



# DESIGN AND DEVELOPMENT OF AN ERGONOMIC BULLOCK CART YOKE USING CAD MODELLING AND FINITE ELEMENT ANALYSIS

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**Abstract:** Bullock carts remain an important mode of transportation and agricultural operation in rural regions, where the yoke serves as a key component for transmitting pulling forces from animals to the cart. Conventional yoke designs often suffer from improper load distribution, reduced durability and discomfort to animals due to non-optimized geometry and material selection. The present study focuses on the design and development of an improved bullock cart yoke using computer-aided design and engineering analysis techniques. A three-dimensional model was developed using SolidWorks considering ergonomic and structural requirements. Finite Element Analysis was performed in ANSYS to evaluate stress distribution, deformation behaviour and structural performance under working load conditions. The proposed design demonstrates improved load transfer characteristics, reduced stress concentration and enhanced durability compared to traditional designs. The developed yoke provides better operational efficiency and improved comfort while maintaining cost effectiveness suitable for rural applications. The study highlights the application of modern engineering design tools in optimizing traditional agricultural equipment.

**Keywords:** Bullock Cart, Yoke Design, Solidworks, Finite Element Analysis, Structural Optimization, Mechanical Design.

## I. INTRODUCTION

Bullock carts continue to serve as an important means of transportation and agricultural support in rural regions where animal-powered systems remain economically viable. The yoke acts as a critical mechanical component that connects the animals to the cart and enables effective transmission of pulling forces during operation. Conventional yoke designs, typically made from wood using traditional practices, have remained largely unchanged for decades despite variations in operational requirements and working conditions.

Traditional yokes often suffer from limitations such as uneven load distribution, excessive localized stresses and inadequate ergonomic consideration, which may lead to discomfort, fatigue and potential injury to the animals. In addition, material degradation and structural wear reduce service life and overall efficiency of the transportation system. These limitations highlight the need for engineering-based design improvements that enhance both structural performance and animal welfare.

With the advancement of computer-aided design and analysis tools, traditional agricultural equipment can be optimized using modern engineering approaches. CAD modelling enables accurate geometric representation, while finite element analysis provides insight into stress behaviour, deformation characteristics and safety performance under working loads without the necessity of physical prototyping.

The objective of this study is to design and develop an improved bullock cart yoke incorporating ergonomic considerations, suitable material selection and structural optimization. The proposed design is developed using SolidWorks and evaluated through ANSYS-based finite element analysis to assess mechanical performance and load-carrying capability. The work aims to improve durability, operational efficiency and animal comfort while maintaining a practical design suitable for rural applications.



## II. LITERATURE REVIEW

### A. Bullock Cart Locking System in Reverse Direction

Pondkule S.M. et al. (2023) developed a mechanical locking system to prevent backward movement of bullock carts on inclined surfaces. Traditional carts require animals to exert continuous effort to hold loads on slopes, leading to fatigue and neck strain. The proposed mechanism automatically locks the cart during reverse motion, improving stability and reducing animal effort. Experimental evaluation showed enhanced safety, better load control, and improved operational efficiency. The study highlights the importance of integrating simple mechanical innovations to improve animal welfare and rural transportation systems.

### B. Design Optimization of Bullock Cart Yoke

Mahesh M. Hombalmath et al. (2021) conducted a design optimization study of a bullock cart yoke to reduce stress concentration on the bullock's neck and shoulders. The research utilized modeling and finite element analysis to achieve improved load distribution and enhanced structural performance. The optimized yoke design minimized localized pressure points, thereby improving animal comfort, pulling efficiency, and durability of the cart system. The study highlights the application of engineering design principles to traditional agricultural equipment for achieving improved efficiency and animal welfare.

### C. Modified Bullock Cart Design

Rushabh A. Chilatre et al. (2018) reviewed various design modifications and technological advancements in traditional bullock cart systems aimed at improving operational efficiency and usability. The study analyzed structural improvements, material enhancements and mechanical innovations focused on better load distribution, durability and animal comfort. The findings emphasized the importance of integrating modern engineering concepts with traditional cart designs to achieve safer, efficient and sustainable rural transportation systems.

### D. Draftability and Enhanced Utilization of Small Bullocks

M.K. Ghosal et al. (2015) conducted an experimental study to evaluate the draft performance and operational efficiency of an improved steel bullock cart design. The research compared cart performance with and without a rubber liner on the wheels to analyze traction characteristics, vibration behavior and load distribution. Results indicated that the modified design improved ride smoothness, stability and animal comfort while enhancing overall transportation efficiency. The study demonstrated that structural modifications and wheel improvements play an important role in optimizing bullock cart performance under rural operating conditions.

### E. Fabrication of Lightweight Farm Yoke Using Composite Materials

V.K. Singh et al. (2012) investigated the fabrication and performance evaluation of a lightweight bullock cart yoke developed using composite materials such as resin, silica, jute fiber and glass wool. The study compared the composite yoke with a conventional wooden yoke by analyzing stress, strain and deformation under operational loading conditions equivalent to a portion of the bullock's body weight. Results indicated improved strength-to-weight ratio, better load distribution and reduced stress concentration on the animal's neck. The research demonstrated the potential of composite materials in developing lightweight, durable and ergonomically efficient agricultural equipment.

## III. PROBLEM DEFINITION AND PROPOSED METHODOLOGY

Traditional bullock cart yokes are generally manufactured using rigid wooden structures that directly rest on the bullock's neck. Such designs result in uneven load distribution and high stress concentration, leading to animal discomfort, fatigue, and reduced working efficiency. The absence of any shock absorbing mechanism further increases vibration transmission during operation on uneven rural terrains.

The primary problem identified in the existing system is excessive compressive stress acting on the bullock's neck due to rigid contact between the yoke and the animal. This study aims to minimize stress transmission while maintaining the structural strength required for heavy load transportation.

To address this issue, a redesigned bullock cart yoke is proposed. The modification involves reducing the neck resting portion of the yoke and introducing a single spring element to act as a shock absorber. The spring compresses under load, thereby distributing forces more uniformly and reducing direct stress on the bullock.

The proposed methodology includes CAD modelling using SolidWorks, followed by static structural analysis using ANSYS to evaluate deformation, stress distribution, and strain behavior under an applied load of 3 tons.



#### IV. DESIGN AND MODELLING

The design of the bullock cart yoke was developed with the objective of reducing stress concentration on the bullock's neck while maintaining sufficient structural strength for load carrying applications. The traditional wooden yoke design was studied and modified to improve ergonomics and load distribution.

The redesigned yoke incorporates a reduced neck resting surface to minimize direct contact pressure on the animal. A single spring mechanism was introduced between the yoke and the cart assembly to act as a shock absorbing element. This modification allows controlled compression under load, thereby reducing impact forces transmitted to the bullock during operation.

The complete three-dimensional model of the yoke assembly was created using SolidWorks software. Individual components such as the wooden beam, fastening elements, and spring arrangement were modeled and assembled to obtain the final configuration. Proper dimensional constraints and assembly relations were applied to simulate realistic working conditions.

Material properties corresponding to traditional wood and spring steel were assigned to ensure accurate structural behavior during analysis. The finalized CAD model was then exported to ANSYS Workbench for further finite element analysis.



Fig. 1: Traditional Bullock Cart



Fig. 2: Proposed Design Bullock Cart

#### V. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) was performed to evaluate the structural performance of the redesigned bullock cart yoke under working conditions. The CAD model developed in SolidWorks was imported into ANSYS Workbench for static structural analysis.

Material properties were assigned to represent wooden components and spring steel elements. Appropriate boundary conditions were applied by fixing the cart connection points while applying an external load equivalent to 3 tons representing the operational load acting on the bullock cart.

Meshing of the model was carried out using suitable element sizing to obtain accurate stress and deformation results. Static structural analysis was conducted to determine total deformation, equivalent (von-Mises) stress distribution, and strain behavior of the redesigned yoke.

The analysis aimed to compare stress distribution and structural response to ensure reduced stress transmission toward the bullock's neck while maintaining adequate strength and stability.

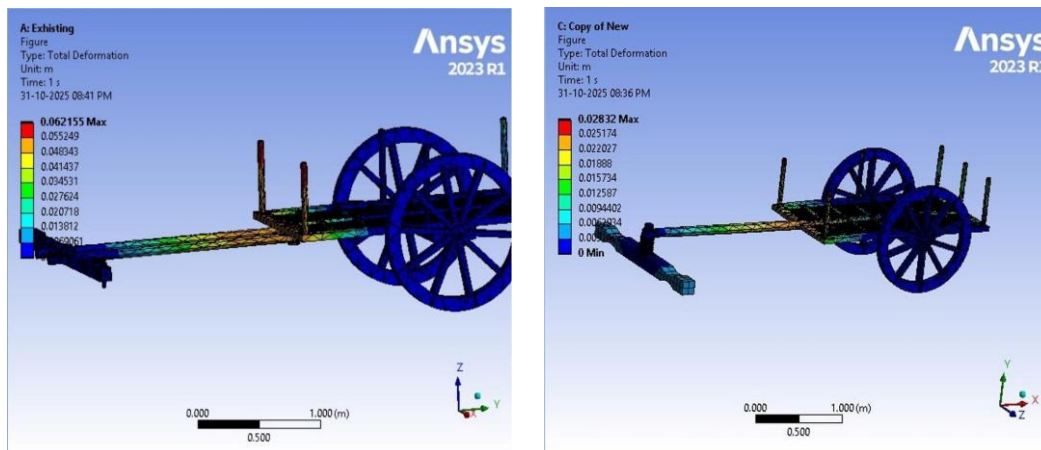


Fig. 3: Ansys analysis on Traditional bullock cart Fig. 4: Ansys analysis on New proposed bullock cart

## VI. RESULT AND DISCUSSION

The performance of the redesigned bullock cart yoke was evaluated using analytical calculations and finite element analysis performed in ANSYS software. The objective was to compare stress distribution, deformation behaviour, and load transfer characteristics between the traditional yoke and the proposed spring-assisted yoke design.

### A. Stress Validation Using ANSYS

Manual stress calculations using the Von Mises criterion resulted in an equivalent stress of approximately  $1.38 \times 10^5$  N/m<sup>2</sup>, whereas ANSYS simulation produced a maximum stress value of  $1.65 \times 10^5$  N/m<sup>2</sup>.

The close agreement between analytical and simulation results validates the accuracy of the proposed design methodology.

### B. Traditional Yoke Performance

Simulation results of the conventional wooden yoke revealed: ●

- Maximum deformation: 0.062 m
- High stress concentration at neck contact region
- Direct transmission of vibration and shock loads
- Uneven load distribution

These observations indicate that the traditional design transfers the pulling force directly to the bullock's neck, leading to discomfort, fatigue, and potential structural failure during prolonged operation.

### C. Proposed Improved Yoke Performance

The redesigned yoke incorporating a compression spring demonstrated significant improvements:

- Maximum deformation reduced to 0.028 m
- Deformation reduced by more than 50%
- Stress shifted away from neck region toward spring assembly
- Improved vibration absorption and smoother motion

The spring mechanism absorbs shocks generated by uneven terrain, preventing sudden load transfer to the bullock and improving operational stability.

### D. Load Application Analysis

A pulling force of 3600 N was applied in the forward direction to simulate real working conditions. The analysis confirmed that:

- Tensile and bending stresses developed within safe limits.
- The compression spring effectively reduced peak stresses.
- Load distribution became more uniform compared to the traditional design.



## E. Comparative Discussion

SR NO.	Parameter	Traditional Yoke	Improved Yoke
1	Stress Concentration	High at Neck	Reduced
2	Deformation	High	Reduced
3	Shock Absorption	Absent	Present
4	Animal Comfort	Low	High
5	Stability	Moderate	Improved

## VII. CONCLUSION

The redesigned bullock cart yoke developed in this study demonstrates significant improvement over conventional wooden yokes in terms of load distribution, structural performance, and animal comfort. The modified design ensures balanced transmission of load between the cart and the bullocks, thereby reducing stress concentration on the neck region and minimizing animal fatigue during prolonged operation.

The introduction of a circular curved neck-contact section with cushioned padding effectively reduces friction and prevents injury, providing improved ergonomic support. Additionally, the incorporation of a centrally positioned spring mechanism acts as a shock absorber, enabling uniform load distribution and reducing sudden impact forces acting on the bullock's neck.

Finite Element Analysis confirmed that the redesigned yoke can safely withstand the applied load condition of 3 tons while maintaining structural stability and acceptable stress levels. Although the fabrication cost is slightly higher than traditional designs, the improved durability, reduced maintenance requirements, enhanced operational efficiency, and better animal welfare make the proposed yoke a sustainable and cost-effective solution for rural transportation and agricultural applications.

Overall, the proposed design successfully integrates traditional utility with modern engineering principles, contributing toward safer, efficient, and animal-friendly bullock cart systems.

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