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ANALYSIS OF INDEPENDENT RARE AXLE SUSPENSION SYSTEM COMPONENTS WITH DIFFERENT MATERIALS

Dr. Srinivasa Murthy M[1] and Dr. Sumana B G[2]
[1]Assistant Professor, Department of Mechanical Engineering, Government Engineering College, Kushalanagar, Karnataka Madapatna, Mysore - Madikeri Road, Kushalnagar, Karnataka 571234, India
[2]Assistant Professor, Department of Mechanical Engineering, Government Engineering College, Hassan, Karnataka 573201, India
[1]msmurthy2005@gmail.com and [2]sumogh76.gec@gmail.com

ABSTRACT
The current investigation on analysis of independent rare axle suspension system components with different materials is done with four different types of materials belongs different chemical compositions. The primary objective of the work is to find the Max. shear stress value against the helical coil spring (HCS) and Trailing arm (TA). The secondary aim of the work is to find out the Max Deflection value of the spring and TA component. For the analysis purpose ANSYS software is used. Stainless Spring Steels SAE 51414 has been proved as the best material.

Keywords: Rare axle, Chemical Composition, HCS, TA, Shear Stress, Deflection, ANSYS

INTRODUCTION
Until my most recent update, the term "Rare Axle Suspension System" wasn't well-known in the automotive engineering or manufacturing community. That might, however, be a reference to a unique or customized suspension system for cars. [1-3] Vehicle suspension systems are essential parts that absorb shock from the road surface to provide stability, control, and comfort. [4-6] Suspension systems that are rare or customized may be made for off-road vehicles, race automobiles, or even special custom builds.[7-9] Please feel free to give any further context or information you may have regarding this word so that I can respond to you more specifically. [10-12].

Typically, a vehicle's solid wheel suspensions are located in the back. The two sets of wheels on the back left and right of this suspension are its primary characteristic.[13-14].The technical system that maintains the vehicle's body and frame in the air while connecting it to the road is called the rear suspension.[16-17] The frame joints, rods that shock absorption, springs that are flexible axles and tyres make up the back stabilization.[18-20]

There are actually two primary forms of dependent rear suspension beams wheel with front-wheel drive vehicles and solid axle for rear-drive vehicles. [21].The most popular axle design in the past was the solid axle, which used coil or leaf spring suspension. [22]

These days, the driving axle housing is suspended using leaf springs. Rubber bushings minimize vibrations and stress from the road.[23] To maintain the wheelbase and track, the front leaf spring serves as a control arm. [24] Axle wind rotation is decreased by its shorter front section.[25]

Because of its rough ride, leaf spring suspension was best suited for vehicles that carried loads rather than passenger cars.[26] A version that uses coil springs for a lighter, smoother ride is rear coil spring suspension. [27]

Other techniques are needed since coil springs are unable to keep the axle in line.[28] One or more upper control arms are used by the suspension for side motion and axle rotation, and two lower control arms are used for wheelbase.[29] Rubber bushings allow compliance and lessen vibration during jounce and rebound. [30]

Using linear beam theory, K-J Mun et al. provide an analytical approach for determining the torsional stiffness in a torsion beam rear suspension system. Additionally, they suggest using potential energy to determine the equivalent spring stiffness at the wheel center. The approach is a useful tool for design engineers because it takes into account the elastic effect of the tubular beam and the stiffness of the rubber bushing. It also yields immediate data on roll qualities.

Fichera et al. modeled torsion beam rear suspensions, a typical part of cars in the B or C class, using a multibody approach. For the elasto-kinematics analysis, they employed SIMPACK multibody code and a linear approach. The study examined the differences in stiffness values between the bushings connecting the torsion beam to the vehicle chassis and the outcomes of multibody simulations using non-linear FE models. Predicting handling performances and NVH quality was the study's main goal.

The use of numerical simulations in automotive component design to shorten design times, save prototype costs, and improve product reliability is the main topic of the study by Márcio Eduardo Silveira et al. They discovered that twist-beam suspensions, which are prevalent in more than 90% of light vehicles in developing nations, provide good cost-benefit ratios and performance that meets expectations. The study's objective was to assess, using a finite element method, how the torsion beam affected the kinematic behavior of a twist-beam suspension under both symmetric and asymmetric loadings.

For the design of car suspensions, Hideki Sugiura et al. suggest using a CAE tool called First Order Analysis (FOA). This tool can be used to calculate the mechanical parameters of torsion beam suspension and is intended for engineers who do not have specialized modeling or analysis knowledge. The tool is useful for planning suspension strategies because it provides experimental verifications and examples to guarantee the success of its use.

Wheel and tire trajectories when shifted from a static position are determined by the suspension geometry, according to Carroll Smith (1978). According to Jörnsen Reimpell et al. (2002), diverse operating circumstances such as loaded/unloaded, acceleration/braking, level/uneven road, and straight running/cornering require current vehicle suspensions to satisfy different requirements. Thomas D. Gillespie highlighted the significance of suspension characteristics in relation to vehicle dynamics, taking into account aspects such as force transmission, kinematic behavior, cost, weight, space, simplicity of manufacture, and assembly. Suspension links, as proposed by Milliken et.al, are necessary for precise knuckle positioning, vehicle maneuverability, and difficult road conditions.

According to John C. Dixon (2007), road roughness and the roll and pitch of moving vehicles are the reasons why suspension is required. Using 60 Si2 Mn A Steel and Chromium-Vanadium alloy, K Pagan Kumar performed a static analysis on a two-wheeler suspension system spring in 2013. Because of its reduced deflection and stress values, the conventional material was determined to be the best. A research paper on the design and analysis of two-wheeler shock absorber coil springs utilizing oil-tempered spring steel and beryllium copper was released in 2018 by Raviraj N. Rathod and Milind S. Bodkhe. Using carbon steel and beryllium copper, A. Vamsi Krishna and Dr. G. Janardhana Raju investigated the structural and modal analysis of two-wheeler shock absorbers in 2019. Abu Sufyan Malik, Mohammed Rizwanuddin, and A. Aravind Reddy determined in 2020 that the ideal material for a shock absorber on a 150cc bike was structural steel.

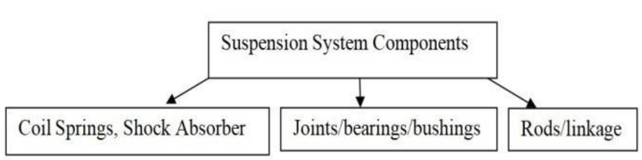


Figure 1a Elements of SS

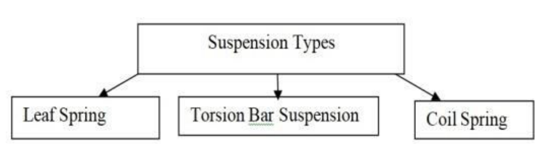


Figure 1b Suspension Types

Trailing arm suspension and short-arm/long-arm suspension are the two varieties of independent rear suspensions.[31] While the short-arm/long-arm suspension is installed on a sub frame with a cast aluminum steering knuckle and variable rate coil springs, the trailing arm suspension permits independent movement of both rear wheels.[31]

REAR SUSPENSION FUNCTIONING

The forces that operate in a suspension system are vertical. The car's weight tends to drag it toward the earth, thus to counteract this, a coil pushes the vehicle upward. A damper is there because, in order to keep the coil push from being too strong, another mechanism is required. The primary job of the damper is to absorb and lessen the coil's compression and rebound.

Common suspension systems include solid rear axles and independent suspension. Rear independent suspension systems allow each wheel to be raised and lowered independently of the other, while solid rear axles only allow one wheel to be pushed up. On rough roads, the ability to raise and lower individual wheels thanks to independent rear suspension systems enhances performance and traction. A consistent contact surface with the road is maintained by this technology.

A solid axle is used in the rear single axle suspension system to link the rear wheels and rear springs. This system consists of a shock absorber, an air spring, and trailing arms. Commercial cars with trailing-arm suspension can have a flatter floor and more cargo space.

The shock absorber is fastened at the clamp, whereas the leaf springs are fastened straight to the frame. Two sets of leaf springs and a bell crank rocker are used by bell crank connected leaf springs to transform translational motion. Rear wheels and rear springs are connected by a rear dual axle solid axle suspension.

The Oxford College of Engineering's Guruprasad et al. discovered that reinforced aluminum enhanced by fly ash had better mechanical properties than monolithic metal. In a research on the finite element analysis and design of tractor rear axles, Chaudhari et al. found that fatigue was the primary factor contributing to shaft failure. Weight transfer was found to be a significant component in the failure study of rear axles with loaded trolleys by Charya et al. Rear axle shaft failures of 575 DI tractors made by Mahindra and Mahindra Ltd. were examined by G.K. Nanaware et al.

Table 1 Vehicle Specifications

Rare Track Width = 1372 mm	Vehicle Weight = 9800 kg	Total Payload Carrying Capacity = 11,8800 Kg
Wheel Base = 1448 mm	Weight per person = 90 kg	Self weight of the axle including the suspension system = 3000 kgs
Motion Ratio = 0.7	No of persons on the vehicle = 6	Total Payload Carrying Capacity = 14000 Kg
Height of CG = 925 mm	Distance of CG from RA = 498 mm	

By shielding the chassis and other components from harm caused by road shocks, the suspension system guarantees a comfortable ride for the occupants. Vibrations from irregular roads damage the basic frame structures, which support the body, engine, transmission, and passengers.

Table 2 Specifications of the Spring & Vehicle

Total number of Coils	8	Inner Diameter,	117.19mm
Number of Active Coil	6	Outer Diameter,	148.44mm
Mean Diameter	133mm	Free length	304.8mm
Solid Length =	110 mm	Factor of Safety	1.9

Pitch 51 mm Spring Index 8.6	

Table 3. Summary on Properties of the Materials Used for the spring

Materials Used	YM (Gpa)	PR	Density (kg/m^3)	YS (Mpa)	TS (Mpa)
High Carbon Steels SAE 1074	210	0.30	785	505	650
Alloy Spring Steels ASTM A401	213	0.29	780	589	683
Stainless Spring Steels SAE 51414	200	0.30	784	638	759
Copper-Base Spring Alloys ASTM B 134	125	0.28	783	738	859

METHODOLOGY

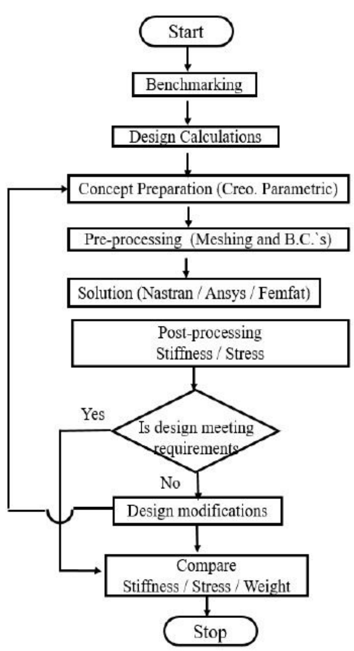
Benchmarking, structural and performance analyses of existing cars, twist beam section design calculations, CAD concept preparation, CAE software verification, and physical validation stage are the first steps in the close profile design process.

DESIGN CRITERIA

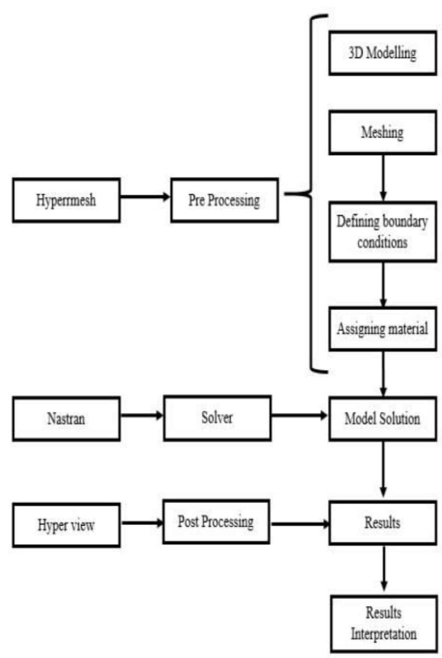
We are going to develop a chassis mechanism using the materials and specifications mentioned above. The assembly and individual component designs are displayed in the design that follows.

Table 4 Summary on ANSYS Analysis

		Total Nodes = 97310
Number of Elements = 87744	BCS is fixed at 3 locations, where the loads are transmitted through wheel centers	ANSYS 17.0 Version



4a Design Flow Chart



4b Flow Chart for Design Validation & Verification

2a 3D Drawing (HCS)

2b 3D Meshing (HCS)

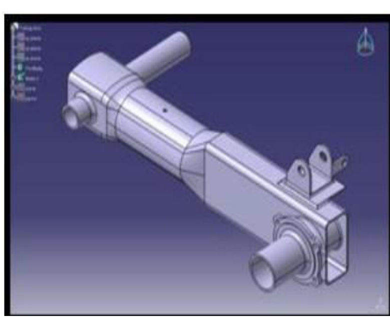
Table 5. Summary on Maximum Shear Stress and Deflection on Spring Materials

Materials Used	MSS (Mpa)	MD(mm)
High Carbon Steels SAE 1074	767	169
Alloy Spring Steels ASTM A401	644	113
Stainless Spring Steels SAE 51414	614	110
Copper-Base Spring Alloys ASTM B 134	675	131

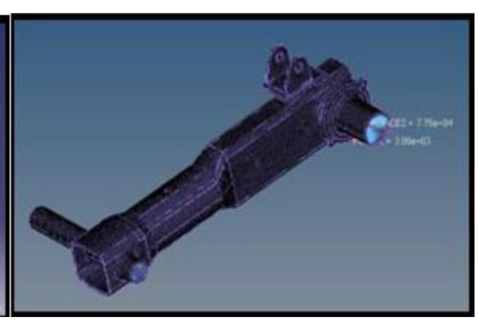
TRAILING ARM

For low mass vehicles, the sprung-to-unsprung weight ratio is essential since it lessens the impact and roughness of the smaller tires. Compared to previous designs, the proposed design coil spring consumes less space and has lower coil diameter, wire diameter, and spring length.

The relationship between operating parameters and their significance in the design of suspension systems is covered in the study. It highlights how challenging it is to define and forecast how different system components will interact and react to different conditions. It also draws attention to how difficult it is to analyze suspension systems with more degrees of freedom.



3a 3D Drawing (TA)



3b 3D Meshing (TA)

Table 6 Summary on Maximum Shear Stress and Deflection on Trailing Arm Materials

Materials Used	MSS (Mpa)	MD(mm)
High Carbon Steels SAE 1074	204.95	1.4
Alloy Spring Steels ASTM A401	205.65	1.5
Stainless Spring Steels SAE 51414	206.57	1.51
Copper-Base Spring Alloys ASTM B 134	204.89	1.53

RESULTS

For both the rear axle suspension systems components spring as well as the trailing arm the maximum shear stress and maximum deflection values are analyzed with the help of ANSYS software. The type of materials is considered on X- axis and MSS and MD values are considered on Y- axis. The change in the material is not linear with MSS and MD for all the cases was noticed.

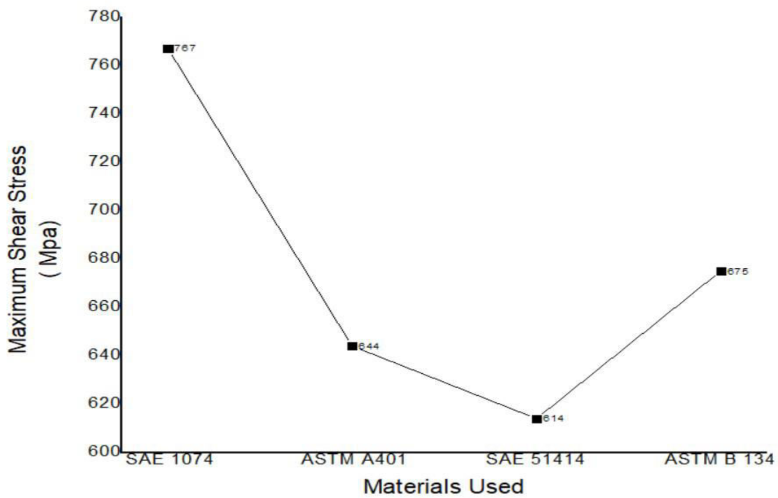


Fig 4a Distribution of MSS (spring)

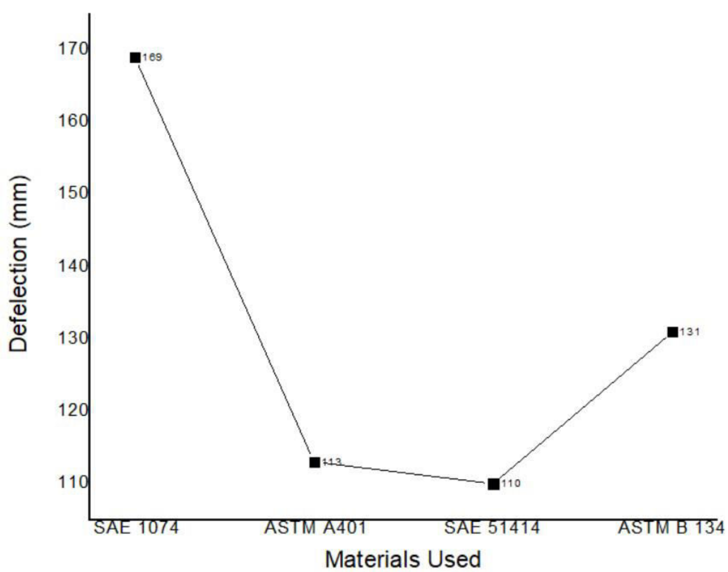


Fig 4b Distribution of MD (spring)

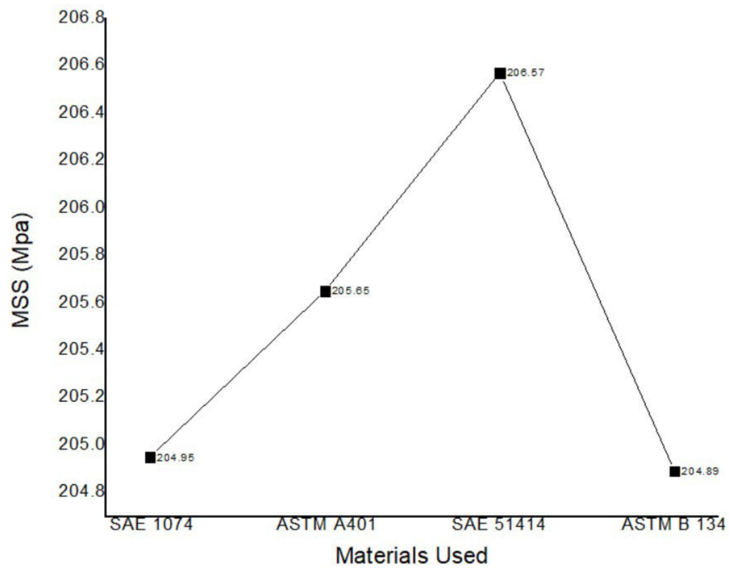


Fig 5a Distribution of MSS (TA)

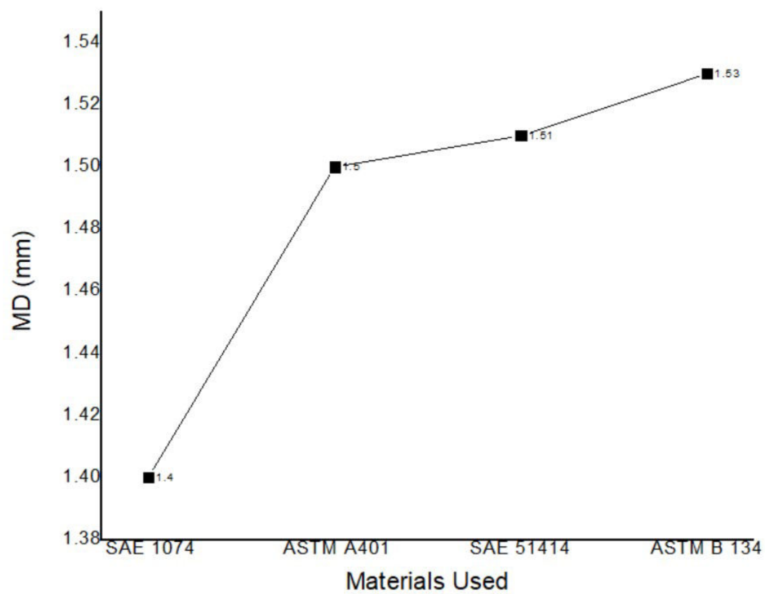


Fig 5b Distribution of MD (TA)

CONCLUSIONS

- **MSS (spring):** Referring to the figure 4a the maximum shear stress (MSS) is achieved for High Carbon Steels SAE 1074 as 767 Mpa. The lowest MSS is achieved for Stainless Spring Steels SAE 51414 as 614 Mpa which is 19.84% lower than SAE 1074 when compared.
- **MD for spring:** Referring to the figure 4b the maximum deflection (MD) is achieved for Copper High Carbon Steels SAE 1074 as 169 mm. The lowest MD is achieved for Stainless Spring Steels SAE 51414 as 110 which is 34.91 % lower than SAE 1074 when compared

- **MSS for TA**: Referring to the figure 5a the maximum shear stress (MSS) is achieved for Stainless Spring Steels SAE 51414 as 206.57 Mpa. The lowest MSS is achieved for Stainless Spring Steels SAE 51414 as 204.89 Mpa which is 0.8% lower than SAE 51414 when compared.
- **MD for TA**: Referring to the figure 5b the maximum deflection (MD) is achieved for Copper Base Spring Alloys ASTM B 134 as 1.53 mm. The lowest MD is achieved for High Carbon Steels SAE 1074 as 1.4 mm which is 8.4 % lower than SAE ASTM B 134 when compared.
- Hence it is conclude that the rear end independent suspension system both the components spring and the TA are replaced with Stainless Spring Steels SAE 51414 as best material.

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