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COMPARATIVE ANALYSIS OF ENGINE VALVE SPRING WITH VARIOUS ALLOYS

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ABSTRACT

Valve springs play a vital role mechanism where there is quick return of energy post motion. On such, the engine valve spring holds dominant role in determining many characteristics of the engine. Performance of the engine valve spring inevitably affects the behavior of the entire system in any I.C. engine. Thereby a constant research must be undertaken to study the behavior of the spring under this horrendous environment. In this research work a comparative study is encapsulated with various alloys like Carbon Steel Wire, VDSiCr, CrSi and Al 2024 T3. Initially the model of a helical valve spring is 3D modelled in CATIA software using macros option to obtain the spline path of the spring. Meshing an analysis part is enumerated by ANSYS software. Prominently a static structural and a fatigue test is performed on the model. The behavior of the system is noted by assigning all the aforementioned material and are deformed up to 35mm (jounce height). Later it is concluded that even though Al 2024 T3 holds enormous benefits it doesn't hold good for engine valve spring as the VDSiCr outperforms in all the parameters.

Keywords: Engine Valve Spring, Carbon Steel Wire, Al 2024 T3, Fatigue.

I. INTRODUCTION

It is a well-known fact that engine valve spring plays dominant characters in determining the behavior of the engine performance. The harmony of the valve springs with the rocker arm movement during the engine's optimum application, pulsates at enormous speed within very limited period of time. This dynamic behavior of the system abruptly interferes with the characteristics of all the components.

This valve spring are held around protective axle or a cylindrical wall, ensuring it does not interfere with the foreign bodies of the engine and thereby monitoring appropriate compression phenomenon. On an average the engine valve springs can operate safely over more than one lakh miles with no hurdles. But these are of ideal conditions if maintained at regular intervals. Supposedly, this scenario occurs least, as the probability of the springs may fail well within the predicted values is always high. Thereby there are enormous opportunity to play around in determine the optimum spring material for the right choice from engineers point of view. Upon entering the materials selection from various alloy in Al sections, Al 2024 T3 emerged out as the trending and bloomed in automotive sessions. Selection of material is involved by inspecting its static structural, modal analysis and fatigue test, to understand the behavior of these system at various judgmental scenarios.

II. RESEARCH GAP

- ❖ On reviewing and researching from various journal papers, it can be concluded that still there are various possibility of improvements in engine valve springs by assigning numerous alloys and scrutinize the behavior of the same.
- ❖ Since Al 2024 T3 deemed to be involved in humungous automotive sector, it might find as alternating material for valve springs.
- ❖ Analyzing the valve spring with aforementioned material to find the fatigue life data.

OBJECTIVES

- Design, develop an ideal valve spring that can accommodate in engine hub and assign various materials like Al 2024 T3, Carbon steel wire, CrSi and VDSiCr.
- Check the relative behavior of the spring by comparing static structural analysis for Al 2023 T3 and renowned VDSiCr material, on how these outperform each other.
- Perform fatigue test, to determine the life, damage and factor of safety under the deformed loads.
- Conclude by analyzing and comparing individual models with other with respect to each other

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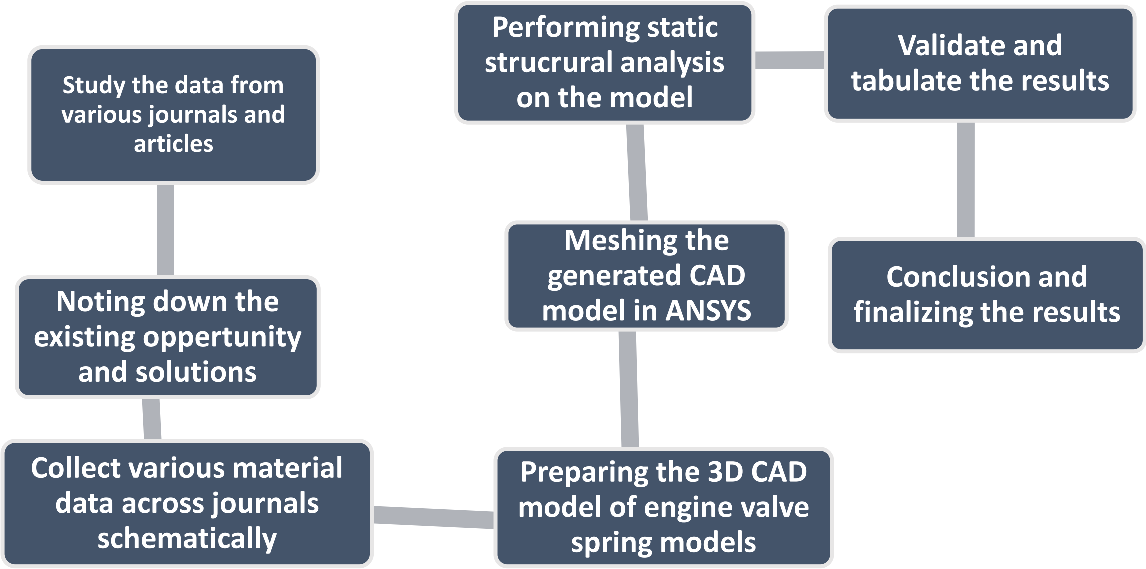
III. METHODOLOGY

The following flowchart gives an insight of how the research study was accomplished as by abiding the steps. Numerous iterations were carried out to accomplish the desired results. The development of ideal spring and side force spring were both 3D modelled, discretized and analyzed only after receiving the relevant details from initial pre-studies.



3.1 Study previous side force spring axis from Journals and relevant articles:

By analyzing the research papers which was relevant to our objective, we accumulated the data required for assigning various materials for the springs. From these data the springs possibilities were examined and noted down from various sources.

3.2 Noting down existing opportunity and solutions:

On referring the aforementioned journals, we had formulated the objectives and set the required analysis to be enforced with relevance to our research work.

3.3 Collect various material data across journals schematically:

The data obtained from journals were tabulated schematically in tabular form. Selection of the materials chosen were wisely made. Data required for the static structural analysis like young's modulus, Poisson's ratio, density, ultimate tensile strength, S-N Curve were retrieved. The following are the data provided as input to the ANSYS across the 4 materials:

Table. 1.1 Different material property assigned to the engine valve spring required for static structural analysis

Materials Assigned to Engine Valve Spring

Character	Al 2024 T3	Carbon Steel Wire	CrSi	VDSiCr
Density (kg/m^3)	2770	7850	7944	7800
Isotropic Elasticity				
Youngs Modulus (Pa)	7.31E+10	2.00E+11	2.07E+11	2.06E+11
Poisson's Ratio	0.33	0.3	0.28	0.311
Bulk Modulus (Pa)	7.17E+10	1.66E+11	1.56E+11	1.72E+11

Shear Modulus (Pa)	2.75E+10	7.60E+10	8.08E+11	7.92E+01
Tensile Ultimate Strength (Pa)	4.30E+08	4.15E+08	3.20E+08	2.23E+09

Since, various trends in aluminium alloys are in a boom over all the automotive sectors, the primary choice was to choose the Al 2024 T3 as the dominant material with others. Al 2024 T3 is well renowned for its high strength and fatigue resistance. As the valve springs are under constant pulsation in fatigue cycles, the adaption to confirm redeemability of Al 2024 T3 needed to be excavated.

Among the valve springs, the glorifying of VDSiCr material has always had a stand out among the manufacturers due to its humungous benefits. VDSiCr possess the best fatigue life than the rest of the material in the category. The only drawback encountered is the manufacturing cost of the valve spring in this material due to tedious path to process VDSiCr to end stage.CrSi is the second most preferable valve spring options when needed to operate under heavy fatigue environment.

3.4 Preparing the 3D CAD model of engine valve spring models:

In accordance with this study an augmented 3D model had to be virtually crated for analysis purpose under computational type. Thereby a powerful modelling tool of CATIA V5 is used for generating the valve spring. Later the helix shape is generated in CATIA by table file and converting from Excel macros from converting spring coordinate system to vehicle coordinate system. The value of each complete turn was broken down into 100 individual sections to obtains smoother curvature in the springs.

In order to generate the spring profile where coordinates are required is listed below for the further reference to enhance the corrections in post analyses. Deliberately the top and bottom end of the springs are flat butt by removing excess materials. This aids in position of the spring under the exact application in the engine bay. The below listed figure have been deliberately shortened up by removing the 0 to 0.05 values to reduce the space occupancy in the report.

Fig1.1 Rendered CAD model of the engine valve spring

3.4.1 Design details of the Engine Valve springs

Table. 1.2 Design values of engine valve spring

Character	Symbol	Value
Wire Dia (mm)	d	3.5
Inside Dia (mm)	Di	24.9 +/- 0.25
Outside Dia (mm)	Do	31.9
Total No. of coils	N	8.77
Total No. of active coils	na	6.77
Dead coils at top end	-	1

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Dead coils at bottom end	-	1
Direction of coil	-	RH
Rate (N/mm)	K	10.14
Free Height (mm)	Ho	77.6
Solid Height (mm)	Hs	30.7
Installed Height (mm)	H1	63.8
Installed Load (mm)	P1	140 +/-9.8
Working Height	H2	45.5
Working Load (N)	P2	325.5 +/-16.28
Valve lift (mm)	-	18.3
End Type	Closed & Ground	

3.5Meshing the generated CAD

In order to obtain a finer meshes along the model, the tool required to discretize was ANSYS workbench, where the model sharp edges don't fail to reach the elemental quality check.

Properties like Jacobian factor, skewness ratio, skew angle was noted down appropriately so that the final analysis would not interfere with the error accomplishment.

Complete tetrahedral dominant elements were undertaken for the meshing. This element is, more accurate but rather requires predominant time for the analysis.

Table. 1.3 Elements and nodes present in the meshed model

Nodes	99531
Elements	53201

It was ensured that the average elemental size were approximately 0.5 mm, with fast transaction under shape distortion of the model geometry/ topology.

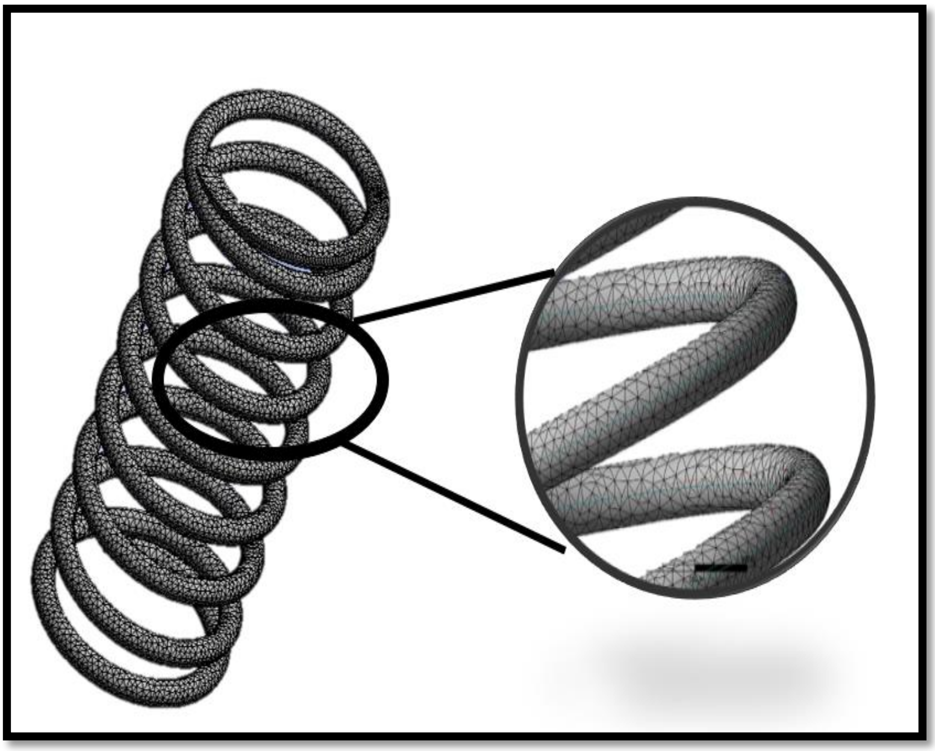

Fig 1.2 Zoomed up view of the meshed model in ANSYS Workbench

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Display	
Display Style	Body Color
Defaults	
Physics Preference	Mechanical
Relevance	0
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Sizing	
Size Function	Adaptive
Relevance Center	Coarse
Element Size	0.50 mm
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Fast
Span Angle Center	Medium

Fig. 1.3 Screenshot of the meshed parameters imbibed I the model from ANSYS Workbench.

3.6 Analysis of the valve spring in ANSYS Workbench:

From the post meshing up the model, the next step is to ensure the right parameters are sent to the analysis tool. A total of 2 step of analysis were performed i.e., static structural analysis and fatigue test were done, by obeying all the required parameters needed for analysis.

In order to virtually manipulate the boundary conditions encountered by the valve spring the engine bay an exact replica was generated. Here top flat region of the helical valve spring is made to deform under 35 mm under downward direction, which shall simulate the compression movement from the rocker arm section of the engine. And in order to encastre one region of the spring to be held stationary, the bottom flat region of the valve spring was chosen. Which replicates the flat platform of the resting portion of the spring under compression. Illustration of both the boundary condition are listed below. These B.C. hold good even for the fatigue tool test too.

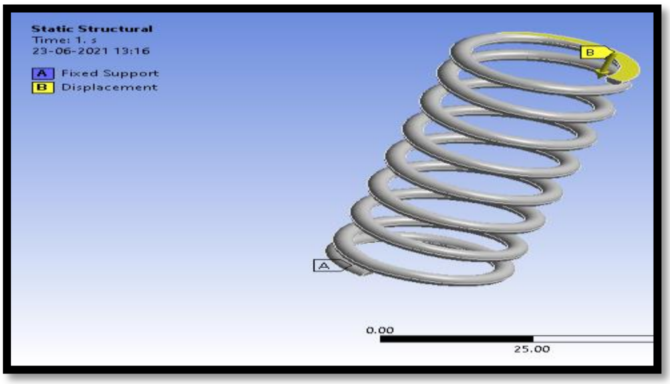

Fig. 1.4 Displacement (yellow region) input portion

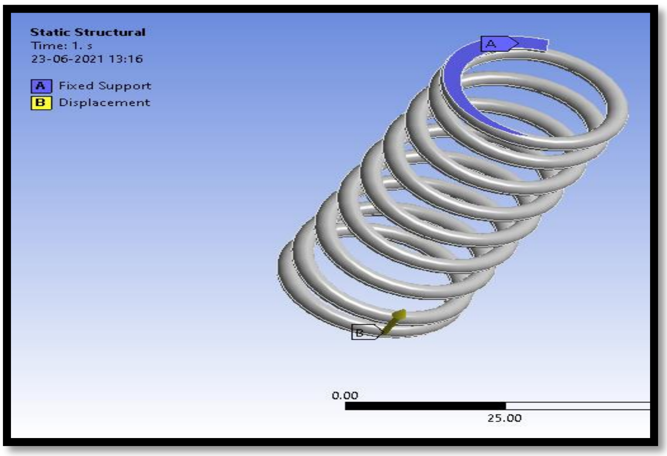

Fig. 1.5 Fixed region (blue colored) at flat portion of valve spring

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In order to retrieve the vital information of the spring's analysis, behaviors like Equivalent's stress, Equivalent Elastic strain, Total deformation, life, damage and factor of safety.

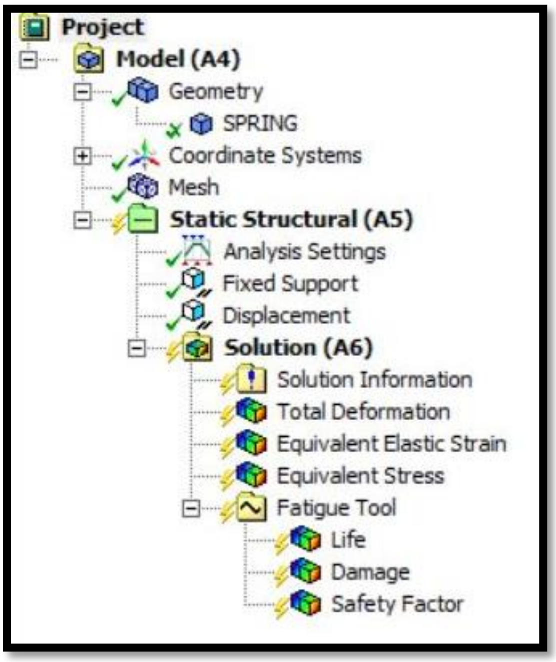

Fig. 1.6 Layout of tree topology in ANSYS Workbench

IV. RESULTS AND DISCUSSIONS

4.1 Post analysis data for Al 2024 T3 material

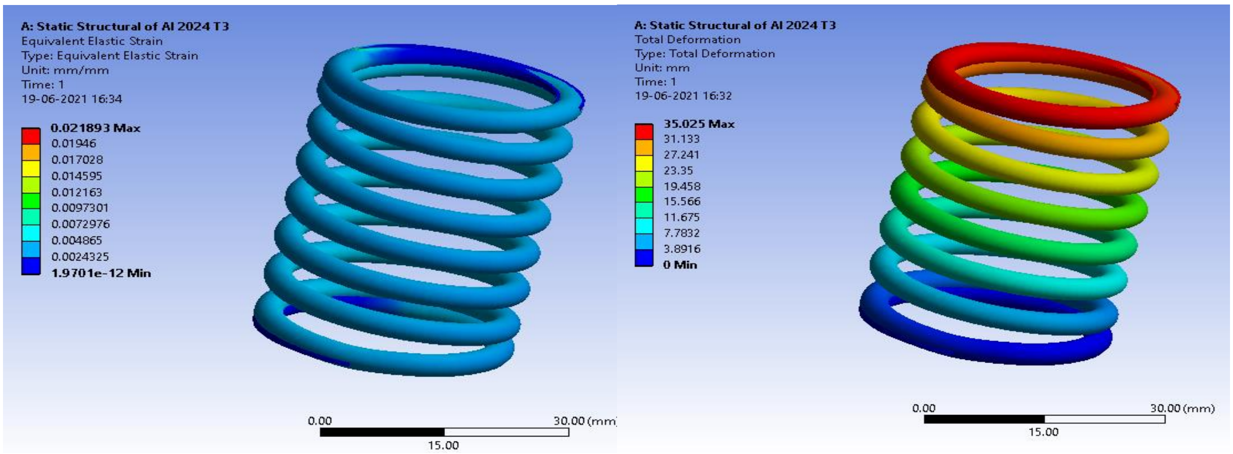

Fig.1.7 (left) Total Deformation & Equivalent elastic strain for Al 2024 T3

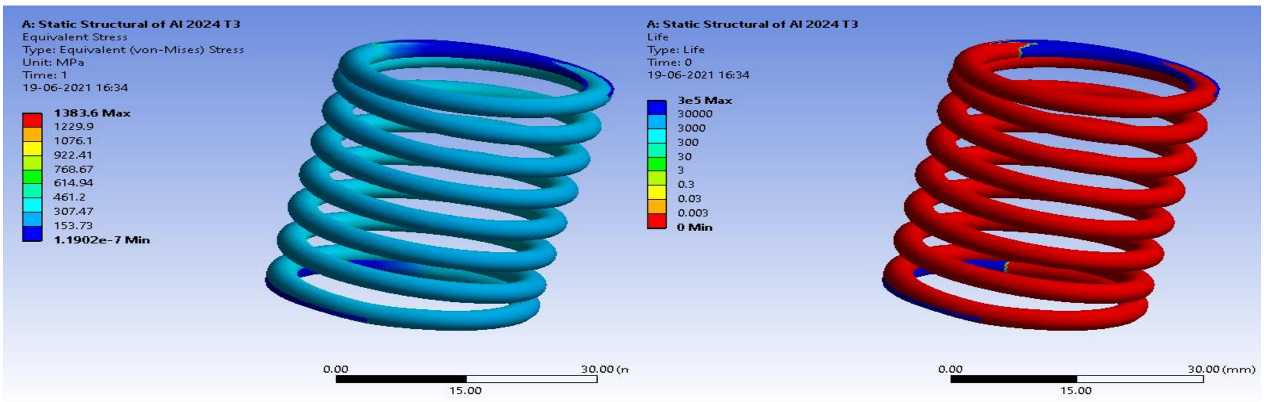

Fig.1.8 (Left) Life value & Equivalent (von-mises) Stress (Right) for Al 2024 T3

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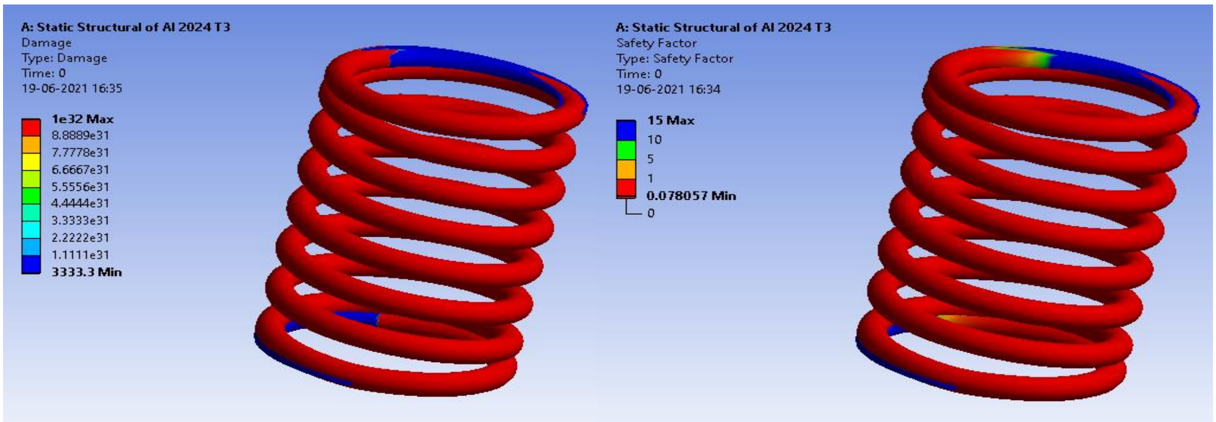

Fig. 1.9 (Left) safety factor and (right) Damage for Al 2024 T3

4.2 Post analysis data for Carbon Steel Wire material

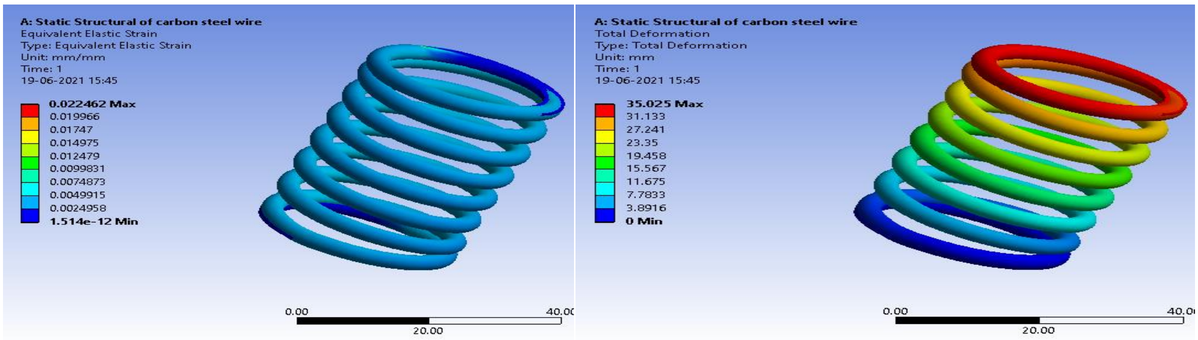

Fig.1.10 (left) Total Deformation & Equivalent elastic strain for Carbon Steel Wire

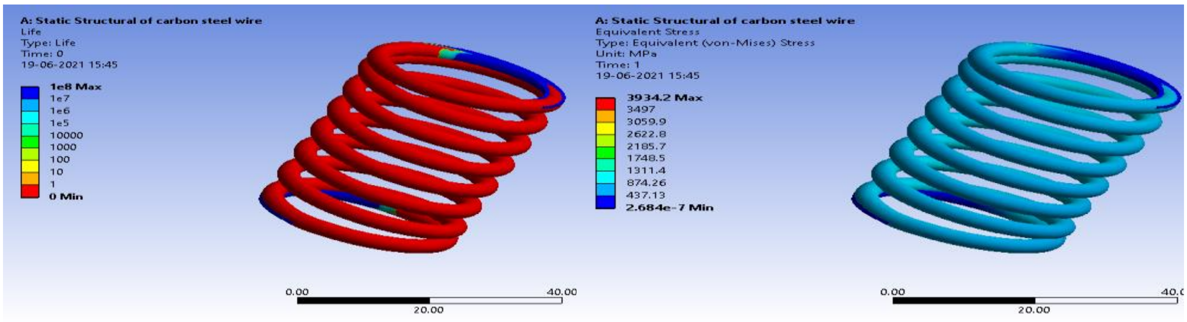

Fig. 1.11 Equivalent (von-mises) Stress (Left) & (Right) Life value for Carbon Steel Wire

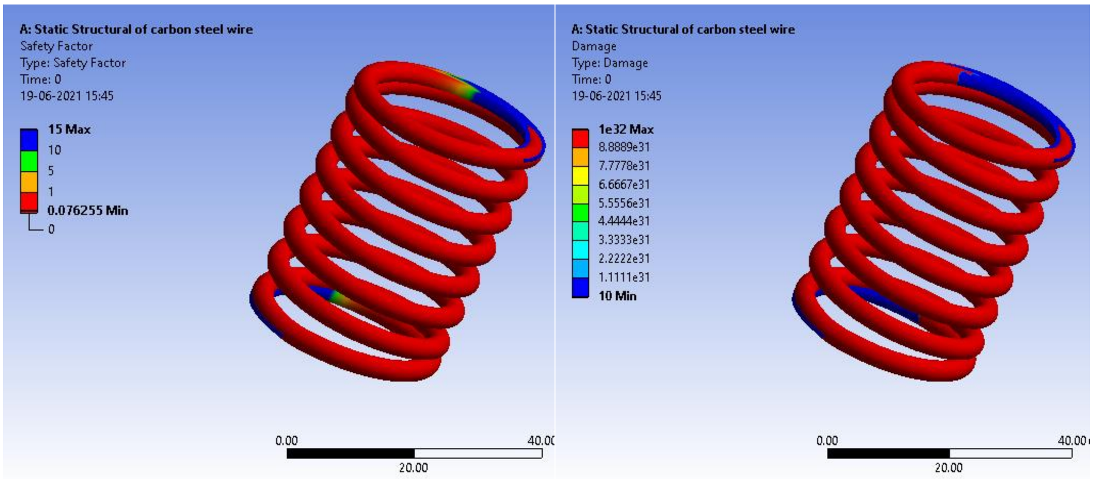

Fig.1.12 (Left) safety factor and (right) Damage for Carbon Steel Wire

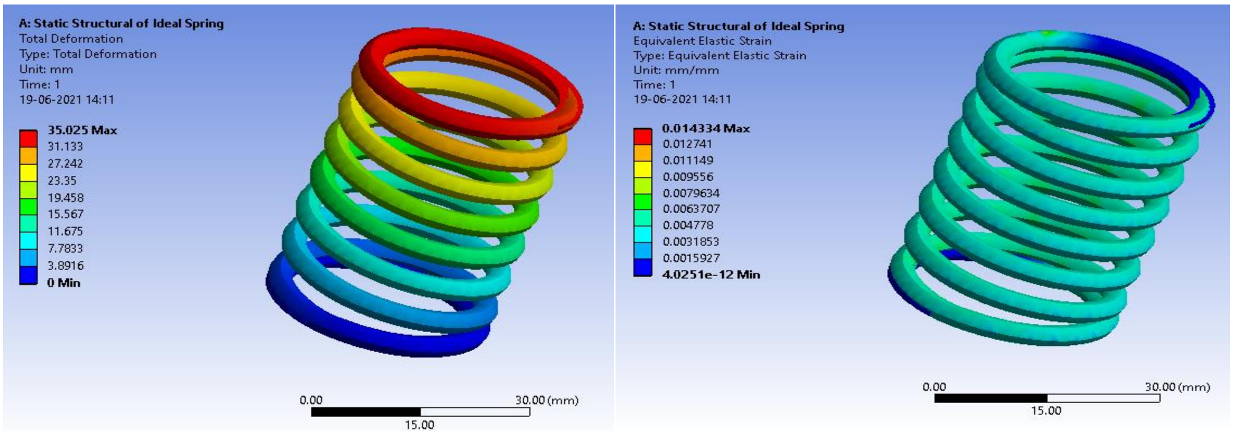

Fig.1.13 (left) Total Deformation & Equivalent elastic strain for CrSi

4.3 Post analysis data for CrSi material

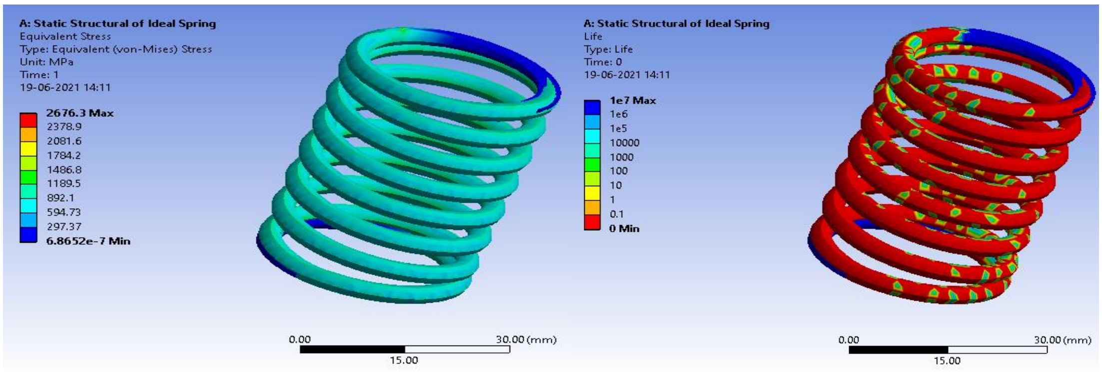

Fig.1.14 (Left) Equivalent (von-mises) Stress & (Right) Life value for CrSi

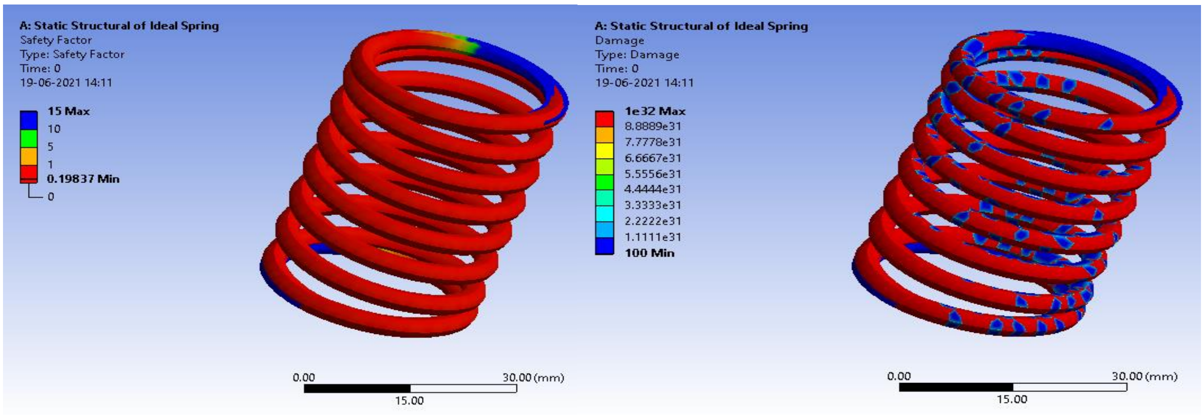

Fig.1.15 (Left) Damage and (right) Safety Factor for CrSi

4.4 Post analysis data for VDSiCr material

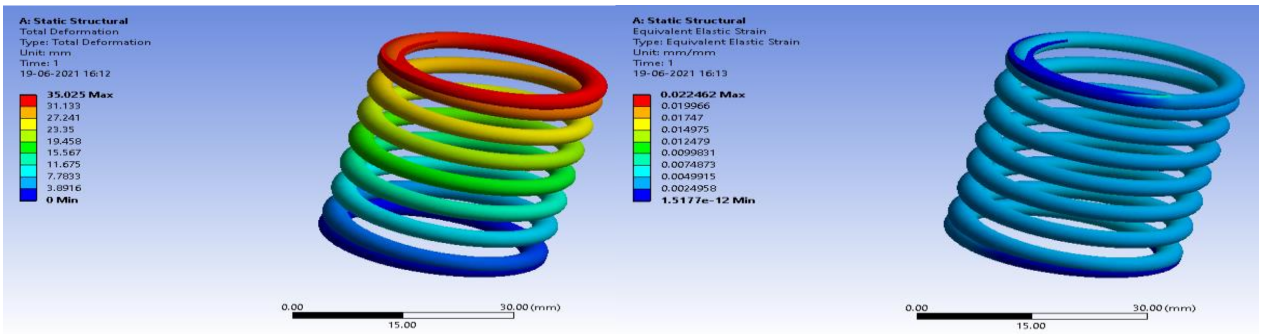

Fig.1.16 (left) Total Deformation & Equivalent elastic strain for VDSiCr

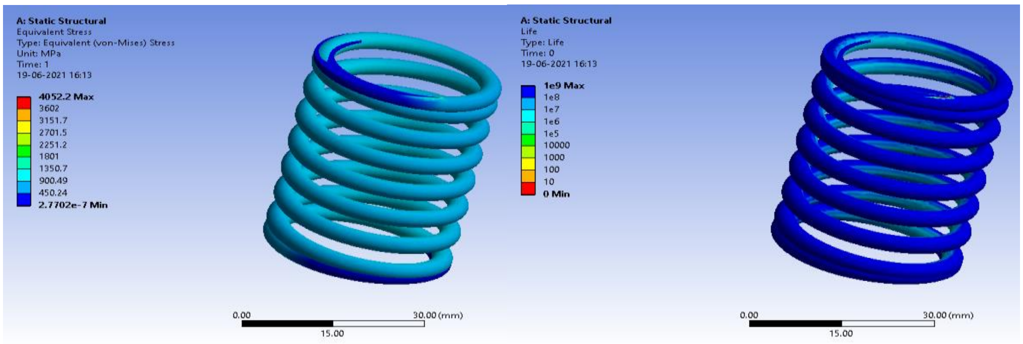

Fig.1.17 (Left) Equivalent (von-mises) Stress & (Right) Life value for VDSiCr

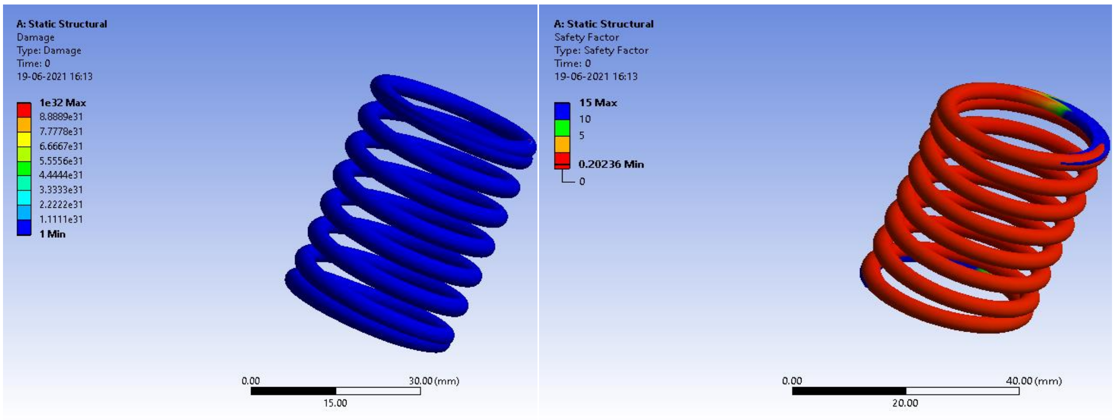

Fig.1.18 (Left) Damage and (right) Safety Factor for VDSiCr

In order to compare the aforementioned data back to tabular form the specs are aligned below for the ease of comparison. This gives us an insight on the material behavior w.r.t each other.

Table. 1.4 Post Analysis Data from Ansys Software

BEHAVIOR	**MATERIALS**			
	Al 2024 T3	**Carbon Steel**	**CrSi**	**VDSiCr**
STATIC STRUCTURAL ANALYSIS				
Total Deformation (mm)	35.025	35.025	35.025	35.025
Equivalent elastic strain	0.021	0.022	0.0143	0.022
Equivalent Stress (Von-Misses) (mm)	1383.6	3934.2	2676.3	4052.2
FATIGUE TEST				
Life	3.0E+05	1.00E+08	1.00E+07	1.00E+09
FOS	1.50E+01	15	15	15
Damage	1.00E+32	1.00E+32	1.00E+32	1.00E+32

V. CONCLUSION

In this research study, an ideal spring was initially modelled later to sent for analysis. The following conclusion were enumerated from the post analysis data.

- Al 2024 T3 possessed the least Von-Mises stress (Equivalent) due to its excellent elastic property, but the spring developed from these materials was unable to withstand to lifespan. It has the least lifespan value.
- Even though VDCrSi holds the maximum stressed among all, this material managed to stand out among all the spring test by surviving the most by having highest lifespan from fatigue test.
- Engineers prefer high lifespan materials for Engine valve spring as the fatigue cycle sustainability is humungous under the application of engine hub.

- Even though Al alloy cost least it has not performed in our test but VDSiCr hold the best position even though it costs higher from procuring raw materials to finished product.

FUTURE SCOPE

For the present study following are some of the future works to be carried out. They are:

- Dynamic analysis and modal analysis shall be performed to understand the behavior of the system, whether resonance phenomenon occur or not.
- Heat flow analysis and CFD analysis shall be carried out to find out the thermal expansions of the engine valve springs as they operate at elevated temperate.
- Mathematical formulation and experimental analysis shall be carried out to cross verify the analysis results.

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