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"OPTIMIZATION OF LEAF SPRING USING COMPOSITE MATERIAL"

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ABSTRACT

In the present scenario the utilization of fuel energy, weight reduction became one of the important factors for automobile industry. Weight reduction can be obtained by the introduction of composite material in the place of conventional material. The introduction of composite material was made it possible to reduce the weight of leaf spring without losing its load carrying capacity and stiffness. The composite material have more strain energy, strong capacity, excellent corrosion resistance, high strength weight ratio with compared to conventional leaf spring and it is lesser in weight with compared to conventional leaf spring. The use of composite material for leaf spring reduces the weight of conventional leaf spring by nearly 80%.

KEYWORDS: *composite material, leaf spring, weight reduce.*

I. INTRODUCTION

In order to limited natural resources and economize energy, weight reduction are the main focus of automobile manufacturer in the present scenario. Weight reduction can be done primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobile Leaf springs mostly used in suspension systems to absorb shock loads in automobiles like light weight motor vehicles, heavy duty trucks and in rail systems [1]. A leaf spring is a long, flat, thin, and flexible piece of spring steel or composite material that resist bending. The basic principle of leaf spring design and assembly are relatively simple, and leaves have been used in various capacities since medieval times. Most heavy duty vehicle today use two set of spring.[2]. The introduction of the composite materials made it possible to reduce the weight of the leaf springs without any reduction of load carrying capacity and stiffness [3,4]. A composite material is define as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of metallic materials. The fatigue strength weight ratios as well as fatigue damage tolerances of many composite materials are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries. High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort [5]. In this research paper we study gives a comparative analysis between steel leaf spring and composite leaf spring. The composite leaf spring is found to have lesser weight, lesser cost, lesser stresses.

II. METHODOLOGY

The following procedure has been adopted to achieve the objectives of the present study

- A collection of data for the multi-leaf spring for a light commercial vehicle locally manufactured.
- Theoretical analysis of the conventional leaf spring.
- Development of CAD models as per the specifications and drawing shared by the manufacturer
- Selection of suitable composite materials which could be used in place of conventional steel material.
- Identification of properties of the selected composite materials from the literature survey and development of CAD models for the laminated spring made from composite material keeping the geometry same as the conventional leaf spring.
- Structural analysis of the conventional and composite material leaf spring CAD models using finite element method.
- Comparison of the results obtained from the analytical calculation and the numerical simulation for conventional steel leaf spring for benchmarking of the software results.
- Comparison of the results of static analysis using an FEA tool for with the objective of identifying the suitable materials which give better performance.

Design of leaf spring:

The leaf spring analyzed in the present study is made up of spring steel graded as SUP9. The composition of material is 0.50-0.060 %C, 0.15-0.35 %Si, 0.035 %S&P, and 0.65-0.95 %Cr. Following are the specification for the spring steel SUP9. The specifications of existing leaf spring are listed in the table no. 1 given below:

Table No.1 Specification of existing leaf spring [6]

Sr. No.	Specification	Value
1	Length of leaves (mm)	965
2	Number of full length leaves	01
3	Width of all leaves (mm)	45
4	Thickness of all leaves (mm)	30
5	Inner radius of the eye(mm)	23
6	Outer radius of the eye(mm)	50
7	Camber (mm)	125
9	Young's Modulus (MPa)	2.1×10^5
10	Poisson's Ratio	0.3
11	Ultimate Tensile Strength (MPa)	1500

12	Yield Tensile Strength (MPa)	1100
13	Density (kg/mm^3)	0.00000785
14	Coefficient of thermal expansion(/^{0} C)	12×10^{-6}
15	Behavior	Isotropic
16	Weight	13 Kg

Materials for Composite Leaf Spring

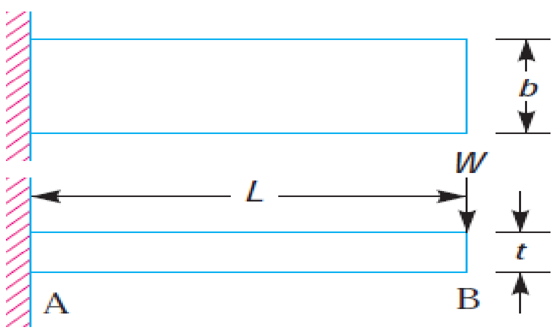
Based on the specific energy of steel spring and some composite materials, and Hybrid (Jute/E-glass/Epoxy) are selected as the spring material. The specifications for the composite leaf spring material are listed in table 2.

Table No.2 Isentropic Properties of composite material [7]

Sr. No.	Specification	Hybrid (Jute/E-glass/Epoxy)
1	Density (kg/mm^3) (ρ)	1460
2	Poisson's Ratio μ	0.22
3	Tensile Strength(MPa)	185
4	Bulk Modulus(MPa)	12500

Validation of Design Data

For evaluating the design of leaf spring it is considered as cantilever beam as shown in fig.4.1



Where,

W= Load applied (N)

t = Thickness of the plate (mm)

b= Width of the plate (mm)

L= Length of the plate (mm)

Form the fig. it is seen that the maximum bending moment ‘M’ occurring at the end A and given by Eq. 1.1a,

And section modulus ‘Z’ eq. 1.1b,

$$Z = \frac{I}{Y} = \frac{b\times t^3/12}{t/2} = \frac{1}{6}\times b\times t^2 \qquad M = W\times L$$

Therefore, Bending stress ‘б’ in such a spring given by eq. 1.1c ,

$$б = \frac{M}{Z} = \frac{6\times W\times L}{b\times t^2}$$

For ‘n’ number of leaves, the above expression can be written as,

$$б = \frac{6\times W\times L}{n\times b\times t^2}\ \text{MPa}$$

Now it is also seen that the maximum deflection occurs in the cantilever beam with concentrated load given by Eq. 1.1d [17],

$$\delta = \frac{W\times L^3}{3\times E\times I}, \qquad (I = \frac{b\times t^3}{12})$$

,

$$\delta = \frac{W\times L^3}{3\times E\times \frac{b\times t^3}{12}} \qquad \delta = \frac{4\times W\times L^3}{n\times E\times b\times t^3}$$

$$\delta = \frac{4\times W\times L^3}{n\times E\times b\times t^3} \qquad \delta = \frac{4\times W\times L^3}{n\times E\times b\times t^3}$$

Analytical Calculation

Table No.3 Analytical stress calculation of steel by using formula

S.NO	Applied Load (Newton)	Theoretical Stresses (Mpa)
1	1000	71.48
2	1500	107.22
3	2000	142.96
4	2500	178.70
5	3000	214.44

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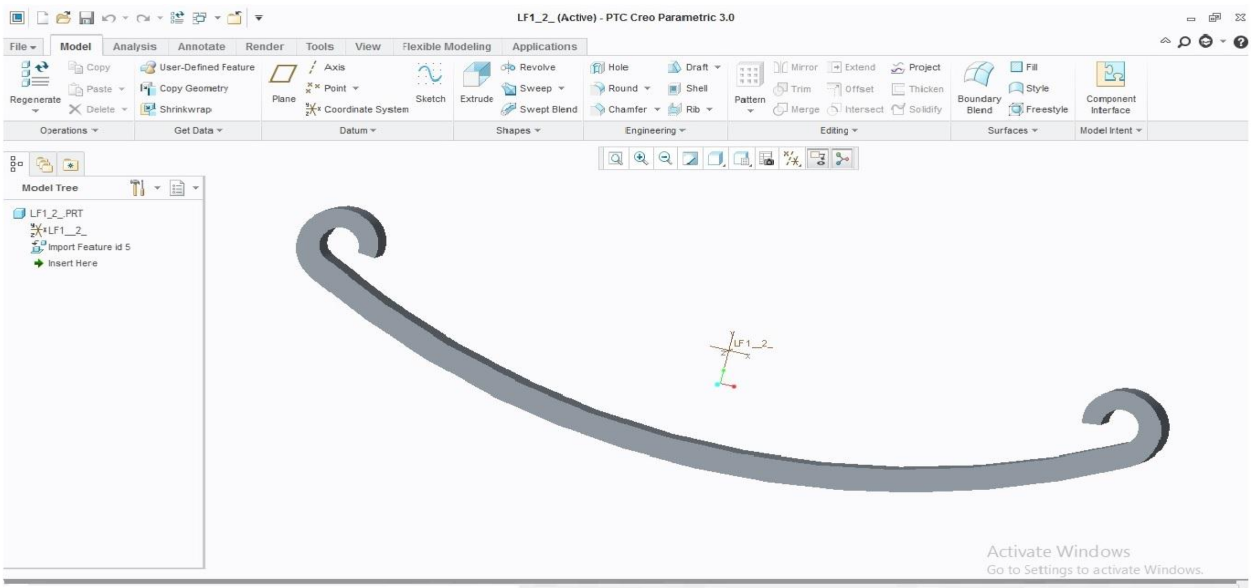
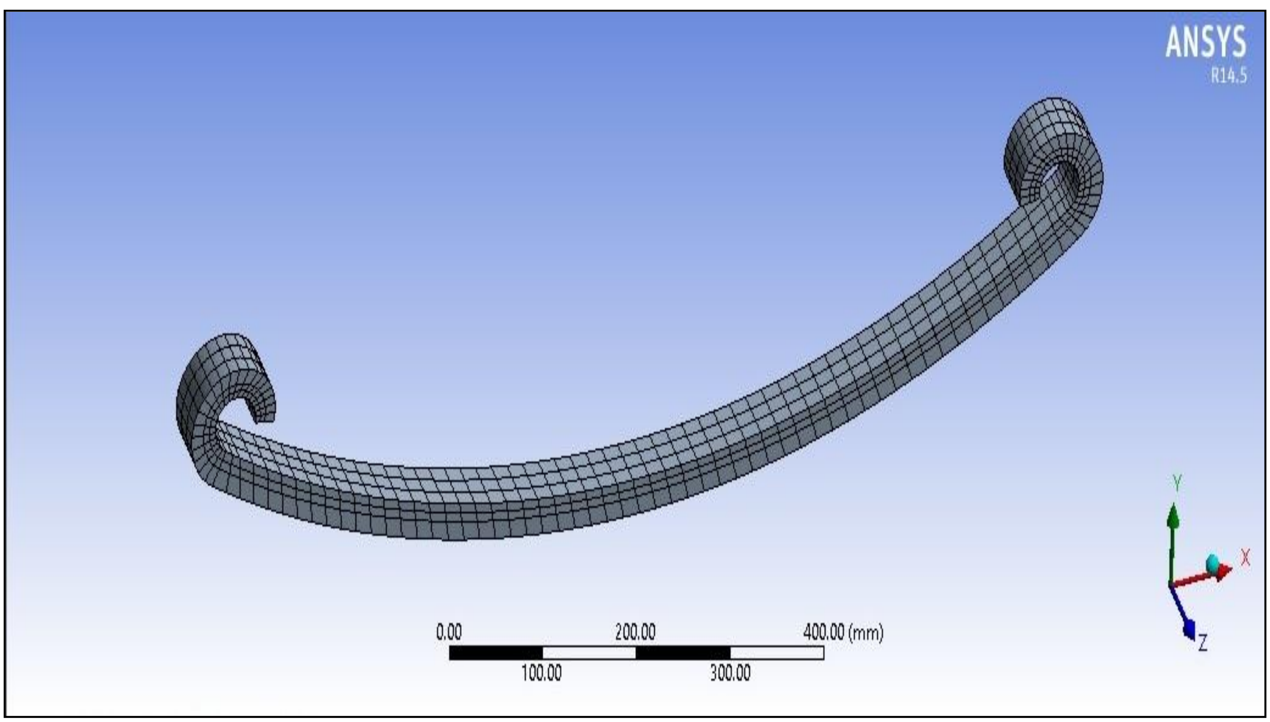
III. SOFTWARE METHOD

CAD Modeling



Meshed Model of Leaf Spring



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IV. STRESS ANALYSIS OF STEEL

On the maximum load 3000 N

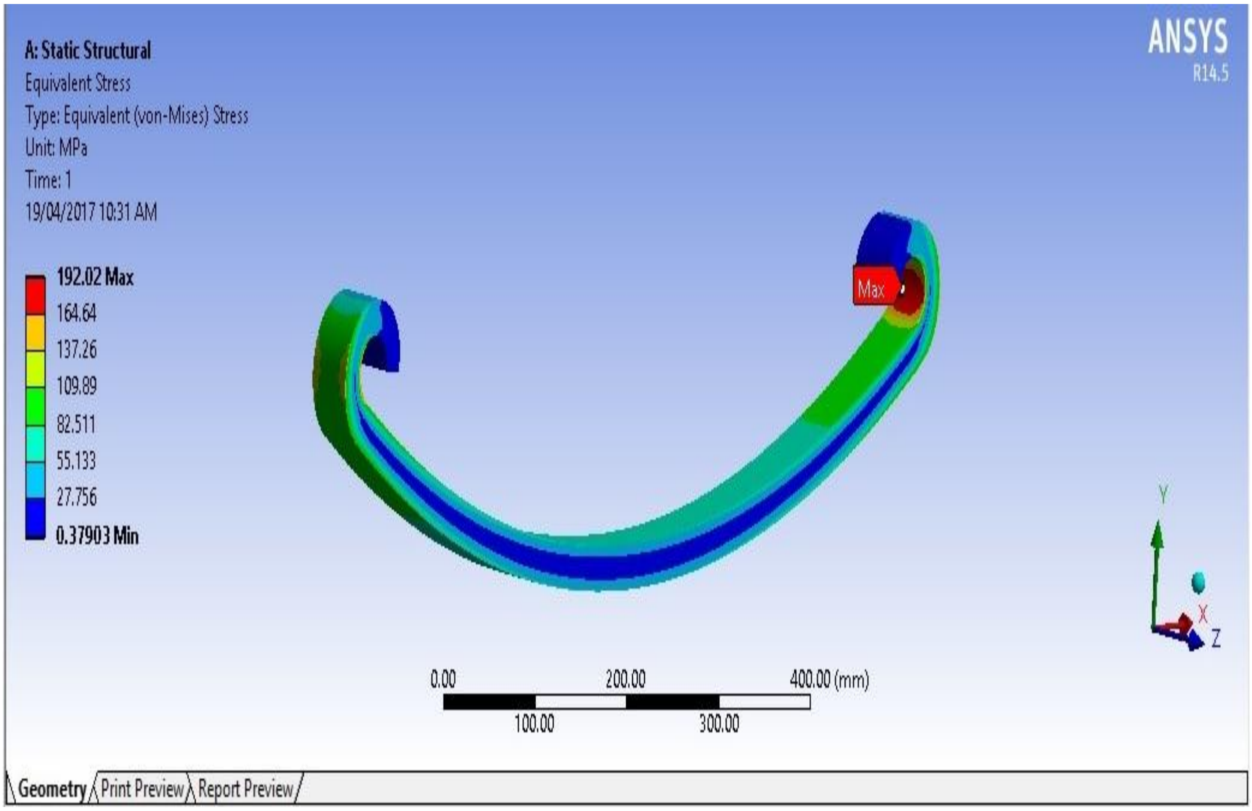

Table No.4 FEA Maximum Stresses in the Mono Leaf Spring Model

S.NO	Applied Load (Newton)	FEA Stresses (Mpa)
1	1000	64.00
2	1500	96.01
3	2000	128.01
4	2500	160.02
5	3000	192.02

FEA stress analysis of Composite Material:

On the maximum load of 3000 N

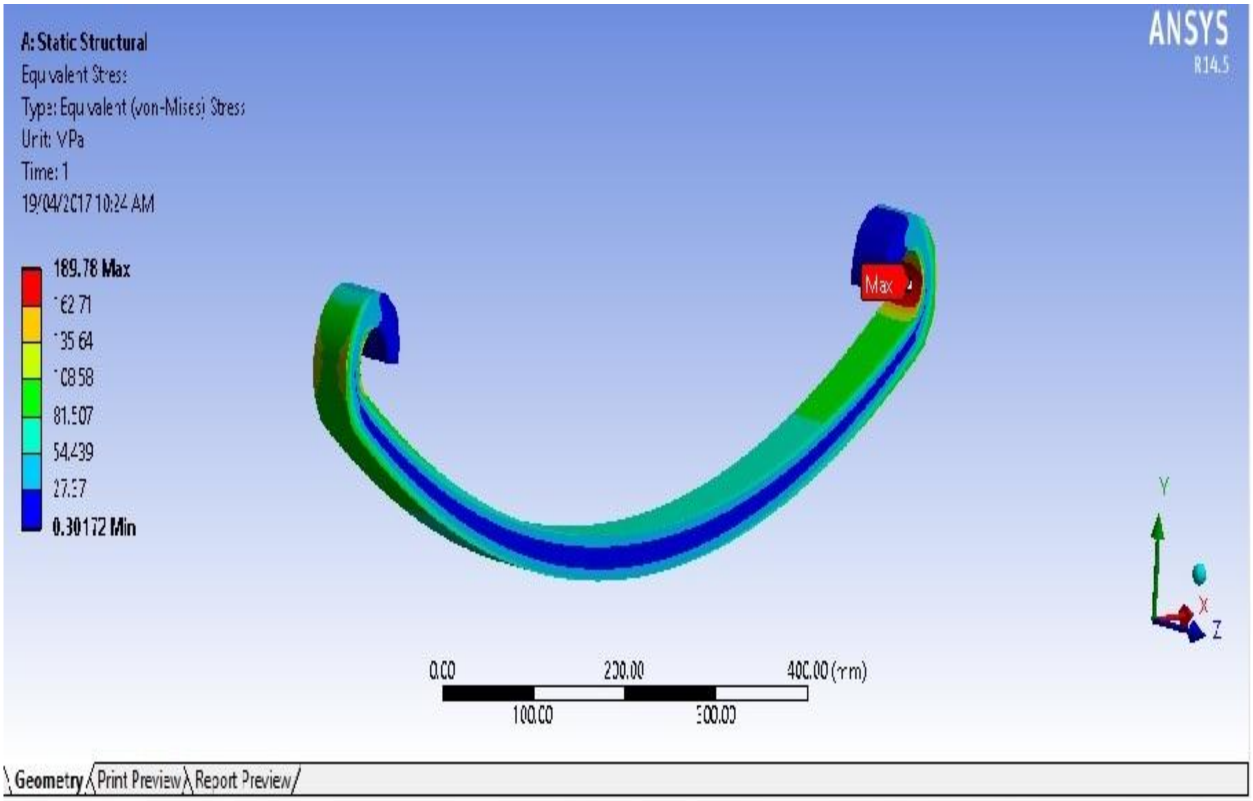

Table No.5 FEA Maximum Stresses of Composite material in the Mono Leaf Spring Model

S.NO	Applied Load (Newton)	FEA Stresses (Mpa)
1	1000	63.26
2	1500	94.89
3	2000	126.52
4	2500	158.15
5	3000	189.78

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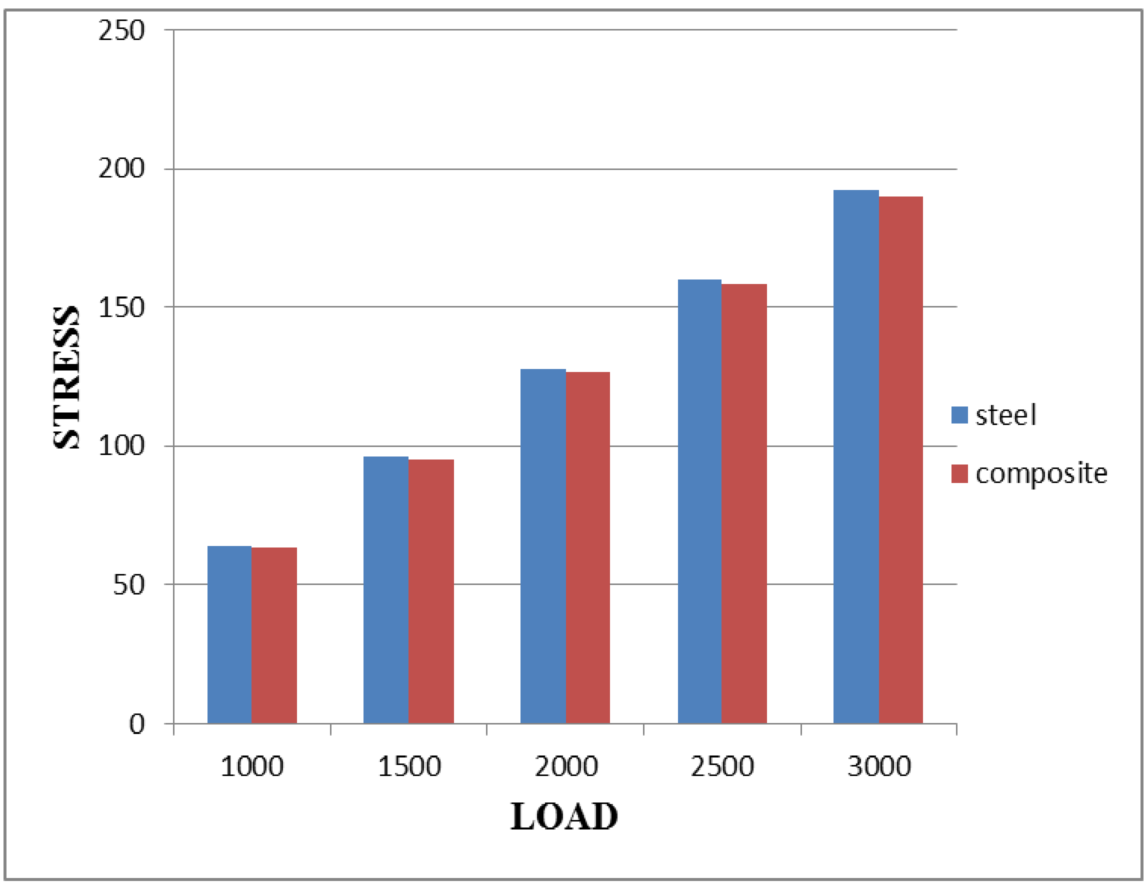
V. RESULT AND DISCUSSION

Result :

Table No .6 Comparison of stress analysis result in the steel and composite material

S.NO	Applied Load (Newton)	Steel	Composite	Difference (%)
1	1000	64	63.26	1.15
2	1500	96.01	94.89	1.16
3	2000	128.01	126.52	1.16
4	2500	160.02	158.15	1.17
5	3000	192.02	189.78	1.18



Discussion:

As we see the above result the stresses induced in composite material is lesser than the comparison of steel . To reduce more stress we increase the quantity of composite material with this composite material. The overall the main aim of this project is reduce the weight of the automobile vehicle without compromise its strength and capacity. By using this composite material weight of the leaf spring is reduce up to 80%. The composite material is suitable for best alternative of the conventional steel leaf spring.

VI FUTURE SCOPE

1. A prototype of Hybrid composite leaf spring can be prepared and after performing the test it can be compared with the analytical results.
2. Measurement of strain and stresses induced in the leaves can be done by using strain gauges and the experimental results could be used to optimally design the leaf spring using composite materials.
3. Modal analysis of the conventional steel and composite leaf spring using simulation or FEA can be done.
4. Effect of variable leaf thickness in the leaves can be studied in terms of maximum stress and deflection.
5. The effect of initial pre-stressing particularly of master leaf due to variation in the curvature (nipping) can also be studied using FEA.
6. The effect of added stresses from transverse forces and from twisting load (which is not considered in the present work) can also be studied by variation in the design of leaf spring such as selecting the master leaf of a superior material than, the rest of the spring.
7. The effect on material saving by reducing the factor of safety (which was taken as 2) can also be studied easily using FEA.
8. The effect of reduction in strength and endurance limit due to the center bolt hole can be studied during the simulation to achieve the results which closely match the experimental testing conditions.

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