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COMPARATIVE ANALYSIS OF CONVENTIONAL LEAF SPRING AND COMPOSITE LEAF

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ABSTRACT
A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of spring. Sometimes referred to as a semielliptical leaf spring (SELS) it takes the form of a slender arc-shaped length of spring steel of rectangular cross section. The centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body.

In the present work, a seven-leaf steel spring used in passenger cars is replaced with a composite multi leaf spring made of glass/epoxy composites. The dimensions sand the number of leaves for both steel leaf spring and composite leaf springs are considered to be the same. The primary objective is to compare their load carrying capacity, stiffness and weight savings of composite leaf spring. Finally, fatigue life of steel and composite leaf spring is also predicted using life data.

INTRODUCTION

Figure 1: Conventional leaf spring

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles By Gulur S et al. It is also one of the oldest forms of springing, dating back to medieval times. Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross section By Jadhav M V et al. The center of the arc provides location for the axle, while tie holes called eyes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions By A V Amrute et al. A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness.

The leaf does the following functions:

- Supports the chassis weight.
- Controls chassis roll more efficiently--high rear moment center and wide spring base.
- Controls rear end wrap-up.
- Controls axle damping.
- Controls lateral forces much the same way a hard bar does.
- Controls braking forces.
- Regulates wheelbase lengths (rear steers) under acceleration and braking.

LITERATURE SURVEY

Hari Pal Dhariwal, Barun Kumar Roy and Raj Kumar Duhan has given in VSRD International Journal of Mechanical, Automobile and Production about a semielliptical leaf spring (SELS) it takes the form of a slender arc-shaped length of spring steel of rectangular crosssection.

Mouleeswaran Senthil kumar, sabapathy vijayarangan has given in A journal paper of "Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi-leaf Spring for Light Passenger Vehicles Using Life Data Analysis" about The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system.

A book of "ENGINEERING COMPOSITE MATERIALS" By Bryan Harris Published by The Institute of Materials, London gives strong fibers. Polymer-matrix composites, Metal-matrix composites, materials factors affecting fatigue behavior of reinforced plastics. On the basis of that a comparative study has been made between composite and steel leaf spring with respect to weight, cost and deflection.

DESIGN AND EXPERIMENTATION

MATERIAL & DIMENSIONS FOR MODELLING OF LEAF SPRINGS

Considering:

Material of the Spring is Structural Steel
Thickness of Leaves = t
Width of Each Leaf = b
No of Leaves = n
Maximum Load = W
Length of Cantilever Spring = L
Modulus of Elasticity of Material = E
Maximum Bending Moment in the Centre (M) = W.L
nf = Number of full length leaves
ng = Number of graduated leaves
n = Total number of leaves (Full length leaves + Graduated leaves)

When there is only one full-length leaf (i.e. master leaf only), then the number of leaves to be cut will be n and when there are two full length leaves (including one masterleaf) [By Ghodake A. P. et al, S. Mehul et al], then the number of leaves to be cut will be (n-1) if a leaf spring has two full-length leaves, then the length of leaves is obtained as follows:

Length of smallest leaf = + Ineffective Length … (3)
Length of next leaf = ×2 + Ineffective Length … (4)

STANDARD DIMENSION OF 'TATA ACE' LEAF SPRING

Thickness of Leaves = t = 9 mm
Width of Each Leaf = b = 60mm
No of Leaves = n = 3
Maximum Load = W = 5.9 KN
Length of Cantilever Spring = L = 863.6 mm
Modulus of Elasticity of Material = $E=200*10^9$ N/m^2
Maximum Bending Moment in the Centre (M) = W.L = 5095.24 KNmm
nf = Number of full length leaves = 1
ng = Number of graduated leaves = 2
n = Total number of leaves (Full length leaves + Graduated leaves)
n = 1 + 2
n = 3

Length of Leaves
Length of Smallest Leaves = 876.3 mm
Length of second Leaves = 876.3 mm
Length of Third Leaves = 863.6 mm

Radius of curvature of the Spring
R = 632 mm

TESTING OF CONVENTIONAL LEAF SPRING
TESTING PROCEDURE

Figure 2: Testing of conventional leaf spring on UTM machine

1) Arrange the holding clamp of UTM machine as per the size of leaf spring.
2) Switch on the CPU of computer and the UTM machine.
3) Reset the UTM machine as per our requirement.
4) The variation in deflection with respect to applied load is selected on the software.
4) Apply the load gradually from starting with 0 KN to maximum load spring sustain.
5) Observe the deflection for that applied load.
6) When inner surface of the leaf spring will get touch to the workbench of UTM machine, stop the load.
7) Observe the maximum deflection occurred in the spring at specific load.
8) Take all the readings of the load vs deflection from the software.
9) Remove the load applied gradually till the spring regains its mean position.
10) Remove the leaf spring from holding clamp fixture.

PRECAUTION

1) Fix the leaf spring on the workbench carefully.
2) Apply the load gradually to avoid the sudden failure in the spring.
3) Control the speed of the UTM machine.
4) Check the initial condition as no load condition on the spring to avoid the faulty readings.
5) Maintain the safe distance from the machine while testing the leaf spring.

OBSERVATIONS

We got the following results by testing the conventional leaf spring on UNIVERSAL TESTING MACHINE. Base on the result obtained by taking suitable load value we prepared following observation table and observed corresponding deflection value. After that we got the graph LOAD VS DEEFLECTION.

OBSERVATION TABLE

Table 1- For Conventional leaf spring

SR NO.	Load applied on conventional leaf spring (Newton)	Deflection occurred in the conventional spring in 'mm'.
1	0	0
2	1000	10.97
3	2000	20.25
4	3000	30.95
5	4000	42.39
6	5000	58.31
7	5900	72.4

GRAPH OF LOAD VS DEFLECTION

For Conventional leaf spring

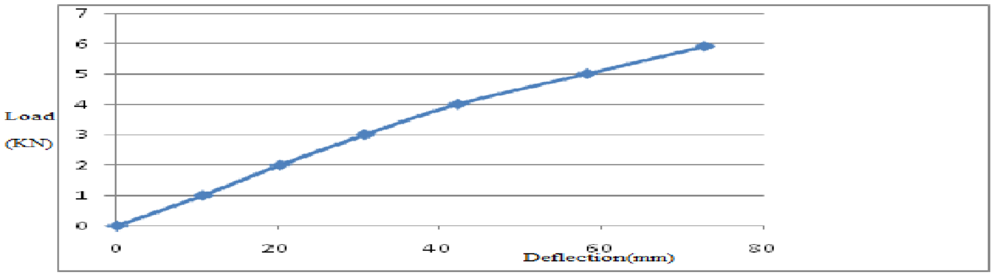

Figure 3: Graph of load vs. deflection for conventional leaf spring

The graph of load vs. deflection is plotted by taking the load in 'KN' on y-axis and deflection on x-axis in 'mm'. From above graph we get the linear relationship between load and deflection. As the load increases the deflection also increases gradually. The graph is passing through the origin. Hence we conclude that the applied load is directly proportional to the deflection occurred in the spring.

MODELING OF CONVENTIONAL LEAF SPRING

We have prepared model of conventional leaf spring on Autocad as well as CATIA software. The standard dimensions are taken from the leaf spring of TATA ACE vehicle.

AUTOCAD MODEL

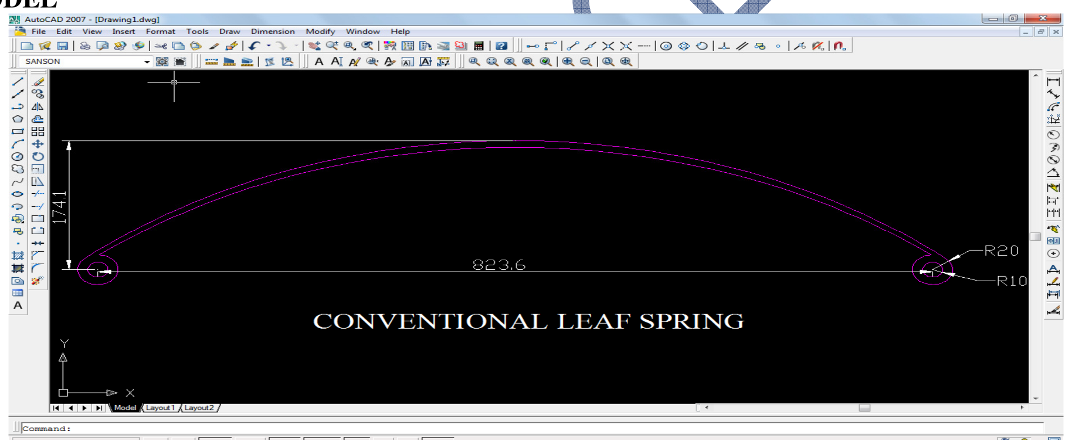

Figure 4: model of conventional leaf spring on Autocad model

CATIA model

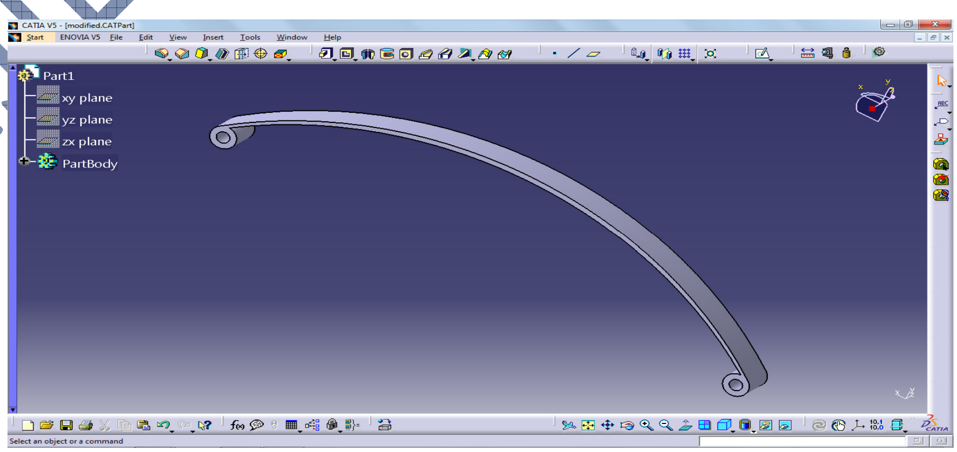

Figure 5: model of conventional leaf spring on CATIA model

ANALYSIS OF CONVENTIONAL LEAF SPRING BY USING ANSYS-12 SOFTWARE.

ANSYS-12 fully supports workbench journaling and scripting.

- Project concept and operation.
- Parameter management.
- Native application: Project schematic, design exploration, engineering data.
- File management.
- Works hand in hand with application level scripting: Design modeler, meshing, mechanical, mechanical APDL, FLUENT, CFX, etc.

We have imported CATIA model in ANSYS12 software for the analysis.

Meshing of spring model

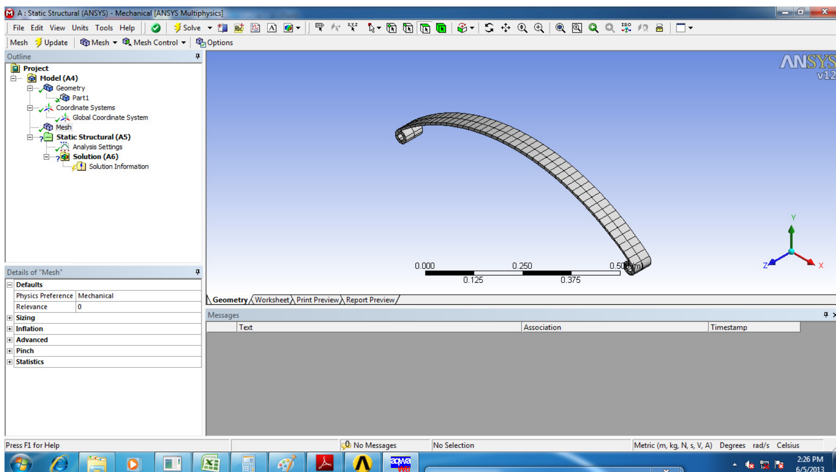

Figure 6: Meshing of conventional leaf spring

Total Deformation of leaf spring

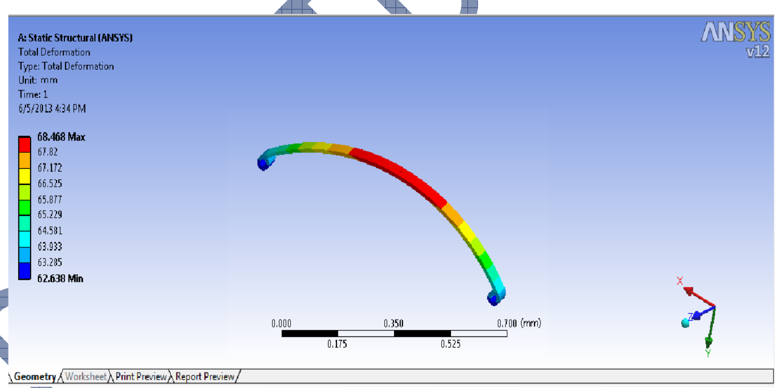

Figure 7: Total deformation of conventional leaf spring

OBSERVATION TABLE

Table 2- For Conventional leaf spring on ANSYS-12

SR NO.	Load applied on the conventional spring in 'Newton'.	Deflection occurred in the conventional spring in 'mm' on ANSYS-12
1	0	0
2	1000	8.783
3	2000	17.201
4	3000	29.136
5	4000	41.435
6	5000	57.874
7	5900	68.468

GRAPH OF LOAD VS DEFLECTION

For Conventional leaf spring on ANSYS-12

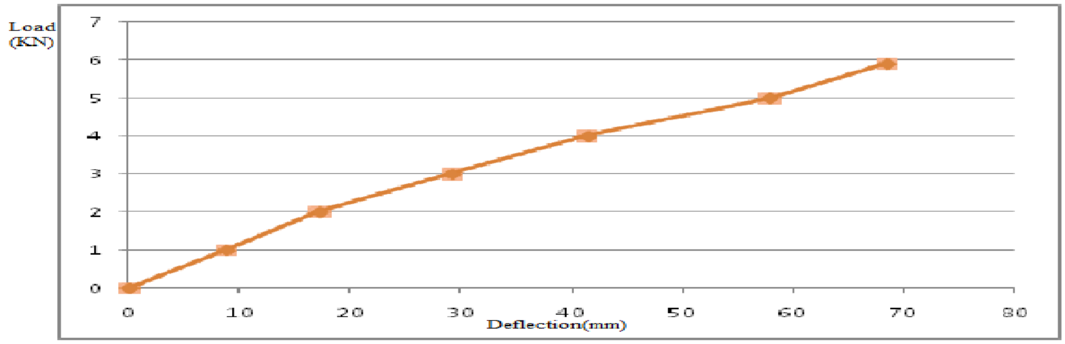

Figure 8: Graph of load vs. deflection for conventional leaf spring on ANSYS-12

The graph of load vs. deflection is plotted by taking the load in 'KN' on y-axis and deflection on x-axis in 'mm'.

From above graph we get the linear relationship between load and deflection. As the load increases the deflection also increases gradually. The graph is passing through the origin. Hence we conclude that the applied load is directly proportional to the deflection occurred in the spring.

COMPOSITE LEAF SPRING

INTRODUCTION OF COMPOSITE LEAF SPRING

In the present scenario, weight reduction has been the main focus of automobile manufactures [By K. R. Jani et al]. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unstrung weight, which is considered to be the mass not supported by the leaf spring [By J. P. Hou et al]. The introduction of composite materials made it possible to reduce the weight of the leaf spring without any reduction on the load carrying capacity and stiffness. Studies were conducted on the application of composite structures for automobile suspension system [By M .M. Shokrieh et al]. A double tapered beam for automotive suspension leaf spring has been designed and optimized. Composite mono leaf spring has also been analyzed and optimized.

It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of composite materials was made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. Since; the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel.

To meet the needs of natural resource conservation and energy economy, automobile manufacturers have been attempting 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 [By M. Venkatesan et al, M. M. Patunkar et al]. Fibre-reinforced polymers have been vigorously developed for many applications, mainly because of the potential for weight savings. Other advantages of using fibre-reinforced polymers instead of steel are:

(a) The possibility of reducing noise, vibrations and ride harshness due to their high damping factors;
(b) The absence of corrosion problems, which means lower maintenance costs; and
(c)Lower tooling costs, which has favourable impact on the manufacturing costs.

Recently, graphite and carbon fibre demonstrate its superiority over other composite material however due to cost and availability limitation the present work restricted to leaf spring made up of glass fibre, and Epoxy resin.

PROBLEMS IDENTIFICATION

The objective of present work is to design, experimental testing and analysis of composite spring made up of E-glass fibres, epoxy resin (general purpose resin) with constant width and thickness throughout its length.

Experimental results from testing the leaf springs under static loading containing the stresses and deflection. These results are also compared with FEA By P. B. Waghmare et al. Testing has been done for unidirectional E-Glass/Epoxy mono composite leaf spring only By Amrita srivastava et al. Since the composite leaf spring is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. Since, the composite spring is designed for same stiffness as that of steel leaf spring, both the springs are considered to be almost equal in vehicle stability. The major disadvantages of composite leaf spring are chipping resistance [By K A Katake et al]. The matrix material is likely to chip off when it is subjected to a poor road environments (that is, if some stone hit the composite leaf spring then it may produce chipping) which may break some fibres in the lower portion of the spring.

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This may result in a loss of capability to share flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problem will not be there. Composite leaf springs made of polymer matrix composites have high strength retention on ageing at severe environments.

The steel leaf spring was replaced with a composite one By G. B. Jadhav et al. The objective was to obtain a spring with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacements. The weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring. Thus, the objective of the unstrung mass is achieved to a larger extent. The stresses in the composite leaf spring are much lower than that of the steel spring By S. M. Savio et al.

ANALYSIS OF COMPOSITE LEAF SPRING ON ANSYS-12

Table 3- MATERIAL PROPERTIES OF E-GLASS/ EPOXY

SR. NO.	PROPERTIES	VALUE
1.	Tensile modulus along X-direction (Ex),MPa	34000
2.	Tensile modulus along Y-direction (Ey), MPa	6530
3.	Tensile modulus along Z-direction (Ez), MPa	6530
4.	Tensile strength of the material, Mpa	900
5.	Compressive strength of the material, Mpa	450
6.	Shear modulus along XY-direction (Gxy), Mpa	2433
7.	Shear modulus along YZ-direction (Gyz), Mpa	1698
8.	Shear modulus along ZX-direction (Gzx), Mpa	2433
9.	Poisson ratio along XY-direction (Nuxy)	0.217
10.	Poisson ratio along YZ-direction (NUyz)	0.366
11.	Poisson ratio along ZX-direction (NUzx)	0.217
12.	Mass density of the material, kg/mm3	$2.6*10^{-6}$
13.	Flexural modulus of the material, MPa	40000
14.	Flexural strength of the material, MPa	1200

OBSERVATION TABLE

The following observations are obtained on ANSYS-12

Table 4- For Composite Leaf Spring

SR NO.	Load applied on Conventional leaf sp Spring (Newton)	Deflection occurred in the Conventional spring (mm) on ANSYS-12
1	**0**	**0**
2	**1000**	**9.587**
3	**2000**	**18.953**
4	**3000**	**31.126**
5	**4000**	**43.032**
6	**5000**	**58.794**
7	**5900**	**71.681**

Graph for Composite Leaf Spring Results Obtained

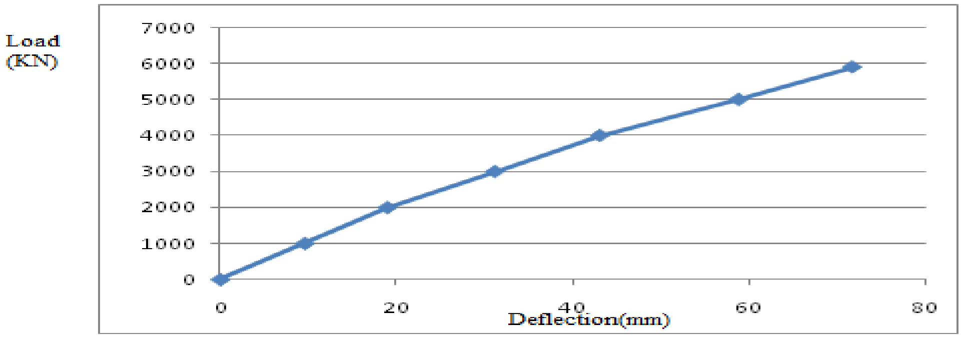

Figure 9: Graph of load vs. deflection for composite leaf spring on ANSYS-12

The graph of load vs. deflection is plotted by taking the load in 'KN' on y-axis and deflection on x-axis in 'mm'.

RESULT

Table 5- COMPARISON OF LOAD Vs DEFLECTION

Sr. No.	Force (KN)	Test Results deflections on UTM of Conventional Leaf Spring in mm	Results obtained on ANSYS-12 for conventional leaf spring g	Results obtained on ANSYS-12 for composite leaf spring in mm
1	1	10.97	8.783	9.587
2	2	20.25	17.201	18.953
3	3	30.95	29.136	31.126
4	4	42.39	41.435	43.032
5	5	58.31	57.874	58.794
6	5.9	72.4	68.468	71.681

COMPARISON OF MASS

Mass of conventional leaf spring =3.518kg
Mass of composite leaf spring =1.232kg

Ratio of mass of composite leaf spring to the mass of conventional leaf spring can be obtained as follows:

= = 0.3501

Percentage Reduction of mass Obtained =

(1 -)*100

= (1-0.3501)*100
= 64.98 %

Percentage Reduction of mass Obtained = 65 %

CONCLUSION

1) A comparative study has been made between composite and steel leaf spring with respect to weight, cost and deflection
2) The composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.
3) Composite leaf spring reduces the weight by 65 % for E-Glass/Epoxy, over conventional leaf spring.
4) Experimental value taken on UTM machine and value obtained on ANSYS-12 nearly matched.
5) It is found that the life of composite leaf spring is much higher than that of steel leaf spring.

FUTURE SCOPE

1) Now a day there is need of weight reduction in Light Utility Vehicle, So by using composite leaf spring in these vehicles we will get sophisticated design.
2) By modifying the properties of material and design parameters composite leaf spring can be use in the Heavy Duty Vehicle also.
3) Nowadays composite leaf spring is convenient to use only on expressways vehicles.
   After improving the quality of roads it can be used in rural area's vehicle also.
4) This world is now replacing conventional accessories by deriving new composites and nano material in metallurgical research.
5) With tremendous improvement in all the accessories of vehicle, new generation of automotives will be capable to reach customer's satisfaction.

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