FEA ANALYSIS AND PERFORMANCE TESTING OF MASTER LEAF

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Abstract

The subject gives a brief look on the suitability of steel leaf spring on vehicles and their advantages. Efforts have been made to find out stress- strain analysis of a leaf spring with varying load. The achievement of weight reduction with adequate improvement of mechanical properties has made steel a very replacement material for convectional steel. Material and manufacturing process are selected upon on the cost and strength factor. The design method is selected on the basis of mass production. The Automobile Industry has shown interest in steel leaf spring since the steel material has high strength to weight ratio good corrosion resistance and mechanical properties. The experiments will be conducted on Universal Testing Machine and numerical analysis was done via (FEA) using ANSYS 14.0 software. Stresses and deflection results were verified for analytical and experimental results. In this work the origin of premature fracture in leaf springs. To this end common failure analysis procedures including examining the leaf spring history visual inspection of fractured specimen's characterization of various properties and simulation tests on real components were used. It is concluded that fracture occurred by a mechanism of mechanical fatigue initiated at the region of the central hole which suffered the highest tensile stress levels. Several factors (poor design, low quality material and defected fabrication) have combined to facilitate failure.

Keyword:-*Ansys 14.0, CATIA V5R17, Steel Leaf Spring, SUP 11A.*

1.INTRODUCTION

It is need of Automobile manufacturer to reduce the weight of vehicles in recent years .The suspension spring is one of most important system in automobile which reduce jerk, vibration and absorb shocks during riding. Steel have been vigorously developed for many applications. Springs are crucial suspension elements in cars necessary to minimize the vertical vibrations impacts and bumps due to road regularities. The functions of the suspension springs for an automobile are to maintain good control stability and to improve riding comfort. The behavior of steel leaf spring is need to be linear in relatively high weight and change in solid axle angle due to weight transfer specially during working of vehicle that will lead to over steer and directional instability under such situation. It is very difficult for driver to control vehicle. These are some defect of metallic leaf spring so considering automobile development and importance of relative aspect such as fuel consumption, weight riding quality, and handling so development in steel material is necessary in the automobile industry. Recently graphite and carbon fiber demonstrate its superiority over other steel material however due to cost and availability. Many papers were devoted to find spring geometry. Multi-leaf springs used as suspension components in some buses were found to fail after a short service time. Spring fractures caused no damage in other structural components of the buses or accidents of any kind. The suspension component is connected at both ends with the bus chassis and rests on the wheel axle. Some mayor leaves fractured within six months of service. In this work, the origin of premature failure in the springs is investigated. To this end common failure diagnosis methods involving examination of manufacturing and failure histories, macroscopic inspection, chemical analysis, metallographic analysis, hardness measurements, static loading tests and fatigue tests, were employed.

2.DESIGNS CONSIDERATION OF STEEL LEAF SPRING

Considering several types of vehicles that have leaf springs and different loading on them, various kinds of steel leaf spring have been developed. In multi-steel leaf spring, the inter leaf spring friction plays a spoil spot in damage tolerance. It has to be studied carefully. The following cross-sections of mono-steel leaf spring for manufacturing easiness are considered.

1. Constant thickness, constant width design.

2. Constant thickness, varying width design.

3. Varying width, varying thickness design.

In this only a mono-steel leaf spring with varying width and varying thickness is designed and manufactured. Computer algorithm using C-language / MATLAB has been used for the design of constant cross-section leaf spring. The results showed that a spring width decreases hyperbolically and thickness increases linearly from the spring eyes towards the axle seat. Fig.2.1.1 shows flowchart of computer algorithm for design of steel leaf spring.

3.MULTI-LEAF SPRINGS

Multi-leaf springs are widely used for automobile and rail road suspensions. It consists of a series of flat plates, usually of semi- elliptical shape. The leaves are held together by means of two U-bolts and a centre clip. Rebound clips are provided to keep the leaves in alignment and prevent lateral shifting of the plates during the operation. The longest leaf, called the master leaf, is bent at both ends to form the spring eye. At the center, the spring is fixed to the axle of the car. Multi- leaf springs are provided with one or two extra full length leaves in addition to the master leaf. These extra full-length leaves are stacked between the master leaf and the graduated-length leaves. The extra full-length are provided to support the transverse shear force. For the purpose of analysis, the leaves are divided into two group's namely master leaf along with graduated-length leaves forming one group and extra full-length leaves forming the other.

4.EXPERIMENTAL PROCEDURE

The chemical composition of EN47 spring steel used was C-0.56 si-0.21 mn-0.80 s&p-1.04 cr-0.018 weight%. The mechanical properties are: yield strength of 1134 MPa, ultimate tensile strength of 1158 MPa. The test material was first heat-treated at 1191 K, and oil-quench hardened. It was tempered at 793 K. This gave a brinell hardness of HB of 335. For the purpose of testing specimens, a steel strip, 1260 x 60 ·x 08 mm thick was used. The arc height was measured using an Almen gauge. In the experimental analysis the comparative testing of steel leaf spring are taken. The deflection or bending tests of both the spring should be study is on the universal testing machine. Move the plunger up to desired height so that we can fix the fixture and leaf spring for test. Fix the position of fixture. On the fixture place the specimen. Set the universal testing machine. Apply the loads in steps of 20 kg gradually. Note down the deflection readings. The studied spring model was installed in seat buses and subject to fluctuating loads and environmental conditions typical of an urban bus. The service conditions were thus the usual for this type of mechanical suspension component. The spring manufacturing process, this is conducted entirely. The thick sheets of steel obtained by hot rolling. Essentially, it involves cutting, forming and punching of the leaves, hardening by quenching and tempering, surface finishing by shot peening, and assembly of individual leaves by inserting a bolt through their central hole and fastening them, at the ends, with two clamps. Testing of steel leaf spring are takes place on UTM. The steel leaf springs are tested by using leaf spring test rig. The experimental set up is shown in Fig. The leaf springs are tested following standard procedures recommended. The spring to be tested is examined for any defects like cracks, surface abnormalities, etc. The spring is loaded from zero to the prescribed maximum deflection and back to zero. The load is applied at the centre of spring. The vertical deflection of the spring centre is recorded in the load interval of 186 N. Static test of steel mono leaf spring Fig.

Fig.4.1Test rig of mono steel leaf spring

5.EXPERIMENTAL SETUP:

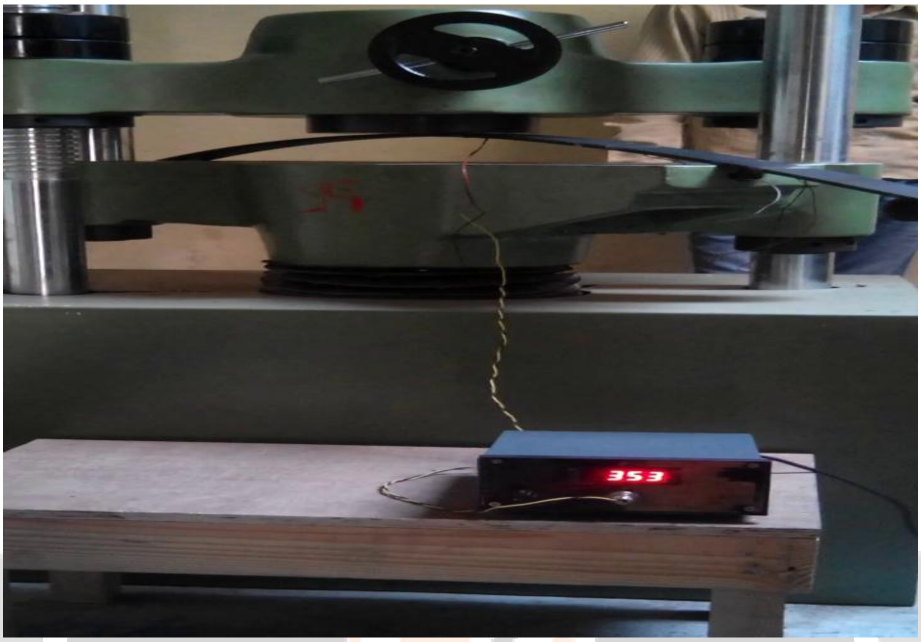


Fig. 5 Testing of Steel Leaf Spring

5.1**STRAIN GUAGE READING FOR EN 47 STEEL LEAF SPRING:-**

Table 5.1: Strain Gauge reading for EN 47 steel leaf spring

Sr. No.	Deflection(mm)	Load(N)	L1(mm)	L2(mm)	L3(mm)
1	5	186	170	165	130
2	10	372	334	350	259
3	15	558	496	526	410
4	20	745	657	693	552
5	25	931	823	874	711
6	30	1117	972	1029	848
7	35	1303	1153	1220	1068
8	40	1489	1388	1477	1248
9	45	1675	1600	1627	1458
10	50	1862	1778	1801	1650
11	55	2048	1996	1998	1714

5.2 STRAIN GUAGE READINGFOR SUP11A STEEL LEAF SPRING:-

Table 5.2: Strain Gauge reading for SUP 11A steel leaf spring

Sr. No.	**Deflection(mm)**	**Load(N)**	**L1(mm)**	**L2(mm)**	**L3(mm)**
1	5	189	48	85	22
2	10	378	161	246	78
3	15	567	278	392	139
4	20	755	391	571	225
5	25	944	496	723	295
6	30	1133	604	894	387
7	35	1322	758	1069	605
8	40	1511	909	1338	810
9	45	1700	1138	1511	980
10	50	1889	1626	1649	1225
11	55	2077	1770	1772	1489

5.3 SAMPLE READIN FOR LAST READING OF TABLE 5:-

ε = 1770 x 10-6 -------- Experimental value

Now,

by using Hooke's law

Stress = Young's Modulus of elasticity x Strain

Stress = 1770 x 10 ^-6 x 2.1 x 10^ 5

= 371.7 N/mm2

Bending stress = 371.7 N/mm2 -------- Experimental value.

5.3ANALYTICAL VALUE:--

We know that for leaf spring,

Bending stress, σ =6 w L / bt2

= (6 x 1038.5 x 545)/(60 x 102)

= 554.88 N/mm2

Bending stress = 554.88 N/mm2 -------- Analytical value.

6.SOFTWARE ANALYSIS

6.1 MODELING WITH CATIA SOFTWARE

The steel leaf spring is analyzed for static strength and deflection using 3D finite element analysis. The general purpose finite element analysis software ANSYS version 11 is used for the present study. Using the advantage of symmetry in geometry and loading, only one-half of the leaf spring is modeled analyzed. The three dimensional structure of the leaf spring is divided into a number eight-nodded 3D brick elements in order to get accurate results, more number of elements are to be created. Hence, an aspect ratio of three is maintained in the finite element model. The variation of bending stress and displacement values are predicted. The steel leaf spring from unreformed shape, it is observed from the results that the steel leaf spring functions equally as the conventional leaf spring under similar loading conditions. Apart from the selection of material and design procedure, the selection of manufacturing process also determines the quality and cost of the product. Hence, the steel leaf spring manufacturing process should fulfill the following criteria.[3]

i. The process should be capable to mass production.
ii. The process should be capable of producing leaf spring with less defect n maximum strength.

RESULTS AND DISCUSSION

6.2 STEEL LEAF SPRING EN 47 & SUP 11A MATERIAL:-

Table 6.A Comparison of results for EN 47 steel leaf spring at a Deflection of 55 mm

Location	**Parameter**	**Analytical value**	**FEM value**	**Expt. value**	**A**	**B**
L1	Bending stress in N/mm^2	548.58	462.62	413.17	10.68	24.68
	Load	2048 N	2048 N	2048 N		

Table 6.B Comparison of results for SUP 11A steel leaf spring at a Deflection of 55 mm

Location	**Parameter**	**Analytical value**	**FEM value**	**Expt. value**	**A**	**B**
L1	Bending stress in N/mm^2	554.88	468.51	371.70	20.66	33.21
	Load	2048	2048	2048		

6.3 WEIGHT CAMPARISON OF STELL AND COMPOSIT LEAF SPRING:-

` As one of the objective of the present work is to reduce the weight of the leaf spring Though in the present thesis the material is replace from steel to glass epoxy composite material the weight comparison is shown in table 6.4

Table 6.4 Weight Comparison of Steel and Composite Leaf Spring

Leaf spring type	Steel	Composite
Weight(Kg)	13.4 (with eye)	4.652 (with eye)

CALCULATION:-

Weight of the steel leaf spring –Weight of the composite leaf spring

=13.400-4.652 = 8.748kg

Weight reduction in terms of %= $\frac{8.748x100}{13.400} = \frac{874.8}{13.400}$ = 65.28%

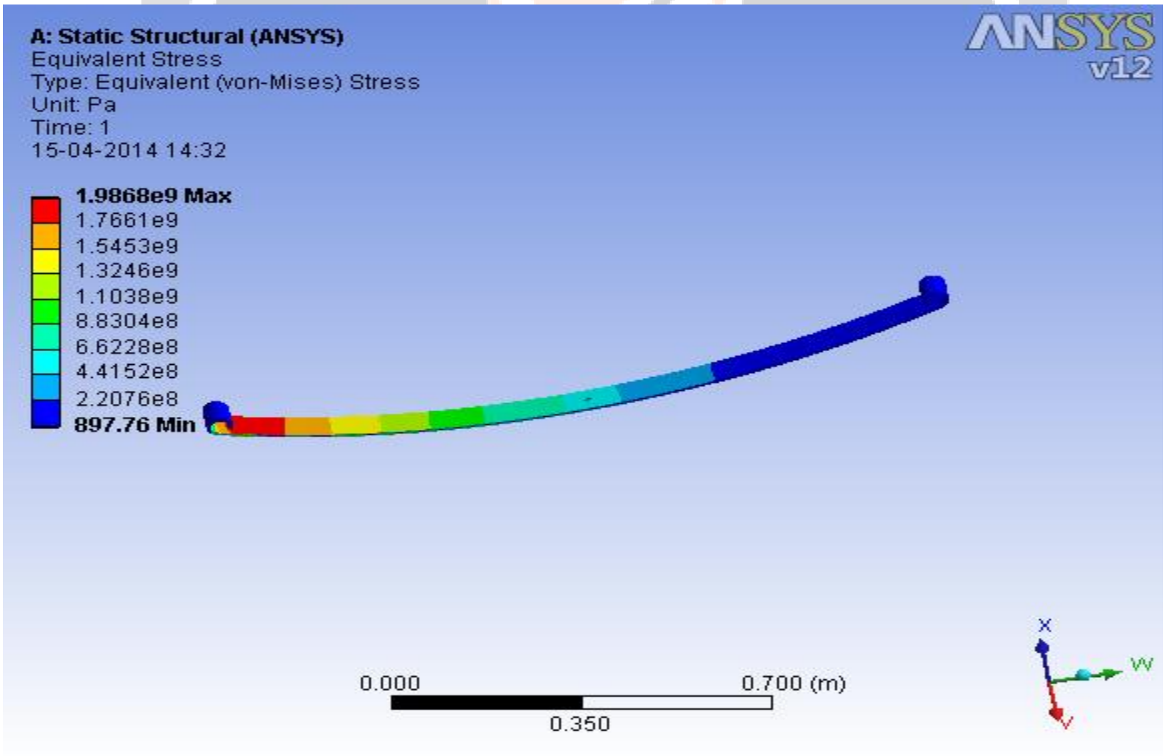
It was cleared that the weight reduction is achieved up to 65.28% than that of composite leaf spring.

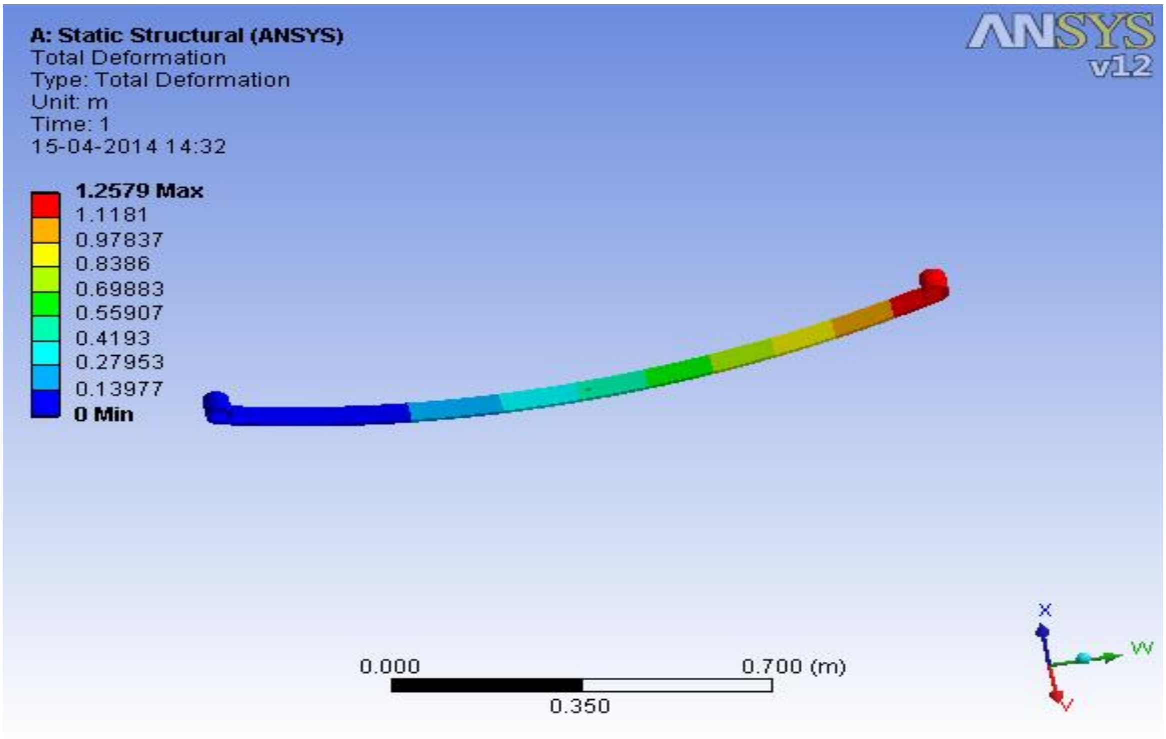
7.CAMPARISON RESULT:-

Table 7 Comparison of results at Location L1, L2 & L3

Parameter	Location	EN 47	SUP 11 A
Maximum Bending Stress at 55 mm	L1	413.17	371.70
	L2	413.58	372.12
	L3	355.40	312.69

7.1RESULT ANALYSIS BY ANSYS

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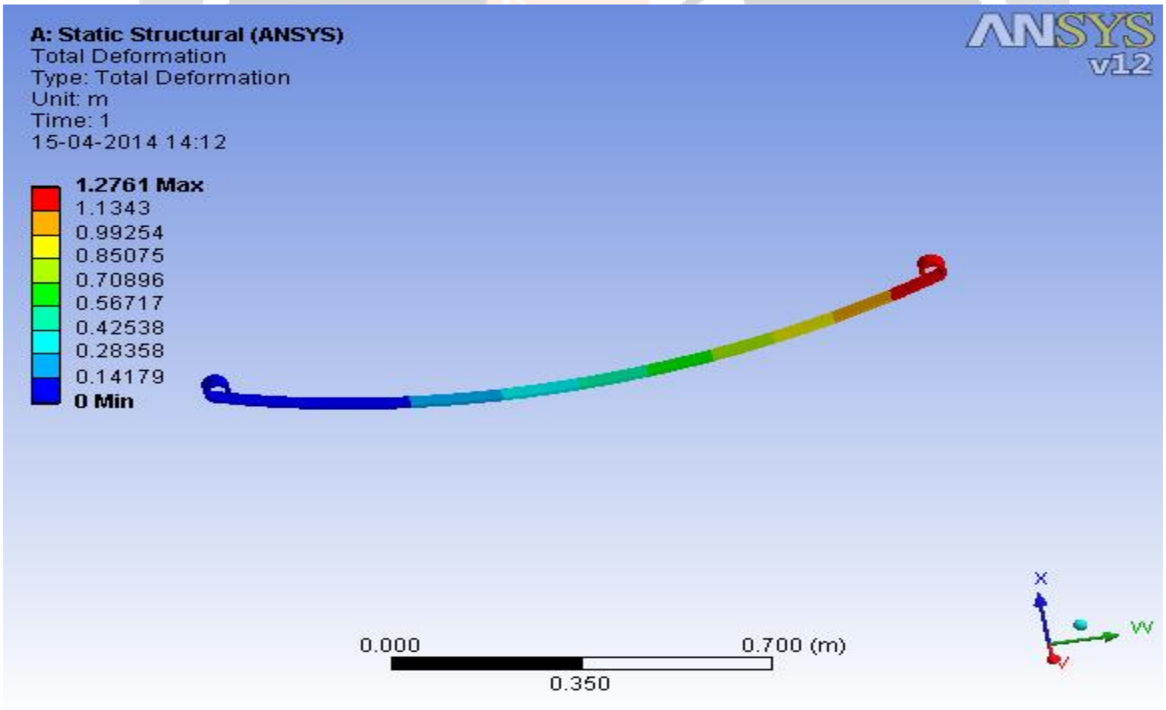
0 Min
ANSYS
v12
0.000
0.350
0.700 (m)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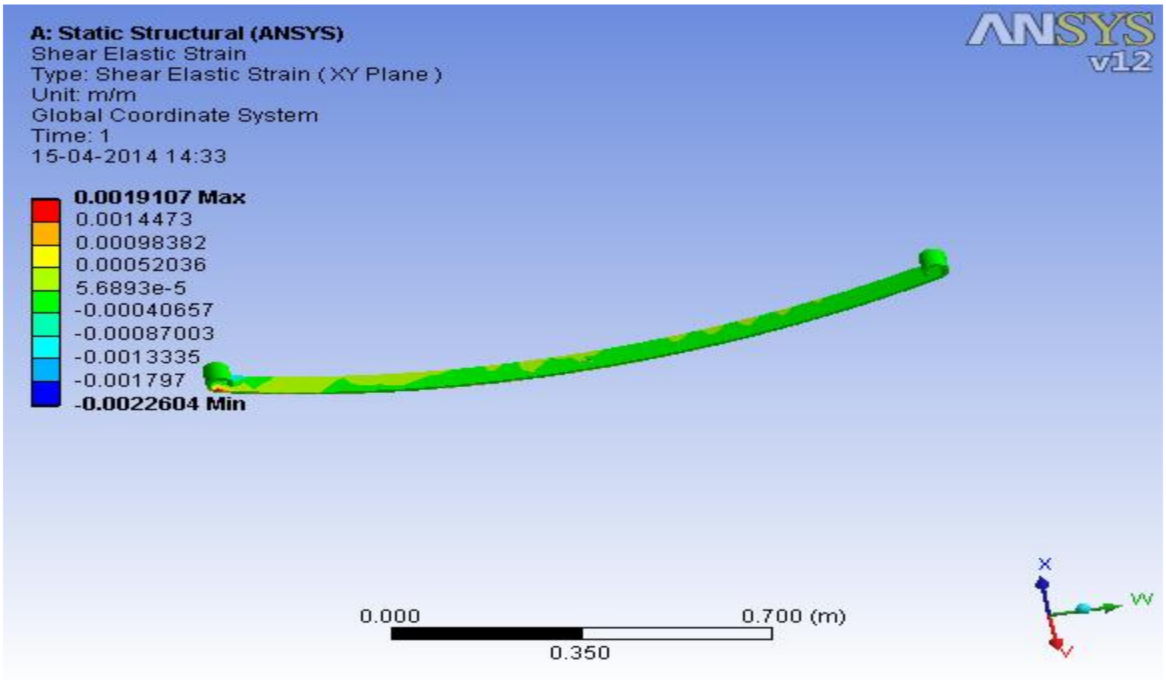
ANSYS
v12
0.000
0.350
0.700 (m)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0.700 (m)
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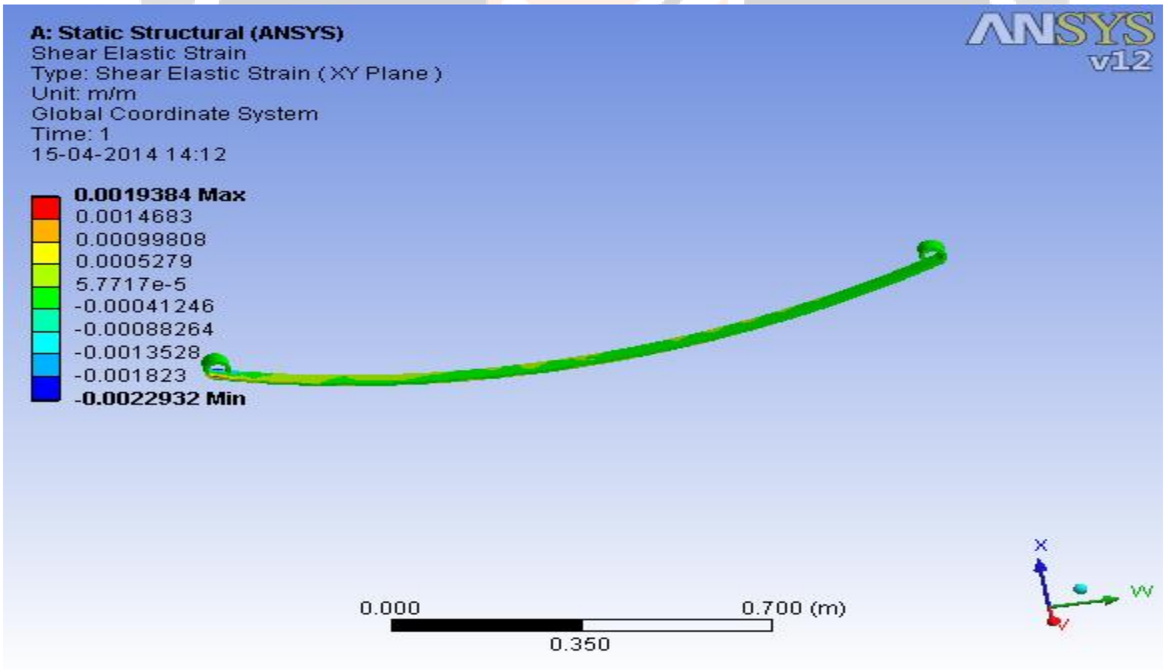
X
W
V


A: Static Structural (ANSYS)
Shear Elastic Strain
Type: Shear Elastic Strain (XY Plane)
Unit: m/m
Global Coordinate System
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-0.00088264
-0.0013528
-0.001823
-0.0022932 Min
ANSYS v12
0.000
0.700 (m)
0.350
X
W
V

8.RESULTS AND CONCLUSION

8.1 STEEL LEAF SPRIN EN 47 & SUP 11A MATERIAL:-

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	Load(N)	2048 N	2048 N	2048 N		

Table 7.B Comparison of results for SUP 11A steel leaf spring at a Deflection of 55 mm

Location	Parameter	Analytical value	FEM value	Expt. value	A	B
L1	Bending stress in N/mm^2	554.88	468.51	371.70	20.66	33.21
	Load(N)	2048	2048	2048		

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