR OF SAFETY |
|---|---|---|---|---|
| 1 | SUBFRAME | 0.5585 | 237.9 | 1.05 |
| 2 | PARALLEL & COMPOUND LINK ASSEMBLY | 0.0368 | 185.35 | 1.35 |
| 3 | REAR CROSSMEMBER BRACKET ASSEMBLY | 1.404 | 233.41 | 1.07 |
| 4 | AXLEEND LINK ASSEMBLY | 0.496 | 183.39 | 1.4 |

The equilibrium stresses of Subframe, parallel and compound link assembly, Rear crossmember bracket assembly and axle end link assembly are all below the yield strength of the material. These values are for 3G load conditions. Hence it is a safe value. The material chosen is structural steel. Structural Steel has a yield strength of 250 MPa. All the values of deformation are less than 1 mm except for rear crossmember assembly. These values are also within the deformation limit. Thefactorofsafetyisbasedontheyieldstrenghtofthematerial used and the maximum stress obtained during analysis. The valuesobtainedare1.05,1.35,1.07and1.4.Thesevaluesaresafe values since they are above 1. Hence this proves that the given design can withstand the load applied.


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## VI. CONCLUSION

- Measurements from the college bus has been taken accurately.
- The Air suspension system has been designed successfully.
- The design has passed the articulationtest.
- Load calculations have been performedsuccessfully.
- The Design has been analyzedsuccessfully.
- Since the FOS for all components are above 1, the material can withstand the loadapplied.

Hence the design created can be incorporated in place of Leafspringsuspensiondesign inBharatBenz917&914.

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