International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 -6435 (Online)), Volume 15, Issue 5, May 2026)

Theoretical and Finite Element Analysis of Chain Sprocket Wheel of Two Wheeler

Rupesh Javale[1], Prof. Dr. A. S. Todkar[2]

[1]*M. Tech Scholar,* [2]*Faculty of Department of Mechanical Engineering, T.K.I.E.T, Warananagar, Kolhapur, Maharashtra, India.*

rupeshjavale23@gmail.com

***Abstract*— The chain sprocket wheel is a vital component in two-wheeler power transmission systems. During operation, fluctuating chain pull produces bending stress at the tooth root region, which may cause wear, fatigue, and tooth failure. In this study, stress analysis of a two-wheeler chain sprocket wheel was performed using theoretical calculations, experimental photoelasticity, and Finite Element Analysis (FEA). Lewis bending theory was used for theoretical stress evaluation, while stress freezing photoelasticity was adopted for experimental analysis. FEA was carried out in ANSYS Workbench to determine von-Mises stress and deformation using mild steel material under two loading conditions. The results obtained from theoretical, experimental, and FEA methods were compared, and maximum stress concentration was observed near the tooth root section. Good agreement among all methods confirmed the accuracy of finite element analysis for stress prediction in sprocket wheels.**

***Keywords*—Chain sprocket, Finite element analysis, Photoelasticity, Lewis equation, Stress analysis, ANSYS, Two-wheeler transmission.**

I. Introduction

A sprocket wheel is a toothed mechanical element used with roller chains for transmission of rotary motion and power. Sprockets are widely used in motorcycles, bicycles, conveyors and industrial machinery because of their positive drive characteristics and high transmission efficiency.

Fig. 1 Sprocket Wheel

In two-wheelers, the chain drive system transmits power from the gearbox output shaft to the rear wheel. During operation, the chain exerts tensile force on sprocket teeth resulting in bending stress at the tooth root region. Repeated cyclic loading may lead to tooth wear, stress concentration and fatigue failure.

Theoretical methods such as Lewis bending theory provide approximate values of bending stress. However, due to complex tooth geometry and dynamic loading conditions, more accurate methods such as Finite Element Analysis (FEA) and experimental stress analysis are necessary.

II. Literature Review

Several researchers have carried out analysis of sprocket wheels using theoretical, experimental and numerical methods.

- Ye Seul Lee et al. investigated analytical and finite element stress analysis of transmission sprockets.
- Parag Nikam et al. performed finite element analysis and optimization of sprocket wheels using ANSYS software.
- Kishor N. Naik et al. compared FEM and photoelastic stress analysis for gear tooth bending stresses.
- Aishwarya Shinde et al. conducted theoretical, experimental and ANSYS-based stress analysis of sprocket wheels.

The literature review indicates that maximum stress concentration occurs at the tooth root section and FEA is highly effective for stress prediction.

III. OBJECTIVES

1. To study chain sprocket mechanisms used in two-wheelers.
2. To calculate bending stress using Lewis equation.
3. To perform finite element analysis using ANSYS.
4. To conduct experimental stress analysis using 3D photoelasticity.
5. To compare theoretical, experimental and FEA results.

IV. THEORETICAL ANALYSIS

Lewis bending theory was used for determining bending stress developed in sprocket teeth.

Parameter	Value
Driver sprocket teeth	15
Driven sprocket teeth	42
Chain pitch	12.7 mm
Pitch circle diameter	170 mm
Service factor	1.2
Module	4.04 mm
Face width	8.51 mm

Table I Sprocket Specifications

Lewis Equation

$$\sigma_b = \frac{Pt}{m \times b \times Y}$$

Where:

- σb = Bending stress
- Pt = Chain tension
- m = Module
- b = Face width
- Y = Lewis form factor

➢ Material properties mild steel.

- Ultimate tensile stress = 655 MPa
- Yield stress = 415 MPa
- Poisson's ratio = 0.27-0.30
- Density =7850 kg/m^3
- Young's modulus = 190 - 210 GPa

○ **Case I**

1. Engine Power- 9.67 kW at 6500 rpm
2. 1^{st} Gear ratio- 13/36 = 0.361
3. Speed of driver Sprocket = 2347 rpm

○ **To find chain velocity (V)**

$$V = \frac{Z1 \times n1 \times p}{60 \times 10^3}$$

$$V = \frac{15 \times 2347 \times 12.715 \times 2347 \times 12.7}{60 \times 10^3 \quad 60 \times 10^3}$$

V = 7.45 m/s

❖ **To find kW rating of chain.**

$$\text{kW rating of chain (kW')} = \frac{(kW\ to\ be\ transmitted) \times Ks}{K1 \times K2}$$

$$= \frac{(9.67) \times 1.2}{1 \times 0.85}$$

kw rating of chain (kW') = 13.65 kW

❖ **To find out Chain Tension (Pt)**

$$Pt = \frac{(kW')1000}{V}$$

$$Pt = \frac{(13.65)1000}{7.45}$$

Pt = 1832.45 N

❖ **Bending Stress on tooth by Lewis equation**

$$\sigma_b = \frac{Pt}{m \times b \times Y}$$

$$\sigma_b = \frac{1832.45}{4.04 \times 8.51 \times 0.393}$$

σ_b = 135.62 N/mm^2

○ **Case II**

1. Engine Power- 12.5 kW at 8500 rpm
2. 5^{st} Gear ratio = 26/24 = 1.08
3. Speed of driven Sprocket = 9180 rpm

❖ **To find chain velocity (V)**

$$V = \frac{Z1 \times n1 \times p}{60 \times 10^3}$$

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 -6435 (Online)), Volume 15, Issue 5, May 2026)

$$V = \frac{15\times9180\times12.715\times9180\times12.7}{60\times10^3 \qquad 60\times10^3}$$

V = 29.14 m/s

- **To find kW rating of chain.**

$$\text{kW rating of chain (kW')} = \frac{(kW\ to\ be\ transmitted)\times Ks}{K1\times K2}$$

$$= \frac{(12.5)\times1.2}{1\times0.85}$$

kW rating of chain (kW') = 17.64 kW

- **To find out Chain Tension (Pt)**

$$Pt = \frac{(kW')1000}{V}$$

$$Pt = \frac{(17.64)1000}{29.14}$$

Pt = 605.69 N

- **Bending Stress on tooth by Lewis equation**

$$\sigma_b = \frac{Pt}{m\times b\times Y}$$

$$\sigma_b = \frac{605.59}{4.04\times8.51\times0.393}$$

σ_b = 44.82 N/mm^2

Case	Chain Tension (N)	Bending Stress (MPa)
Case I	1832.45	135.62
Case II	605.69	44.82

Table II Theoretical Result

The theoretical analysis indicates that the sprocket wheel is safe under operating conditions.

V. Experimental Analysis

Experimental stress analysis was performed using three-dimensional photoelasticity with stress freezing technique.

The photoelastic model was prepared using Araldite CY-230 resin and HY-951 hardener. The stress freezing process involved application of load, heating above critical temperature, controlled cooling under load and slicing of the model.

5.1 The prepared mould contains a negative impression of the sprocket wheel.

Fig 2 Rubber Mould

5.2 The final model accurately represents the sprocket geometry used in actual applications.

Fig 3 Casting

5.3 The load is applied gradually to avoid sudden shock on the brittle photoelastic model and placed in stress freezing oven.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 -6435 (Online)), Volume 15, Issue 5, May 2026)

Fig 4 Load Applied over Sprocket and placed in stress freezing oven.

5.4 The model is removed from the oven and thin slices are cut at critical locations.

5.4 The equipment shown in below figure is Polariscope which can be used after stress freezing process take place.

Fig. 5 Polariscope

5.5 Fringes can visible under polariscope in monochromatic light

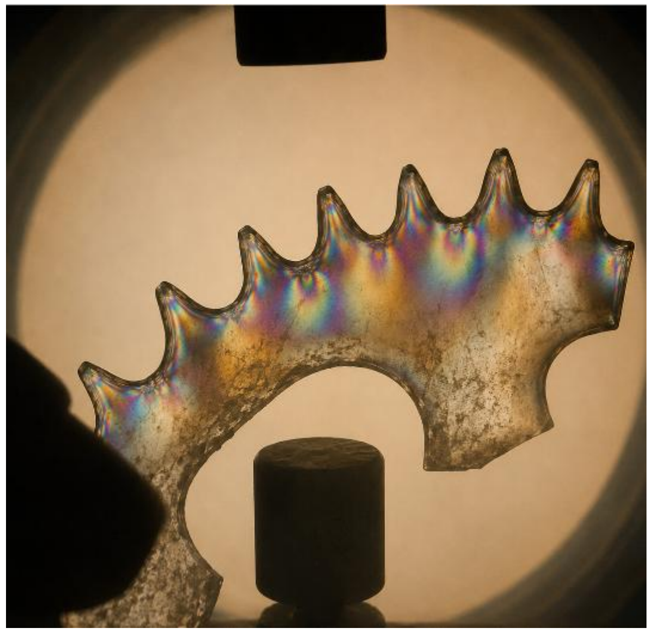

Fig 6 Isochromatic fringe pattern at toot root

The material fringe value of this Photoelastic material is 0.37 N/mm.

5.6 Stress on Photoelastic Model

The fringe order for the photoelastic sprocket model was determined experimentally using the circular polariscope arrangement. The maximum fringe concentration was observed near the tooth root section, indicating maximum bending stress in that region.

Specimen Calculation for Case II

The fringe order was evaluated using Tardy compensation method.

Fringe order is given by:

$$N_f = N + \frac{\theta}{180}$$

Where,

N = Fringe order of the nearest fringe with respect to the point of interest = 5

θ = Angle through which the analyzer is rotated so that the nearest fringe passes through the selected point = 54°

Substituting these values,

$$N_f = 5 + \frac{54}{180}$$

$$N_f = 5 + 0.30$$

$$N_f = 5.30$$

Therefore, the fractional fringe order at the point of interest is obtained as:

$$N_f = 5.30$$

The material fringe value is: F_σ = 0.37 N/mm

The slice thickness of the model is: h = 2 mm

Stresses developed in the slice are given by:

$$\sigma_1 - \sigma_2 = \frac{N_f \times F_\sigma}{h}$$

Where,

σ_1, σ_2 = Maximum and Minimum Principal Stresses

N_f = Precise fringe order measured at the point of interest = 5.30

F_σ = Material fringe value = 0.37 N/mm

h = Slice thickness = 2 mm

As σ_2 is equal to zero at the boundary and σ_1 is equal to bending stress,

Therefore,

Bending stress generated in the model:

$$\sigma_m = \frac{5.30 \times 0.37}{2}$$

$$\sigma_m = 0.981 \text{ N/mm}^2$$

Hence,

Bending Stress Developed in the Photoelastic Model: σ_m= 0.981 N/mm²

i) Scaling Model to Prototype

The stresses were scaled from the model to the prototype using the following relation:

$$\sigma_p = \sigma_m \times \left(\frac{T_p}{T_m} \times \frac{h_m}{h_p} \times \frac{L_m}{L_p}\right) \text{ ....Eqn. No. 5.3}$$

T_p = the torque acting on the prototype.

T_m = the torque applied to the model.

σ_p = stress developed in the prototype.

σ_m = stress developed in the model.

As model and prototype have same dimensions.

$L_m = L_p$ and $h_m = h_p$

Therefore, the equation reduces to:

$$\sigma_p = \sigma_b \times \left(\frac{T_p}{T_m}\right)$$

We have,

Torque on Prototype (T_p) = 51425 N-mm

Torque on Model (T_m) = 1.5 × 9.81 × 85

T_m = 1251 N-mm

Substituting values,

$$\sigma_p = 0.981 \times \left(\frac{51425}{1251}\right)$$

$$\sigma_p = 40.35 \text{ N/mm}^2$$

Therefore,

Bending stress at root of sprocket tooth:

$\sigma_p = 40.35 \text{ N/mm}^2$

The experimentally obtained prototype stress was approximately 40.35 MPa.

VI. FINITE ELEMENT ANALYSIS

Finite Element Analysis was carried out using ANSYS Workbench software.

Property	Value
Material	Mild Steel
Young's Modulus	200 GPa
Poisson's Ratio	0.3
Density	7850 kg/m³
Yield Strength	415 MPa

Table III Material Properties

FEFEA Procedure

1. CAD model creation in CATIA
2. Import into ANSYS Workbench
3. Meshing using tetrahedral elements
4. Boundary condition application
5. Load application
6. Solution and post-processing

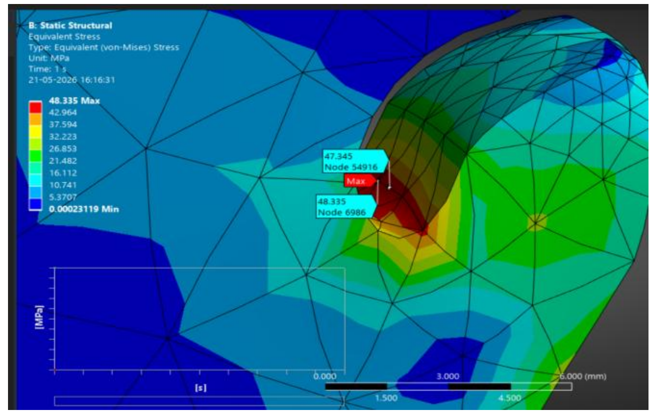

Fig 7 Case II Stress result over Sprocket Teeth.

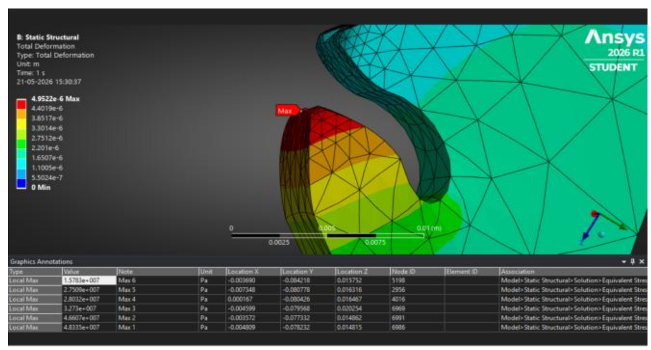

Fig 8 Defromation

The results obtained from ANSYS analysis are summarized below.

Parameter	Case I	Case II
Applied Load	1832.45 N	605.69 N
Maximum Von-Mises Stress	131.35	48.34 N/mm²
Maximum Deformation	0.01345 mm	0.00495 mm
Critical Region	Tooth Root	Tooth Root

Table IV Finite Element Analysis Result.

VII. RESULTS AND DISCUSSION

Method	Case I Stress (MPa)	Case II Stress (MPa)

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 -6435 (Online)), Volume 15, Issue 5, May 2026)

Method	Case I Stress (MPa)	Case II Stress (MPa)
Theoretical	135.62	44.82
Experimental	—	40.35
FEA	13135	48.34

Table V Comparison Table

The finite element results closely matched the experimental and theoretical values. Maximum stress concentration occurred at the tooth root section in all methods.

VIII. Conclusion

1. Maximum stress concentration occurs at the tooth root section of the sprocket wheel.
2. Lewis equation provides reasonable estimation of bending stress.
3. Finite element analysis accurately predicts stress distribution and deformation.
4. Experimental photoelasticity successfully validates FEA results.
5. The sprocket wheel made of mild steel is safe under operating conditions.

IX. Future Scope

1. Dynamic analysis of sprocket wheel can be performed.
2. Fatigue analysis under cyclic loading can be carried out.
3. Composite materials may be investigated for weight reduction.
4. Topology optimization can be used for improved design.
5. Wear and thermal analysis may be included in future work.

References

[1] Ye-Seul Lee, Mohammod Ali, Md Nafiul, Islam,Kamal Rasool, Bo-Eun Jan, Md Shaha Nur Kabir ,Tae-Kyung Kang & Sun-Ok Chung paper on "*Theoretical Analysis of Bending Stresses to Design a Sprocket for Transportation Part of a Chinese Cabbage Collector*", Journal of Bio-systems Engineering Print ISSN 1738-1266 May 2020

[2] Parag Nikam and Rahul Tanpure, "*Design Optimization of Chain Sprocket Using Finite Element Analysis*", Int. Journal of Engineering Research and Application, ISSN: 2248-9622, Vol. 6, Issue 9, (Part-5) September 2016, pp.66-69.

[3] R. S. Dwyer-Joyce, R. Lewis, A. Ward, E.A. Patterson. "*Determination of Impact Stresses in an Automotive Chain Drive Component*" SAE Technical Paper April 2006.

[4] Kishor N. Naik and Dhananjay R Dolas, "*Static Analysis of Bending Stresses on Spur Gear Tooth Profile by using Finite Element Analysis & Photo Elastic*" Technique International Journal of Current Engineering and Technology P-ISSN 2347 – 5161 Vol.6, No.1 Feb 2016 pp 284-288

[5] Ronak Suthar "*Analysis of Sprocket Strength Finite Element Analysis Method*" International Journal of Advanced in Management, Technology and Engineering Sciences ISSN NO: 2249-7455 Volume 7, Issue 12, 2017 pp 109-119.

[6] M.Lohith Srikrishna Varma, I.Rama Pavan Kumar Varma, M.Hari Krishnam Raju "*Design And Analysis Of Chain Sprocket Using Different Method*" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-1S3, June 2019 pp 248-253.

[7] Abhishek burua and samitra kaur Review on "*Design Optimization of Sprocket Wheel Using Different Techniques*" International Journal of Advanced Mechanical Engineering. ISSN 2250-3234 Volume 8, Number 1 2018, pp. 55-62.

[8] Prashant Patil, Narayan Dharashiwkar, Krishnakumar Joshi, Mahesh Jadhav "*3d Photoelastic and Finite Element Analysis of Helical Gear*" machine design, Vol.3 2011 No.2, ISSN 1821-1259 pp. 115-120.

[9] Design of Machine Element by V. B. Bhandari Mc Graw Hill Publiation