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Investigation of Helical Spring by Varying Loads and Cross Sections

Teddy Jefri[1], NandaKumar[2]

[1]*PG Scholar, Department of Engineering Design, Government college of Technology, Coimbatore.*
[2]*Professor, Department of Engineering Design, Government college of Technology, Coimbatore.*

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Abstract - *When a spring is stretched or twisted by an external force, strain-energy is stored in the spring, which is then released when the external force is withdrawn. The most significant component of a vehicle suspension is the compression spring system, which is designed to halt shock impulses. Suspension systems employ the compression and expansion cycle transformation concept. In motorbikes, suspension systems are used to increase handling, braking performance, safety, and comfort by separating passengers from road noise, bumps, and vibration. The purpose of the shock absorber is to absorb or disperse energy. Because of the greatly reduced amplitude of disturbances, it reduces the effect of driving over rough terrain in a vehicle, resulting in improved ride quality and better comfort. When a spring breaks, an examination is required to assess the material quality utilised in the manufacture of any functioning equipment or a functional model. The best material for the job can be selected based on availability, quality, price, and compatibility with working methods. At the moment, manufacturing industry spring design engineers prefer to employ this approach over a real one. A suspension system is constructed in CATIA- V5R19 and studied in ANSYS 17.2 with various material characteristics in this work.*

***Key Words*: Helical Spring, Low Carbon Steel, Chromium Vanadium Steel, Square, Elliptical, Circular.**

1. INTRODUCTION

Coil springs are a basic flexible mechanical element used in many industrial applications such as balancers, brakes, vehicle suspensions and engine valves to perform functions such as applying force, storing or energy absorption, flexibility of mechanical systems and maintaining force or pressure.In addition, for the most popular forms of vibration absorbers, helical springs act as the elastic element. Non-circular springs for lateral space limits and circular helical springs with a non-prismatic shape for vertical space constraints can be used to prevent this. The most prevalent non-circular helical springs seen in light firearms are rectangular helical springs. Spring deflection under axial load and maximum stresses induced are two important factors to consider when designing and selecting springs for practical applications. One of the key focuses of helical spring research is stress analysis. Hard Drawn Wire, Phosphorus Bronze, Spring Brass, Oil Tempered Wire, Chrome Silicon, and Stainless Steel are some of the most prevalent spring materials.

2. LITERATURE REVIEW

[1] Investigations with the pioneering works that the boundary element method used to apply theory of elasticity and to develop an approximate result to satisfy governing equations and boundary conditions along the surface of the helical.

[2] Design and optimization of helical springs with a circular and a triangular profile was studied and from analysis, the circular profile has a lesser total deformation and a lesser equivalent maximum strain compared to triangular profile.

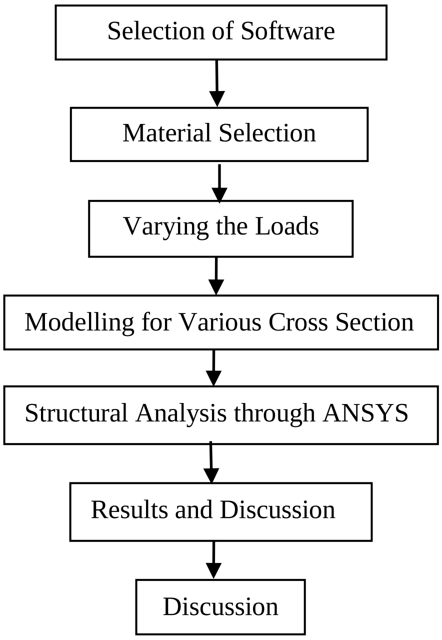
[3] Deflection induced in chrome silicon spring is very much less than deflection induced in hard drawn carbon spring. So, Chrome silicon spring steel is the optimum suitable material with low weight and high stiffness for helical spring application like mono shock suspensions in bikes and many more.

[4] Investigations on the premature failure of suspension helical spring of a passenger car, which failed during the service within few months and identified the reasons for the failure. The results stated that the inherent material defect in association with deficient processing led to the failure of the spring.

[5] Helical springs subjected to axial load under different dynamic conditions. The mechanical system, composed of a helical spring and two blocks, is considered and analyzed. Multi body system dynamics theory is applied to model the system, where the spring is modelled by Euler–Bernoulli curved beam elements based on an absolute nodal coordinate formulation.

[6] Methodology Presented for designing prismatic springs of non- circular helical shape and non-prismatic springs of circular helical shape using analytical and numerical methods using CAD and FEM. It is found that working on modelling and analysis of different types of helical springs with variable cross sections in research works using different available software from past to present.

3. METHODOLOGY



4. MATERIAL PROPERTIES AND SPECIFICATION OF THE SPRING

According to the direction and type of the force exerted by the spring when it is deflected, helical springs are classed as helical compression springs or helical extension springs. The helical compression spring is covered in this section.

For Low Carbon Structural Steel (LCS) Young's modulus =1.98e5MPa, Poisson ratio =0.3, Density=7700 kg/m^3
For Chromium Vanadium Steel (CVS) Young's modulus =2.07e5MPa, Poisson ratio =0.3, Density =7860kg/m3

Table -1: Analyzed Material Properties

Modeling and analysis of several materials for helical springs were carried out in this study. Low carbon structural steel and chromium vanadium steel were used as the materials.

4.1 Modelling of Spring using CATIA V5

FOR CIRCULAR CROSS SECTION

Step 1: Select Part Design from the Mechanical Design menu. Click on the drawing and select the XY plane.

Step-2: From the profile tool bar, select the point and move it to a distance of (50,0) from the relevant axis.

Step 3: Select the helix tool from the Exit app and design the helix profile with the appropriate dimensions.

Step 4: Draw the circular cross section on a plane perpendicular to the helix profile.

Step-5: Select the rib option from the sketch-based tool bar and rib along the profile by clicking on the Exit app. Draw ends supports with the sketch-based tool bar and the profile tool bar.

Repeat the above steps and change the cross section as SQUARE and ELLIPSE.

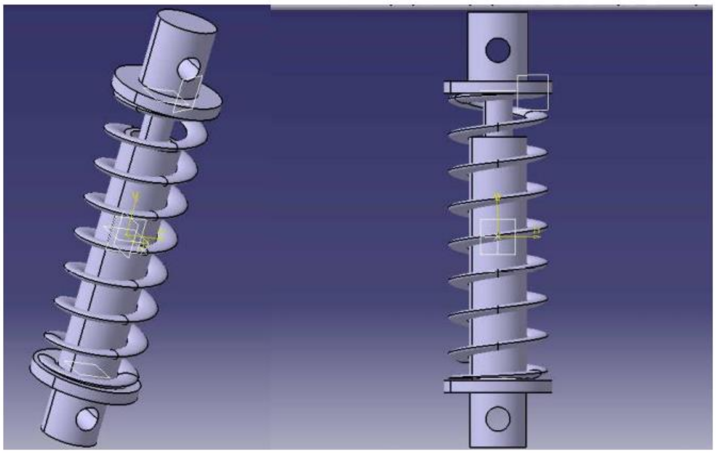


Fig -1: Elliptical cross section helical spring

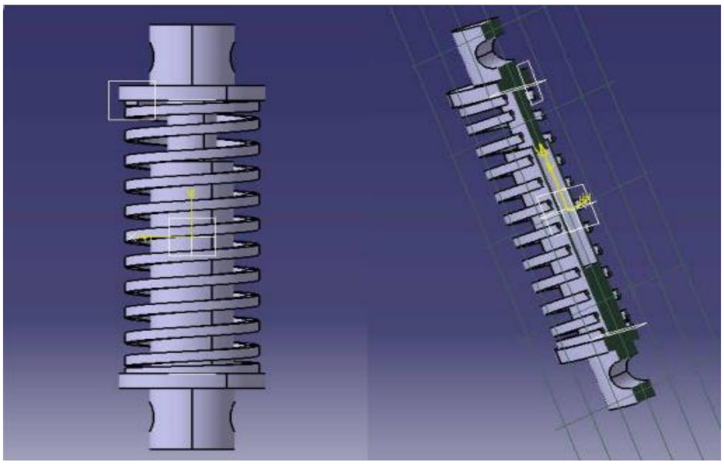


Fig -2: Square cross section helical spring

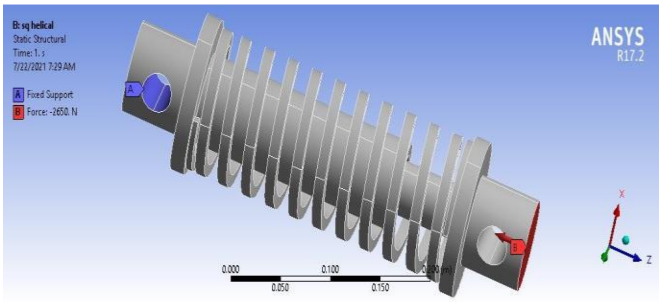


Fig -3: Square cross section helical spring

5. STATIC STRUCTURAL ANALYSIS OF HELICAL SPRINGS

ANSYS 17.2 is used for pre- and post-processing of the static analysis of conventional helical coil springs. Types of mesh, mesh size, spring seat types, and spring end connection types are all considered. To begin, the spring is meshed with various mesh kinds and sizes, and the results are compared. Finally, the various forms of spring end connections are investigated, and an analytical model is developed based on all of these factors. Total deformation, equivalent elastic strain, equivalent von Mises stress, shear strain, and elastic shear stress of the coil spring according to applied force are selected and their convergences tracked during the analytical process.

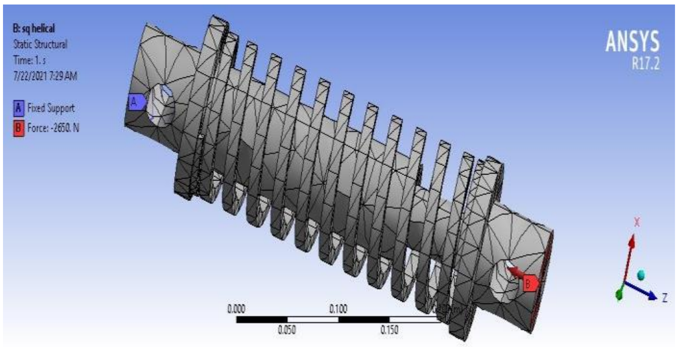


Fig -5.1: Meshing of Square Helical Spring

During analysis, rigid blocks are used as spring seats at the top and bottom of the spring. Until they approach a size limit, smaller elements give superior results until unanticipated effects arise at the spring ends and contact areas of the spring end and spring seat. The unexpected results at the spring ends and contact regions may be interpreted as erroneous results due to the analytical model, but they are unimportant since the findings can be explained by looking at the maximum shear stress value, which should be towards the coil's core. Changing the spring material from the material library provided in ANSYS work bench follows a similar method.

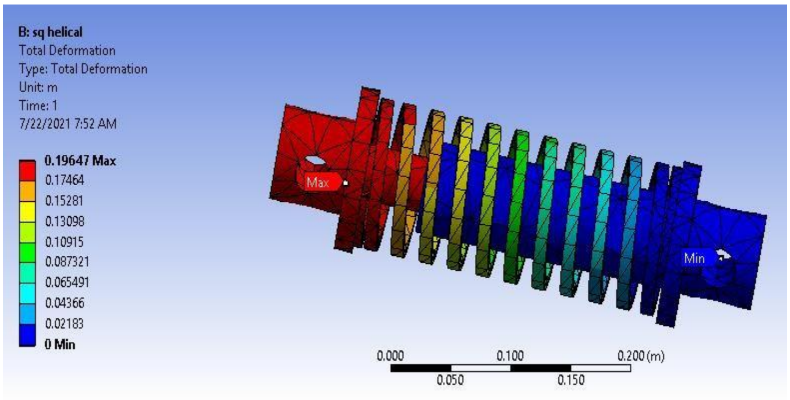


Fig -5.2: LCS spring with load of 2750N (Total Deformation)

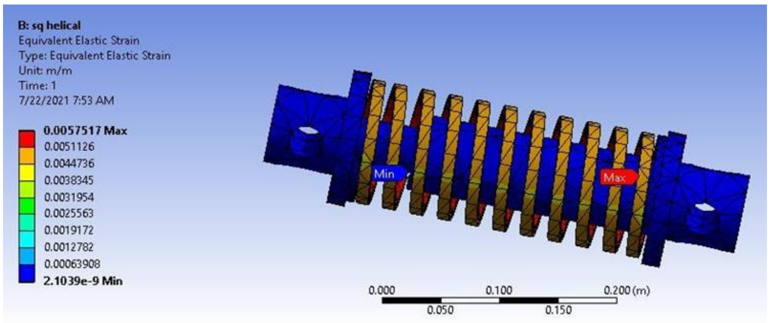


Fig -5.3: LCS spring with load of 2750N
(Equivalent Elastic Strain)

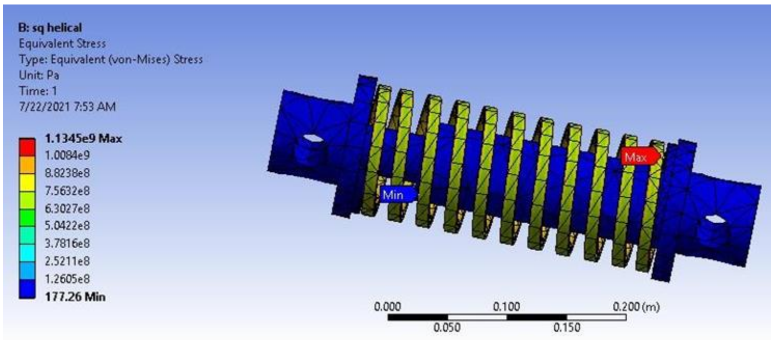


Fig -5.4: LCS spring with load of 2750N
(Equivalent Von Mises Stress)

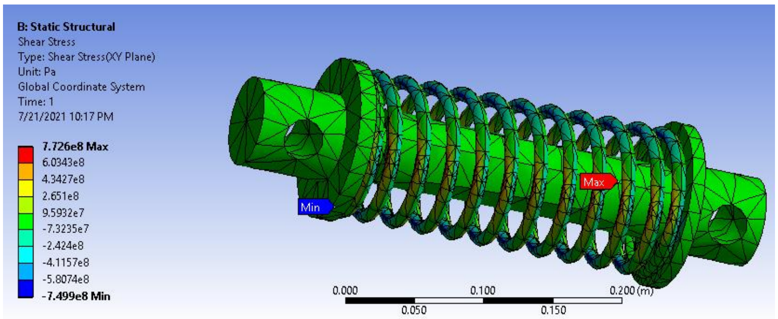


Fig -5.5: LCS spring with load of 2750N (Shear Stress)

6. RESULTS AND DISCUSSION

Table 6.1 Results for Low Carbon Steel Material for Load Of 2750N

SPRING CROSS SECTION	Circular Helical		Elliptical Helical		Square Helical	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Total Deformation	0.29548	0	0.054516	0	0.19647	0
Equivalent Elastic Strain	0.008381	3.49E-10	0.002927	2.67E-14	0.0057517	2.10E-09
Equivalent Vonmises Stress	1.55E+09	31.496	5.66E+08	0.0020144	1.13E+09	117.26
Shear Stress	7.73E+08	-7.50E+08	3.03E+08	-3.10E+08	5.52E+08	-5.52E+08
Shear Elastic Strain	0.010692	-0.010377	0.00418	-0.00043	0.00764	-0.00764

Table 6.2 Results for Low Carbon Steel Material for Load of 4000N

SPRING CROSS SECTION	Circular Helical		Elliptical Helical		Square Helical	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Total Deformation	0.42979	0	0.079296	0	0.28578	0
Equivalent Elastic Strain	0.01219	5.0812e-10	0.004257	3.8871e-14	0.0083661	3.0602e-9
Equivalent Vonmises Stress	2.2516e9	45.813	8.2272e8	0.00293	1.6502e9	257.83
Shear Stress	1.238e9	-1.0908e9	4.4002e8	-4.5108e8	8.031e8	-8.0304e8
Shear Elastic Strain	0.015551	-0.015094	0.00608	-0.00624	0.01114	-0.01113

Table 6.3 Results for Chromium Vanadium Steel Material for Load of 2750N

SPRING CROSS SECTION	Circular Helical		Elliptical Helical		Square Helical	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Total Deformation	0.26826	0	0.049556	0	0.16856	0
Equivalent Elastic Strain	0.0080453	2.9969e-10	0.002846	4.7802e-15	0.0053357	1.7722e-9
Equivalent Vonmises Stress	1.5334e9	23.787	5.7593e8	0.00275	1.002e9	110.83
Shear Stress	7.6391e8	-4.517e8	3.8787e8	-3.1568e8	5.4096e8	-5.4092e8
Shear Elastic Strain	0.009373	-0.0092249	0.00377	-0.003873	0.006637	-0.006643

Table 6.4 Results for Low Carbon Steel Material for Load of 4000N

SPRING CROSS SECTION	Circular Helical		Elliptical Helical		Square Helical	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Total Deformation	0.39019	0	0.072082	0	0.25478	0
Equivalent Elastic Strain	0.011702	4.3591e-10	0.00414	6.9531e-15	0.0080539	2.6749e-9
Equivalent Vonmises Stress	2.2595e9	34.6	8.3772e8	0.004	1.6614e9	166.45
Shear Stress	1.111e9	-1.0935e9	4.4782e8	-4.5918e8	8.1655e8	-8.0654e8
Shear Elastic Strain	0.013634	-0.01348	0.00549	-0.005635	0.017019	-0.011349

When compared to total deformation in chromium vanadium steel, low carbon steel showed a 48 percent reduction in deformation.
When the load is raised, the total deformation, shear strain, and shear stress all rise.
The stress and shear stress of the two materials are almost equivalent under the same load (tested under a load of 2750N, 4000N).
Low carbon steel, despite its high cost, has benefits for the suspension system, such as reduced weight and greater strength.

6.1 Comparison of Different Cross section

Total deformation, elastic strain, equivalent (von mises) stresses, maximal shear stresses, and shear strain are tabulated, and graphs containing those results are presented to study.
Deformation, strain, stress, and shear stress rose when the load was raised from 2750 N to 4000 N for various materials, matching respective cross sections were created using ANSYS 17.2 software, and the pictures are displayed in the figures.

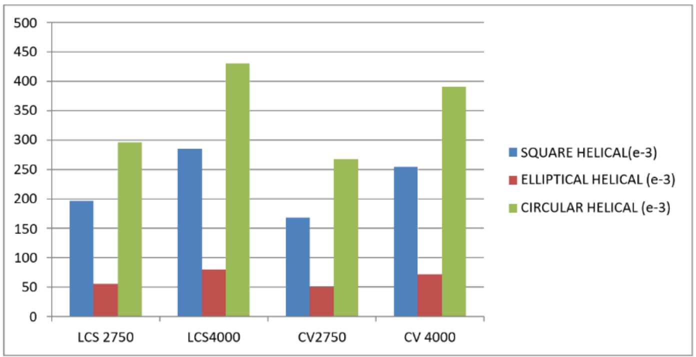


Fig -6.1: Comparison of Total Deformation

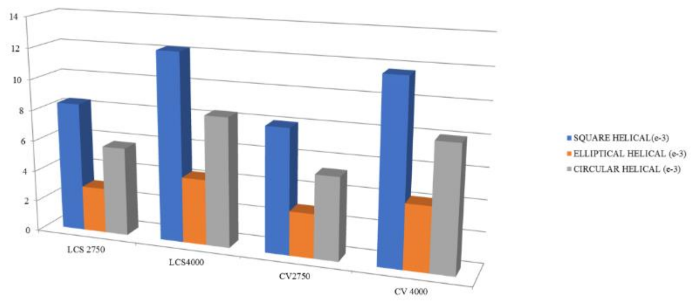


Fig -6.2: Comparison of Equivalent Elastic Strain

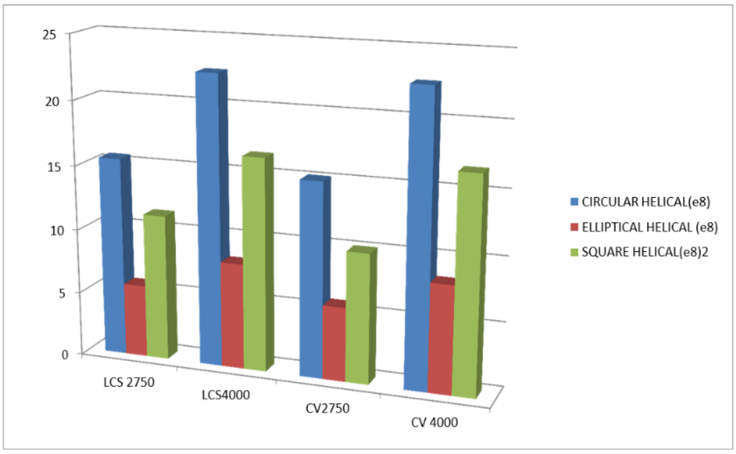


Fig -6.3: Comparison of Equivalent Von Mises Stress

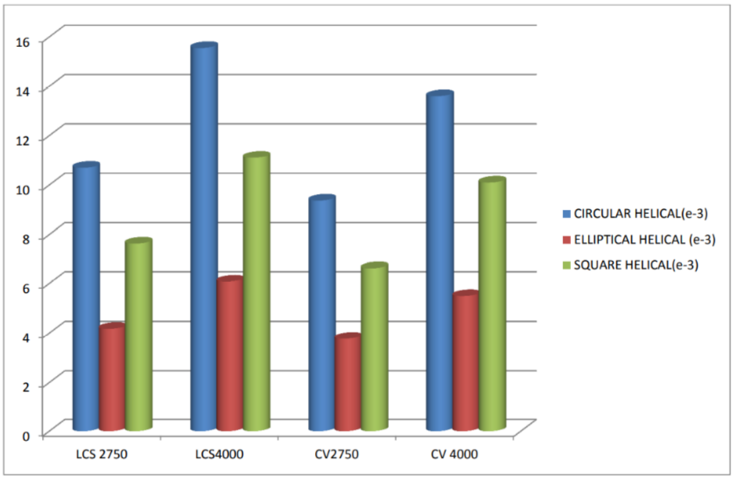


Fig -6.4: Comparison of Equivalent Shear Strain

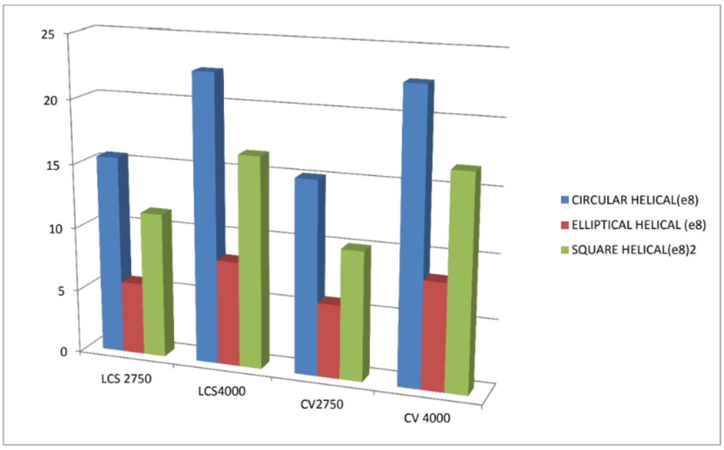


Fig-6.5: Comparison of Shear Stress

During the preliminary investigation, it became evident that a lot of thought had gone into the design of circular cross-section springs, especially when it came to calculating stiffness under various loading conditions.
The validity of the FEA using ANSYS based on the linearity between load and deformation must be recognised before the study's conclusions can be accepted. Strain energy is used to store the work done by the deformation of the spring's helix.

As verified by comparison of findings, the strain energy in the finite element model properly approximated the strain energy predicted theoretically for a unit volume of the linear elastic spring.

7. CONCLUSIONS

CATIA V5R19 and ANSYS 16 were used in this work to simulate and analyze a coil or helical spring, which is a key component of current automobile suspension systems.
To model the spring under varied loads, two alternative materials were used.
For all load levels, the findings showed that the spring built of structural steel had the least amount of overall deformation.
Low carbon steels exhibited a 14 percent reduction in deformation when compared to chrome vanadium steels.

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