Design and Analysis of Suspension System for Light Weight Vehicle

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Abstract

An Independent wheel suspension system is used nowadays in almost all new modern cars. The conventional system which uses dependent suspension is not of much use as it creates more jerk in the car body. Normally, when any bump or hindrance comes across the vehicle, the suspension system reduces the disturbance in the car. The dependent system is connected with chassis and car body frame. So with any jerk, the car body faces the disturbance. In Independent wheel vehicle suspension, the spring is connected with the wheel, which absorbs all shock and does not allow any jerk in the car body.

The research paper covered a brief literature review on the analysis of the independent suspension system. First studied existing suspension design as per standard design procedure then identifying design issue in existing design by using mechanism calculation. By using CAD tools like Solid work for a critical component of independent suspension for analysis purposes and according to result for the conclusion. Optimization of taper spring concerning material properties and plot result.

IndexTerms–*Independent suspension system, Car body, Design, Analysis, CAD.*

1. INTRODUCTION

A suspension system is an assembly of springs, shock absorbers and linkages that connects a vehicle to its wheels. In a running vehicle, it is the suspension system that keeps the occupants comfortable and isolated from road noise, bumps, and vibrations. The suspension system also provides the vehicle excellent handling capabilities, allowing the driver to maintain control of the vehicle over rough terrain or in case of sudden stops. Additionally, the suspension system prevents the vehicle from damage and wear.
The basic components of the suspension system include springs, shock absorbers, kinetic parts, and auxiliary devices. The springs absorb impacts and provide cushioning when a wheel hits a bump in the road. The springs also resist the wheel's movement and rebounds, pushing the wheel back down. The type, number, and location of the springs differ based on a different type of suspension system, which will be demonstrated in the next section. The shock absorbers (dampers) restrain the spring motions and prevent the spring from continuing vibrating. In a suspension system, one shock absorber is located at each wheel.

2. LITERATURE SURVEY

Mahmoud Omar, M.M. El-Kassab, Walid Abdelghaffar **[1]** were represented the active performance compared against the passive is performed experimentally and numerically utilizing SIMULINK's Simscape library. Both systems are modeled as single-degree-of-freedom to simplify the validation process. Economic considerations were considered during the rig's implementation. The rig consists of two identical platforms fixed side by side allowing testing two independent suspensions simultaneously. Position sensors for sprung and unsprung masses on both platforms are installed.

Tian Mi, Gabor Stepan, Denes Takacs**[2]** was presented to study the shimmy problem of the electric vehicle with independent suspensions, a 5 DoF model is established using the Lagrange Equation. Gyroscopic moment and tire nonlinearity are both considered, and tire-road constraint equations are derived on the non-slip assumption. Stability charts are conducted with the linearized model, while the numerical simulation is also made so that these two methods can verify each other. The results show that bifurcation occurs at certain vehicle forward speeds. Suspension structural parameters, such as caster angle, affect wheel shimmy. Furthermore, the presented model enables the analysis of any parameters in the system, and as an example, the influence of dampings on shimmy is investigated.

Carlos Arana, Simos A. Evangelou, Daniele Dini **[3]** had represented the potential of the Series Active Variable Geometry Suspension (SAVGS) for comfort and road holding enhancement. The SAVGS concept introduces significant nonlinearities associated with the rotation of the mechanical link that connects the chassis to the spring-damper unit. Although conventional linearization procedures implemented in multi-body software packages can deal with this configuration, they produce linear models of reduced applicability.

Jan Dizo, StasysSteisunas, Miroslav Blastnicky**[4]** had focused on the vibration analysis of the coach, which wheel is damaged by the wheel-flat. Analyses are carried out in multibody software and results are evaluated in terms of influencing suspension parameters to change on accelerations output signals. The article consists of two parts. The first part is aimed at the problem of the damaged wheel's origin and its consequence during rail vehicles running on tracks during real operation. There is also included the system of forces and accelerations measurement during rail vehicles running on the given track section. The second part is focused on the assessment of selected measured parameters of a rail vehicle with wheel-flat which are obtained from computer simulations. As evaluation parameters signals accelerations in the selected location during passenger car running on the straight track for various stiffness of coil spring of the primary and secondary suspension were assessed.

Anirban. C. Mitra, Gourav. J. Desai, Saaish. R. Patwardhan**[5]** had represented one of the challenging tasks for engineers. The main function of any suspension system is to reduce or eliminate the road excitations transmitted to the vehicle body. An effort has been made in this paper for a passive suspension system by using an optimization technique called the Genetic algorithm to absorb vibrations as per ISO 2631-1: 1997 standards. The spring stiffness (ks), damping coefficient (cs), sprung mass (ms), unsprung mass (mu), tire stiffness (kt) are optimized in such a way that ride comfort is increased. The quarter car and driver seat with the driver's body is simply modeled together as four degrees of freedom (DOF) system by using SIMULINK for analyzing the ride comfort.

A.A. Koshurina, M.S. Krasheninnikov, R.A. Dorofeev**[6]** had represented a universal Arctic rotary-screw rescue vehicle (URV) was chosen as an object of the research. At the moment this rescue vehicle is being developed at the NNSTU named after R.E. Alekseev. A distinctive feature of the URV is the original design of an operated equalizing beam suspension, which has not previously been used for this kind of vehicle. The analysis of the equalizer beam various designs is presented in the article. Calculation schemes and simulation models are developed following the specificity of the rotary-screw vehicle motion. The models and strength calculations have been carried out with standard tools of Autodesk Inventor 2015. The article presents the stress-strain states of different equalizing beam embodiments. The conclusion about the reasonability of the application of the particular equalizer beam embodiment for developing a rotor-screw rescue vehicle is based on the performed comparative analysis of researched constructions.

PanosBrezas, Malcolm C. Smith, Will Hoult **[7]** had represented the problem of optimal control for semi-active vehicle suspensions. A specific goal is to develop an algorithm that is capable of optimizing ride and handling behavior simultaneously in an experimental situation. A time-domain optimal control approach is adopted in which ride and handling are modeled as exogenous disturbances acting on the vehicle: road disturbances (modeled stochastically), and driver inputs (treated as deterministic quasi-static disturbances). A control algorithm is derived from a solution of the stochastic Hamilton–Jacobi–Bellman equation for the finite horizon case. The advantages of the approach are demonstrated experimentally on a test vehicle performing a steering maneuver on a bumpy roundabout.

Werner Scheele, Igor Iroz**[8]** had represented, to random excitation by the unevenness of the road. For a dynamical analysis, vehicle models of the vertical vibrations, as well as guideway models of the road unevenness, are required. The fundamental dynamics of vehicle suspensions can be already modeled by a quarter car featuring the decoupling of the car body motion and the wheel motion. This suspension model is characterized by five design parameters where two of them, the shock absorber and the tire spring, are highly uncertain due to wear and poor maintenance. For the assessment of the vehicle's performance three criteria have to be used: ride comfort, driving safety, and suspension travel. These criteria depend on all the five design parameters resulting in a conflict or a Pareto-optimal problem, respectively. In this paper, the uncertainties of the parameters are projected into a criteria space to support the decision to be made based on a Pareto-optimal problem. Simulations with uncertainties support the robust suspension design. It is shown that controlled suspension parameters remain uncertain due to the unpredictable decisions made by the driver.

M. Soleymani, M. Montazeri-Gh, R. Amiryan**[9]** had represented the design of an adaptive active suspension system, to simultaneously improve ride comfort and travel suspension under various traffic conditions, is addressed in this paper. For this purpose, using a full-vehicle model, with eight degrees of freedom, two separate fuzzy controllers are designed for front and rear suspensions. The parameters of the fuzzy controllers are then tuned for various traffic conditions of a driving pattern, using a multi-objective Pareto-optimal solution.

VladimírGoga, Marian Klúcik**[10]** had represented vehicle suspension is to achieve good driving stability and passenger comfort regardless of the road surface. These requirements are often contradictory. This article aims to show the possibilities offered by a combination of modeling in a virtual environment and evolutionary computation in the process of optimization. The mathematical half-car model was created in Matlab/Simulink. Passive suspension parameters (damping and stiffness coefficients) were optimized with the use of evolutionary computation. Results from simulations of the model with original and optimized suspension parameters were compared.

SamantSaurabh Y., Santosh Kumar, Kaushal Kamal Jain, Sudhanshu Kumar Behera**[11]** had represented in detail the design procedure of the front double A-arm pushrod suspension system for a formula student race car. The type of suspension system used generally is reviewed. The CAD models of the components in the suspension system are made using SolidWorks and the Finite element analysis of the components is done using ANSYS Workbench. Both kinematic and dynamic analysis of the designed suspension system is performed. The results of vibration or ride analysis and roll steer analysis are also presented for the designed suspension system. The method for spring design is elucidated. This work emphasizes the method for designing and analyzing the suspension system for a race car in various aspects.

KameshJagtap, YogeshRathod, AnmayShedge, MitaliGramopadhye, Prof. VivekDiware**[12]** had represented an On-Road Commercial Vehicles in terms of its all-terrain capability due to its large travel and Ride Quality; also it has to face various ground conditions such as mud, ice, rocks, bumpy tracks, etc. Hence it needs to be Robust enough to sustain in such frequently occurring Undulations. Suspension systems of commercial vehicles are designed considering normal road conditions. While designing the suspension system of an ATV, various terrain conditions have to take into consideration. This paper gives a review of suspension systems for ATV.

Prof. Sameer Verma, Parvez Raza **[13]** had represented a very popular and efficient form of the suspension system. It has one control arm and a strut assembly. Coil spring and shock absorber will normally from parts of the strut assembly. Macpherson suspension system is generally used as the front suspension system in passenger cars. Coil spring may be mounted on the control arm instead of being around the strut. On this type, the shock absorber connects the knuckle to the frame. This type of suspension strut is often also used on the rear suspension system. Macpherson strut is set up is still popular in high-performance passenger cars.

Reena Mishra, AnandBaghel**[14]** had represented the significant increase in the research activity on the front wishbone in the last few years, the present article identifies and highlights the various research that is most relevant to the design, analysis, and optimization of the front wishbone suspension system. Present work is focused in the field of the material selection methods, impact load, deformation of the material, stress, weight reduction for ATV vehicle for improving the stability and handling of the vehicle to minimizing the un-sprung mass, better durability and less expensive also. The outcome of the discussed research is intended to give the reader a brief verity of the research carried out on the front wishbone suspension system.

Dongchen Qin, Junjie Yang, Qiang Zhu, Peng Du **[15]** had represented one of the key parts in vehicles, which can directly influence such performances as steering stability and ride comfort. The multi-body dynamics model of multi-purpose vehicles (MPV) front suspension is built with ADAMS/VIEW, and the location parameters of the front wheel are simulated. To improve the kinematics performance and steering stability, the sensitivity analysis and optimization design for the front suspension are carried out. The results can provide some guide and reference for the R&D of the MPV.

Jihui Liang, Lili Xin **[16]** had represented Suspension system transfers force and torque between the wheel and automobile frame, guides, and controls the relative motion of the wheel and automobile body to ease up the impact from the road surface and the shock from attenuation system. Kinematic characteristics of the suspension refer to variation regularities of parameters such as kingpin inclination angle, camber angle, caster angle, and the like when automobile wheels jump up and down, namely, wheels and vehicle bodies have relative movement in the vertical direction. Rational choice of suspension structure and performance parameters has a great and direct influence on the traveling smoothness, steering stability, and comfortableness of the automobile.

P. Nagarjuna, k. Devaki Devi **[17]** had represented the Suspension system of an automobile plays an important role in ensuring the stability of the automobile. Although it has been achieved to a considerable extent, another major aspect of the suspension system is passenger car is luxury. A lot of research is going on in this direction, which led to the development of an independent suspension system. The control arm plays a major role in an independent suspension system. It is generally made of forged steel which has considerable disadvantages such as weight, cost, etc. The project involves the development of sheet metal control arm, which has many advantages over forged metal. The component has been modeled using the curves extracted from the workspace available in PRO-E. This model is translated into a STEP file, which is then retrieved in 'Unigraphics' for analysis. The model is subjected to different load conditions and thus analyzed using Structures P.E solver. The stress and stiffness of the model are studied from the results obtained from the analysis to verify the success of the design.

Mohammad ImanMokhlespourEsfahani, MasoudMosayebi**[18]** had represented Simulation accuracy by recent dynamic vehicle simulation multidimensional expression significantly has progressed and acceptable results not only for passive vehicles but also for active vehicles normally equipped with advanced electronic components is also provided. Recently, one of the subjects that have been considered, is increasing the safety car in design. Therefore, many efforts have been done to increase vehicle stability, especially in the turn. One of the most important efforts is adjusting the camber angle in the car suspension system. Optimum control camber angle in addition to vehicle stability is effective in the wheel adhesion on road, reducing rubber abrasion and acceleration and braking. Since the increase or decrease in the camber angle impacts the stability of vehicles, in this paper, a car suspension system mechanism is introduced that could be adjusted camber angle and the mechanism is an application and also inexpensive. To reach this purpose, in this paper, a passive double wishbone suspension system with a variable camber angle is introduced and then a variable camber mechanism designed and analyzed for study the designed system performance, this mechanism is modeled in Visual Nastran software and kinematic analysis is revealed.

Arvin Niro[19] had represented a big part of NASA's curiosity into exploring what is beyond our atmosphere and NASA's rovers have allowed us to do just that. They are equipped with state of the art technology that allows us to see and measure if life can exist elsewhere. In this project, we aim to design and build a suspension system that can be incorporated onto a rover that was constructed last semester at Kapiʻolani Community College by Eric Caldwell and Lee Do. This rover features wireless technology and a mecanum drive system that allows it to be extremely maneuverable. However, due to its maneuverability, this generates uncontrollable vibration in the rover. In an attempt to suppress the vibration, a double-wishbone suspension design was used with a spring and damper system to reduce and dampen the vibration generated from the mecanum wheels. The result of this allowed a suspension system to be designed and optimized for this specific rover by utilizing SolidWorks and finite element analysis to decide the overall design of the system.

Dr. Naser LAJQI, Dr. Azem KYÇYKU, Dr. Shpetim LAJQI **[20]** had represented the research methodologies utilized for developing a suspension system for four-wheel-drive terrain vehicles. The main research methods can be identified as literature studies; design processes by applying CAD systems, numerical analysis methods, mathematical modeling and simulation, optimization of the mechanical systems, as well as the comparison, analysis, and evaluation of the obtained results. The proposed suspension system for the terrain vehicle was successfully derived from a classic double-wishbone control arm. Optimization of the suspension parameters for passive ones is performed by Multi-Objective Genetic Algorithms, whilst for active damping force by employing the Hooke-Jeeves non-linear programming method. Based on comprehensive analysis it is shown the active systems are more adequate. The proposed suspension design provides relatively small lateral wheel motion, zero camber angles, and effectively absorbs the vibrations caused by road excitation.

3. OPTIMIZATION OF TAPER SPRING

The simulation and analysis of coil spring were done with different materials. The materials selected were steel structure, copper alloy, and carbon composite. The coil spring was simulated with Solidworks 2020 with specific dimensions which are listed in Table 5.1.

Table 1 The Specification of Taper Spring

No	Specification	Value
1	Outer diameter	135 mm
2	Inside diameter	115 mm
3	Wire diameter	10 mm
4	Free length	160 mm
5	Number of active coils	5
6	Pitch	35 to 8 mm
7	Taper angle	270°

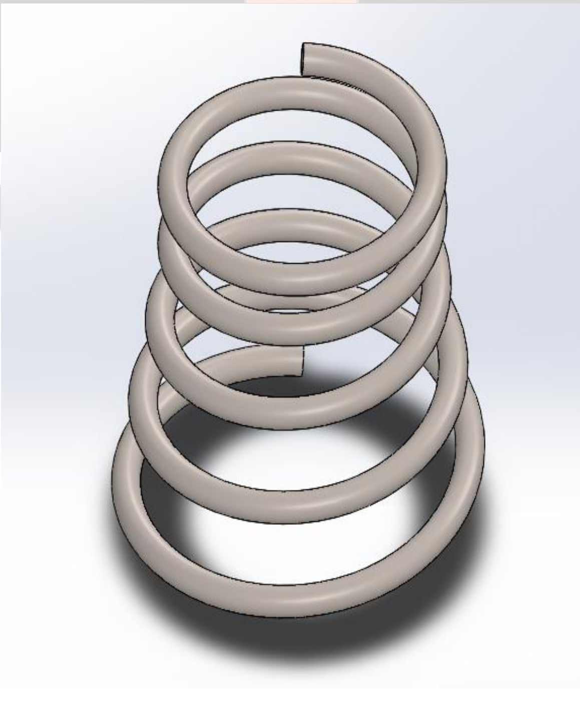

Fig. 1 The Taper Spring

The properties of materials used for producing the coil spring in this paper listed in Table 2.

Table 2 Properties of Material

Materials	Steel Structure	Copper Alloy
Density	7850 kg/m3	8300 kg/m3
Young Modulus	2 X 1011 Pa	1.1 X 1011 Pa
Poisson ratio	0.3	0.34

The numerical analysis was done by using a finite elements analyzer in Solidworks 2020. The spring has meshed with programmed generated mesh with fine meshing. The mesh of taper spring shown in Figure 2.

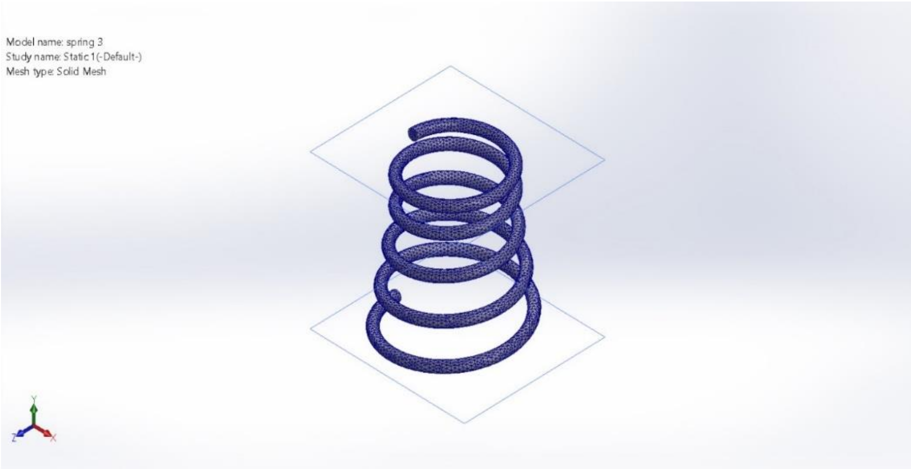

Fig. 2 The Mesh of Taper Spring

Mesh Information
The mesh type is solid mesh.
Mesher used curvature-based mesh.
Total nodes are 100855.
The total elements are 61482.
The spring was fixed in the bottom end and the load was subjected to the upper end with different values (1500, 2000, 2500) N to get the total deformation, stress, strain, and shear stress. The analysis was carried out with static analysis in Solidworks 2020. The analysis steps could be summarized as the flow chart in Figure 3.

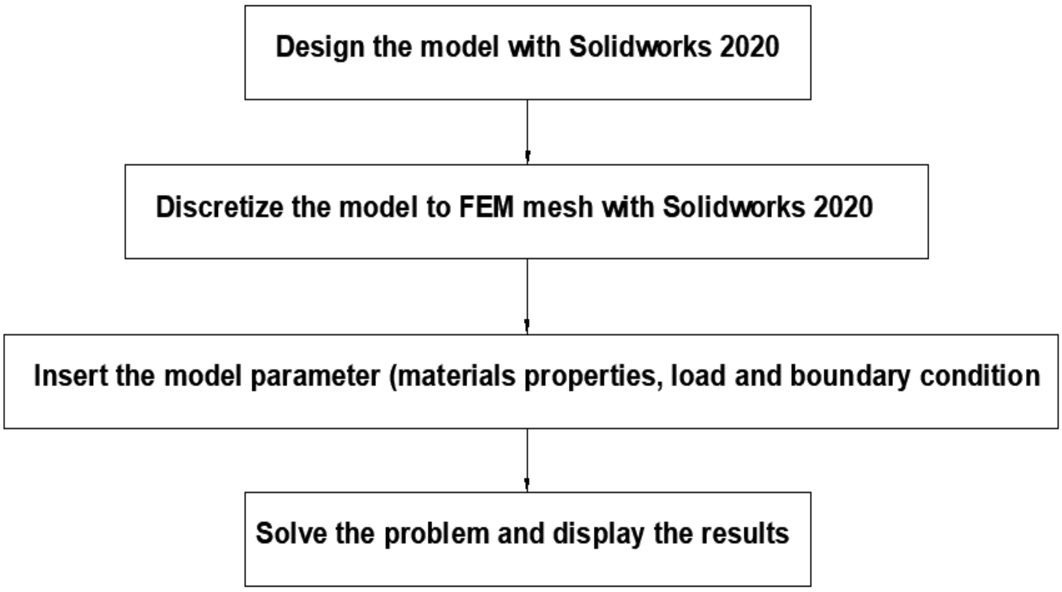

Fig. 3 Flow Chart for Analysis Process

5.2 RESULTS

The total deformation, stress according to von – Mises theory, strain, and shear stress were obtained numerically for the three materials with various values of the load to compare between them and choose the best material that can be used in the production process of the tapered spring in modern automobiles. For the value of load (1500N), the maximum total deformation happened in taper spring made of Steel Structure and it was (167 mm) as shown in Figure 4 below.

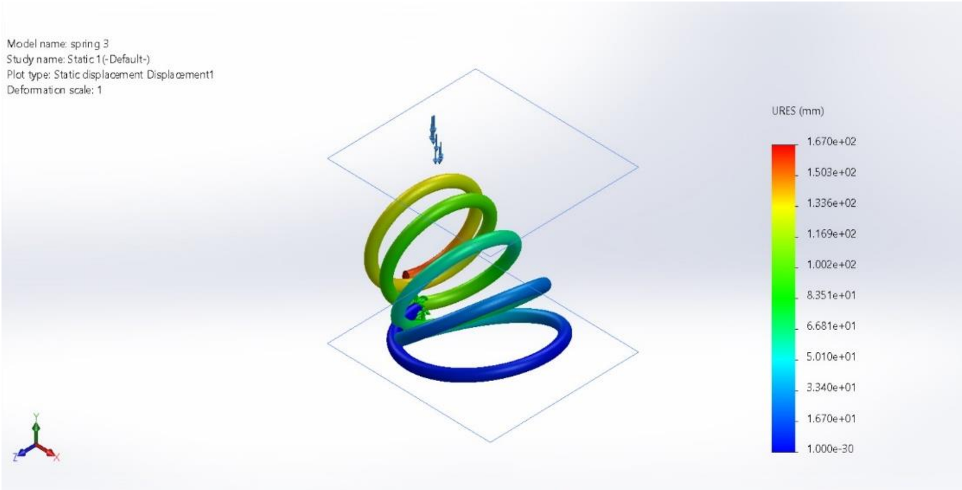

Fig. 4 Total Deformation in Spring Made of Steel Structure

While the minimum total deformation happened in spring made of Copper Alloy and the value was (133 mm) as shown in Figure 5 below

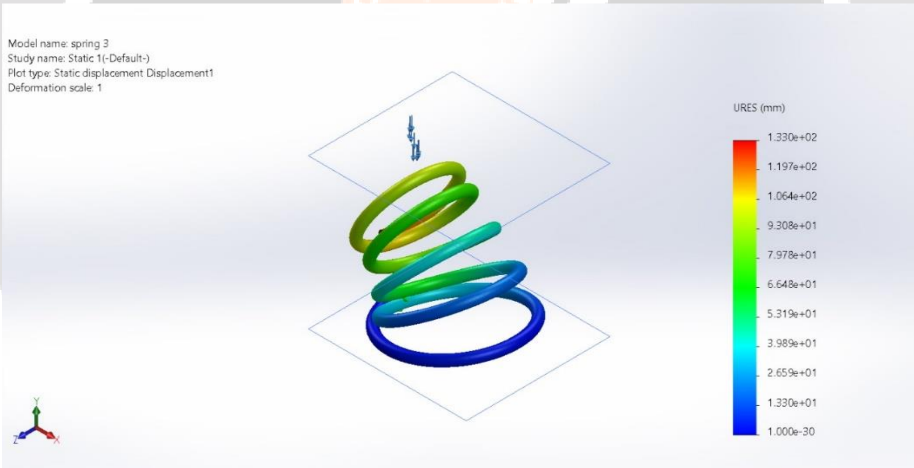

Fig. 5 Total Deformation in Spring Made of Copper Alloy

For the stress, under load (1500N) the maximum stress according to von-mises theory occurred in spring made of steel structure and the value was (1902 MPa) as shown in Figure 6 below.

Fig. 6 The Stress in Spring Made of Steel Structure

The minimum value of stress under load (1500) N happened in Copper Alloy with the value (723.2 MPa) as shown in Figure 7.

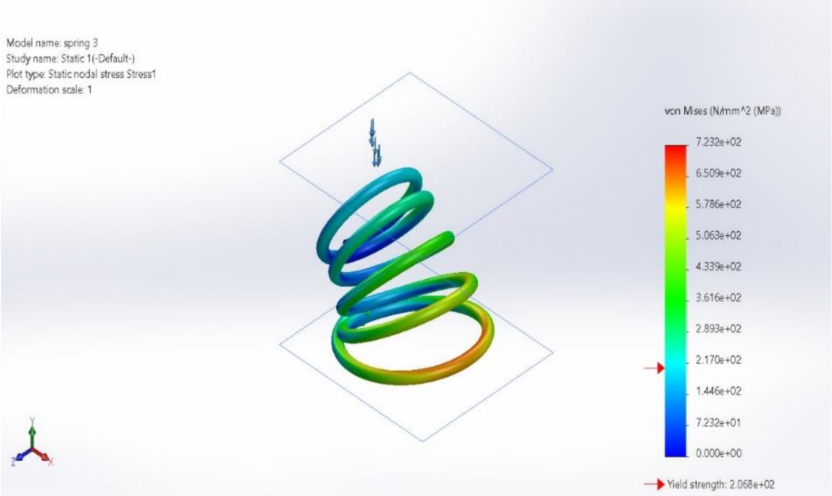

Fig. 7 The Stress in Spring Made of Copper Alloy

For the strain under load (1500N), the maximum strain occurred in spring with copper alloy with value (0.005341mm/mm) as shown in Figure 8 below.

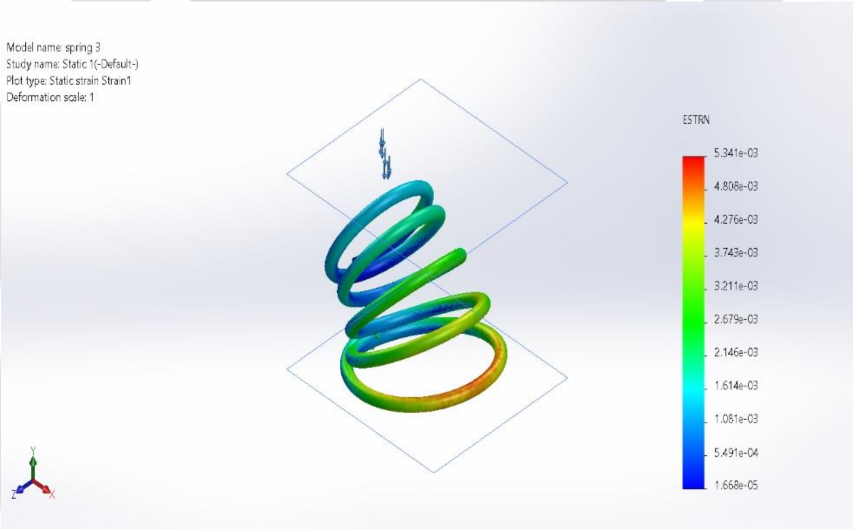

Fig. 8 The Strain in Spring Made of Copper Alloy

The minimum strain occurred in spring made of carbon composite and the value of strain was (0.006849 mm/mm) as shown in Figure 9 below.

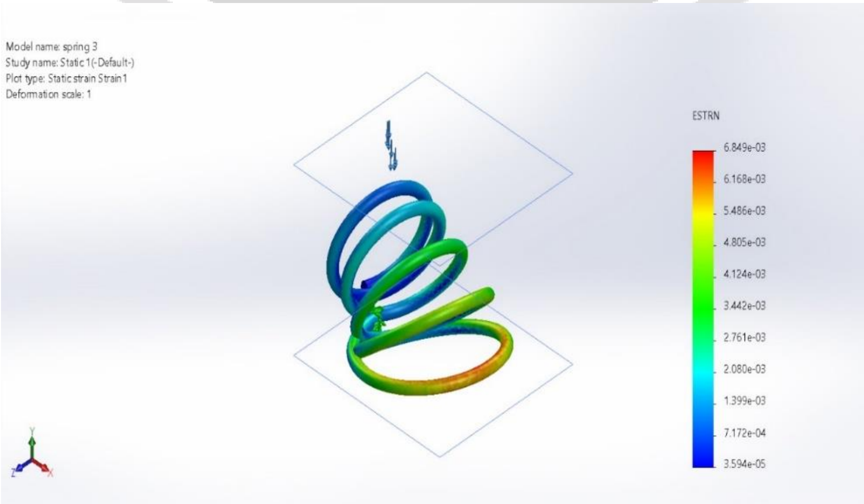

Fig. 9 The Strain in Spring Made of Steel Structure

The results (total deformation, stress, and strain) for different loads (1500) N for the three materials could be summarized in Table 3 below.

Table 3 Result for Load (1500N)

Materials	Load (N)	Total Deformation (mm)	Stress (MPa)	Strain (mm/mm)
Steel Structure	1500	167	1902	0.006849
Copper Alloy	1500	133	723.2	0.005341

The results (total deformation, stress, and strain) for different loads (2000) N for the three materials could be summarized in Table 4 below.

Table 4 Result for Load (2000N)

Materials	Load (N)	Total Deformation (mm)	Stress (MPa)	Strain (mm/mm)
Steel Structure	2000	160.4	1811	0.006520
Copper Alloy	2000	118.8	631.4	0.004667

The results (total deformation, stress, and strain) for different loads (2500) N for the three materials could be summarized in Table 5 below.

Table 5 Result for Load (2500N)

Materials	Load (N)	Total Deformation (mm)	Stress (MPa)	Strain (mm/mm)
Steel Structure	2500	220.6	2650	0.009617
Copper Alloy	2500	109.8	575.4	0.004257

The comparison of total deformation at various values of load for the two materials shown in Figure 10.

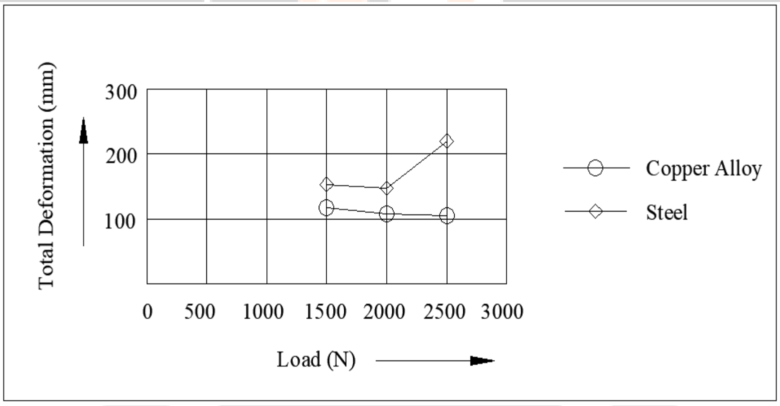

Fig. 10 Total Deformation (mm) vs. Load (N)

The comparison of stress at various values of load for the two materials shown in Figure 11.

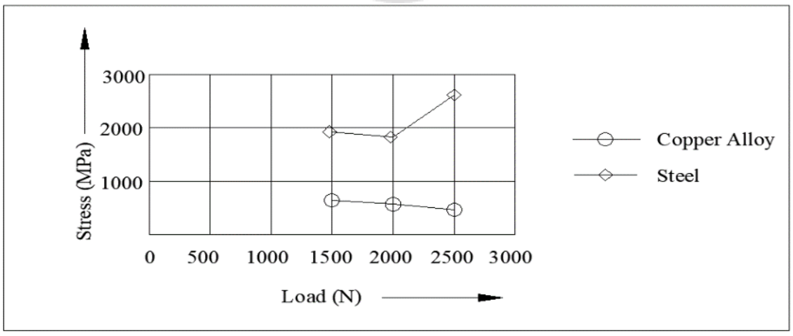

Fig. 11 Stress (MPa) vs. Load (N)

The comparison of strain at various values of load for the two materials shown in Figure 12.

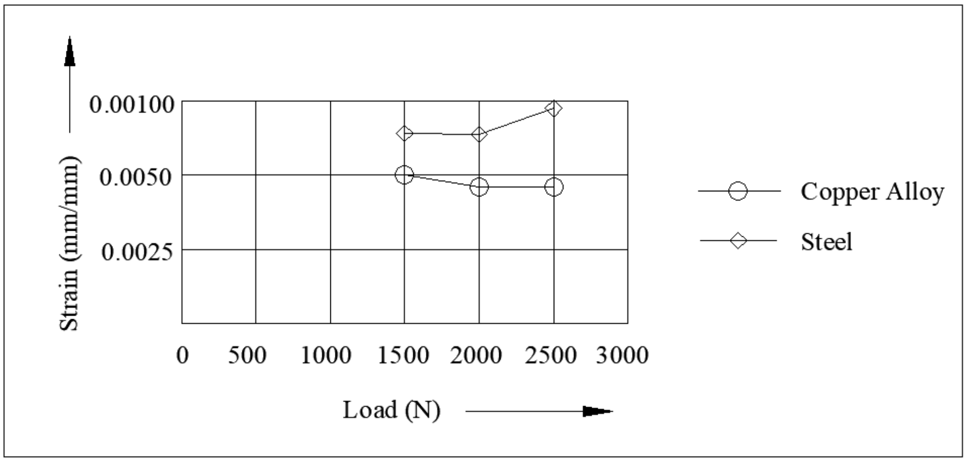

Fig. 12 Strain (mm/mm) vs. Load (N)

CONCLUSION

In this study, the simulation and analysis of tapered spring which is the main part of the suspension system in modern vehicles were carried out by using Solid works 2020. Two different materials were chosen to manufacture the spring under various values of the load. The results showed that the less value of total deformation happened in spring made of copper alloy for all the values of the load. The deformation reduced by 20% in copper alloy comparing with the deformation in the steel. The deformation, strain, and stress increased by increasing the load in case of steel material. It could be concluded that the copper alloy is the suitable material to fabricate the tapered spring in the suspension system in automobiles.

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