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Design and Analysis of Corrugated Box Elevetor System

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Abstract: In today's fast-moving manufacturing and logistics environment, efficient material handling plays a key role in improving productivity and maintaining workplace safety. Corrugated boxes are widely used for packaging and storage because they are lightweight, economical, and recyclable. However, manual handling of these boxes, especially when vertical movement between floors is required, leads to low efficiency, higher labor dependency, and increased risk of injuries , this project presents the design and analysis of a corrugated box elevator system developed to transport corrugated boxes vertically in a safe, reliable, and cost-effective manner. The system is designed by carefully considering industrial requirements such as load capacity, lifting height, speed of operation, space limitations, and safety. Major components including the supporting frame, lifting platform, guide rails, drive mechanism, motor, and transmission system are designed using standard mechanical engineering principles, all components are modeled and assembled using SolidWorks software. Structural analysis is carried out using SolidWorks Simulation to study stresses, displacements, and factor of safety under maximum loading conditions. The analysis results show that the elevator system is structurally safe and suitable for industrial use. The proposed design reduces manual effort, improves material handling efficiency, and enhances operational safety, making it ideal for small and medium scale industries.

I. INTRODUCTION

Material handling equipment plays a major role in modern industrial operations by improving productivity, reducing manual labour, and ensuring safe transportation of materials. In industries such as packaging, warehousing, logistics, food processing, pharmaceutical, and e-commerce sectors, corrugated boxes are widely used for storage, packaging, and transportation of products. Due to the rapid growth of industrial automation and mass production systems, efficient handling of corrugated boxes has become essential for improving operational efficiency and reducing processing time. Traditionally, corrugated boxes are lifted and transferred manually from one floor level to another. Manual material handling requires more labor effort, increases operational cost, reduces productivity, and may lead to workplace accidents, fatigue, and material damage. Continuous manual lifting also creates ergonomic problems for workers and affects the overall efficiency of industrial operations. Therefore, industries are increasingly adopting automated material handling systems to improve safety, reduce human effort, and achieve faster transpo rtation of materials. A corrugated box elevator system is a mechanical lifting arrangement designed to transport corrugated boxes vertically between different levels safely and efficiently. The system helps industries automate the movement of boxes with smooth operation and minimum manual intervention. The elevator system mainly consists of structural frame members, lifting platform, guide rails, shafts, bearings, electric motor, gearbox, chain and sprocket drive mechanisms, and supporting components. Proper design of these components is necessary to ensure safe operation, load carrying capacity, structural stability, and long service life. The present project focuses on the design and analysis of a corrugated box elevator system suitable for industrial material handling applications. The main objective of the project is to design a compact, economical, and structurally safe elevator system capable of transporting corrugated boxes with reduced vibration and smooth vertical movement. Mild steel is selected as the primary material for the frame and structural members because of its good mechanical strength, weldability, availability, low manufacturing cost, and ease of fabrication. The design process includes load calculations, shaft design, motor power calculation, torque calculation, and selection of suitable transmission components. The complete system is modeled using SolidWorks software to develop accurate 3D CAD models and assemblies. Structural analysis is carried out using SolidWorks Simulation to evaluate stress distribution, deformation, and factor of safety under working load conditions. Finite Element Analysis (FEA) helps in validating the structural safety and reliability of the system before fabrication. The developed corrugated box elevator system offers several advantages such as reduction in manual handling effort, increased productivity, improved workplace safety, reduced material damage, compact structure, low maintenance requirements, and efficient material transportation. The system can be effectively used in packaging industries, warehouses, logistics centers, distribution units, manufacturing plants, and automated storage systems.

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1.1. Problem Statement:

In many industries, corrugated boxes are transported manually from one level to another. Manual handling increases labor cost, causes material damage, reduces productivity, and may lead to worker fatigue and accidents.
Existing lifting systems are often expensive, bulky, and consume high power. Improper design may also lead to vibration, instability, and unsafe operation.
Therefore, there is a need to design a safe, economical, and efficient corrugated box elevator system that can:
1) Reduce manual handling effort
2) Improve productivity
3) Ensure safe transportation of boxes
4) Minimize vibration and instability
5) Reduce operational cost

1.2. Objective

The objectives of the project are:
To design a corrugated box elevator system for industrial applications.
1. To reduce manual effort in material handling.
2.To ensure smooth and safe lifting operation.
3. To select suitable materials and components.
4. To perform structural analysis using SolidWorks Simulation.
5.To evaluate stress, deformation, and factor of safety.
6. To improve productivity and operational efficiency.

1.3 Scope:

The scope of the project includes the design, modeling, and analysis of a corrugated box elevator system used for vertical transportation of boxes. The scope covers:
1 Study of existing material handling systems.
2 Selection of suitable lifting mechanism.
3 Design calculations for load and power requirements.
4 Material selection for frame and structural components.
5 3DCADmodelingusingSolidWorks.
6 Structural analysis using simulation tools.
7 Assembly and working analysis of the system.
8 Cost estimation and performance evaluation.

II. LITERATURE REVIEW

Material handling systems are essential in modern industries for improving productivity, reducing manual labor, and ensuring safe transportation of goods and materials. Among various material handling equipment, elevator systems and conveyor mechanisms are widely used in packaging, warehousing, logistics, and manufacturing industries for efficient vertical and horizontal transportation of materials. Corrugated boxes are commonly used for packaging applications because of their lightweight structure, low cost, and ability to protect products during storage and transportation. Due to the increasing demand for automation in industries, efficient corrugated box handling systems have become an important area of research and development.

Several researchers have studied elevator mechanisms and automated lifting systems to improve operational efficiency and reduce labor dependency. Studies show that automated box handling systems significantly improve productivity while reducing worker fatigue and workplace accidents. Properly designed elevator systems ensure smooth material flow, higher reliability, reduced downtime, and safe operation under varying load conditions.

Research on chain drive and belt drive lifting mechanisms indicates that chain-driven systems provide better load carrying capacity, durability, and positional accuracy for vertical lifting applications. Chain and sprocket arrangements are widely preferred in industrial elevators because they can withstand higher loads and provide slip-free power transmission compared to belt-driven systems. Researchers also emphasize the importance of proper guide rail alignment and platform balancing to minimize vibration and improve stability during operation.

Many studies focus on structural design and material selection for elevator frames and lifting platforms. Mild steel is commonly used due to its high strength, good weldability, low manufacturing cost, and easy availability. Researchers have shown that optimization of structural members can reduce overall system weight while maintaining adequate

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strength and safety. Proper selection of bearings, shafts, and transmission components improves operational life and reduces maintenance requirements.

Recent advancements in CAD and CAE technologies have improved the design and analysis process of material handling systems. Software such as SolidWorks and ANSYS are widely used for 3D modeling, motion analysis, and structural analysis of elevator systems. Finite Element Analysis (FEA) helps engineers evaluate stress distribution, deformation, and factor of safety before fabrication. Simulation-based analysis reduces design errors, improves reliability, and minimizes development cost and time.

Several research papers also highlight the use of automation and smart monitoring systems in industrial elevators. PLC-based control systems and IoT-enabled monitoring technologies are increasingly used for automatic operation, fault detection, overload protection, and predictive maintenance. These technologies improve system efficiency, operational safety, and real-time performance monitoring.

Studies on industrial safety emphasize the importance of designing lifting systems with proper safety factors, emergency stopping mechanisms, overload protection, and vibration control. Excessive vibration and improper alignment can lead to structural failure, noise generation, and reduced component life. Therefore, structural analysis and dynamic stability are critical aspects in elevator system design. Based on the literature review, it is observed that an efficient corrugated box elevator system should have:

1 High load carrying capacity Smooth and stable operation
2 Proper structural strength
3. Minimum vibration and deformation
4 Economical manufacturing cost
5 Reliable power transmission system
6 Safe working conditions

The present project focuses on the design and analysis of a corrugated box elevator system that fulfills these requirements. The system is designed to reduce manual handling effort, improve productivity, and ensure safe transportation of corrugated boxes in industrial environments. Structural analysis is carried out to validate the design under working load conditions and ensure reliable performance.

III. METHODOLOGY

The methodology followed in this project is divided into systematic steps to achieve the project objectives.

1. Problem Identification and Literature Study The industrial problem of excessive weight, high cost, and material wastage in existing elevator system was identified. A literature survey was conducted to understand conveyor design principles, material selection, and safety factors.
2. Material Selection Different materials were studied and compared based on strength, cost, weight, availability, and suitability for abrasive material handling. plain carbon steel was selected as an alternative to SS304 due to its lower cost and acceptable mechanical properties.
3. Design Calculations Design calculations were carried out for all major components of the corrugated Box elevator system, including plate thickness, width, length, and load conditions. Factor of safety was selected considering abrasive material transportation.
4. Cost and Weight Analysis Weight of the elevator system was calculated for both existing and modified designs. Material cost comparison was done to evaluate cost savings achieved through redesign.
5. 3D Modeling and Assembly All components of the box elevator system were modeled using SolidWorks. The complete assembly was created by properly constraining individual parts.
6. Structural Analysis Using SolidWorks Simulation Static structural analysis was performed on the assembly to determine stress and displacement under working loads. The results were compared with allowable limits to ensure safe operation.
7. Comparison and Validation The existing and modified designs were compared based on weight, cost, factor of safety, stress, and displacement. The final design was validated as safe and economical.
8. Documentation All design calculations, simulation results, comparisons, and conclusions were documented in the final project report.

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IV. NUMERICAL STUDY

SERVICE DATA ➤Material Handling Type: Corrugated Boxes
1. Maximum Load Capacity: 50 kg
2. Elevator Height: 3 m
3. Platform Size: 600 mm × 600 mm
4. Shaft Length: 2440 mm
5. Shaft Outside Diameter: 33 mm
6. Shaft Inside Diameter: 24.5 mm
7. Transmission System: Chain and Sprocket Drive
8. Motor Speed: 1440 RPM
9. Material Used: Mild Steel
10. Coefficient of Friction: 0.38
11. Pitch Value: 31 mm
12. Acceleration due to Gravity: 9.81 m/s2

Shaft Design Calculations

1. Uniformly Distributed Load

q=2.14 kg/m=21 N/m
L=2440 mm=2.44 m
For uniformly distributed load:
Ra+Rb=qL =21×2.44 =51.24 N
Since the loading is symmetrical: Ra=Rb*Ra
= Rb Ra=Rb= 51.24/2
Ra=Rb=26.52 N

2.Bending Moment Calculation Maximum bending moment for UDL:
$BM=qL^2/8$ $BM=21\times(2.44)^2/8$ BM=15.6282 Nm

3.Calculation Given: do=33 mm=0.033 m di=24.5 mm=0.0245 m π=3.142
The bending stress of the shaft was calculated using standard hollow shaft equations and was found within allowable safe limits for mild steel material.

4.Torque Calculation

T=1010.9353 Nm
Allowable shear stress according to ASME code:
τ=53×106 N/m2
Using torsional design equations, the required shaft diameter was obtained as: d=5.7912 cm
Therefore, the shaft is safe under torsional loading conditions.

5.Motor Power Calculations

➤ Capacity, Q = 0.8333 kg/s
➤ Conveyor Length, Lv = 2.44 m
➤ Vertical Height, H = 1.840 m
➤ Friction Coefficient Factor = 2.7
➤ Overloading Factor = 1.2

Power Required for Elevator System P=Q×g×(Lv×2.7+H)×1.2 P=0.8333×9.81×(2.44×2.7+1.84 0)×1.2 P=82.68 W
For safety purpose, selected motor power: P=90 W

6.Velocity Calculations

Given: S=31mm=0.031 Velocity equation: V=S×π V=0.031×3.142 V=0.09740m/s
Driving Force Calculations
Material Weight Calculation: qm=8.56×2.44
qm=20.88
kgqm = 20.88 \ kgqm=20.88 kg
Driving Force Calculation
Calculated driving force:
F0′=136.57N Angular force:F0=0.04198 N Condition for safe operation:
F0′>F0 136.57>0.0419
Therefore, the corrugated box elevator system operates safely under working conditions.

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Final Results

Parameter	Value
Maximum Load Capacity	50 kg
Shaft Length	2440 mm
Shaft Diameter	5.7912 cm
Motor Power	90 W

Parameter	Value
Elevator Velocity	0.0974 m/s
Maximum Driving Force	136.57 N
Material Used	Mild Steel
System Condition	Safe

V. SOLIDWORK PARTS MODELING OF ELEVATOR SYSTEM.

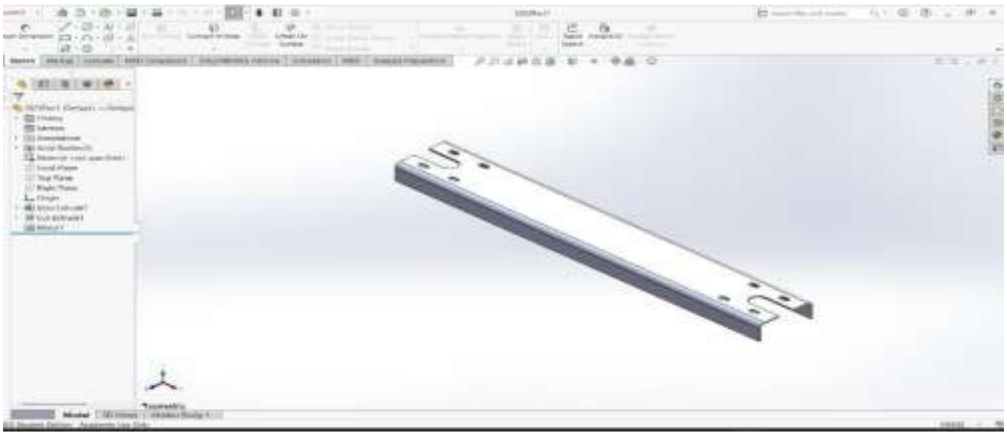

Fig.4.1.Linear Support

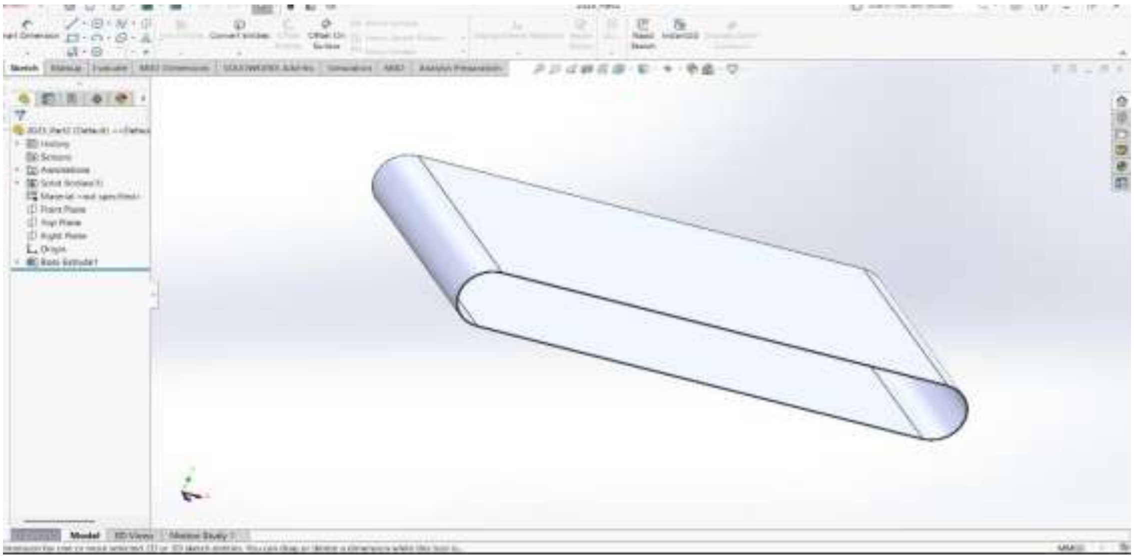

Fig 4.2.Support Plate

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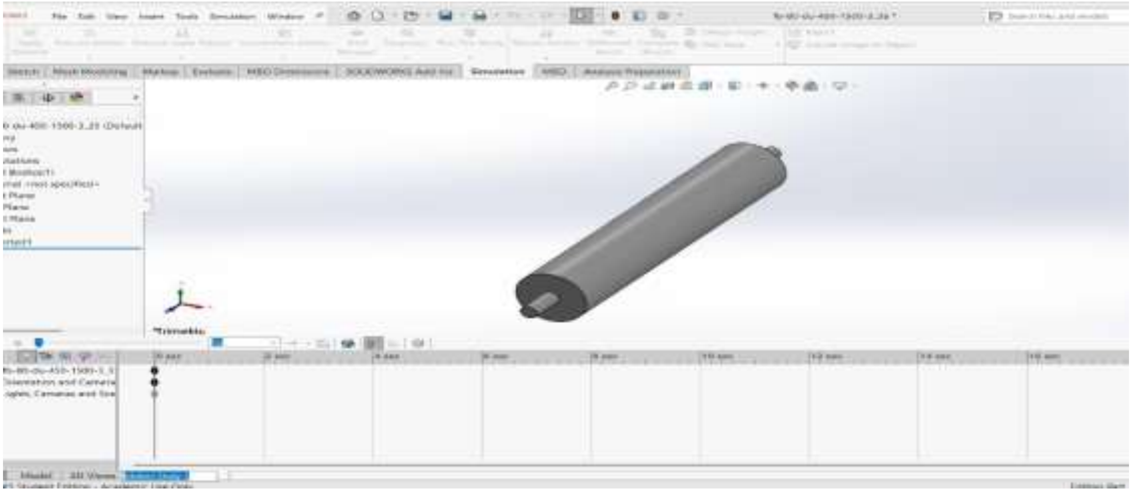

Fig 4.3 Roller Support

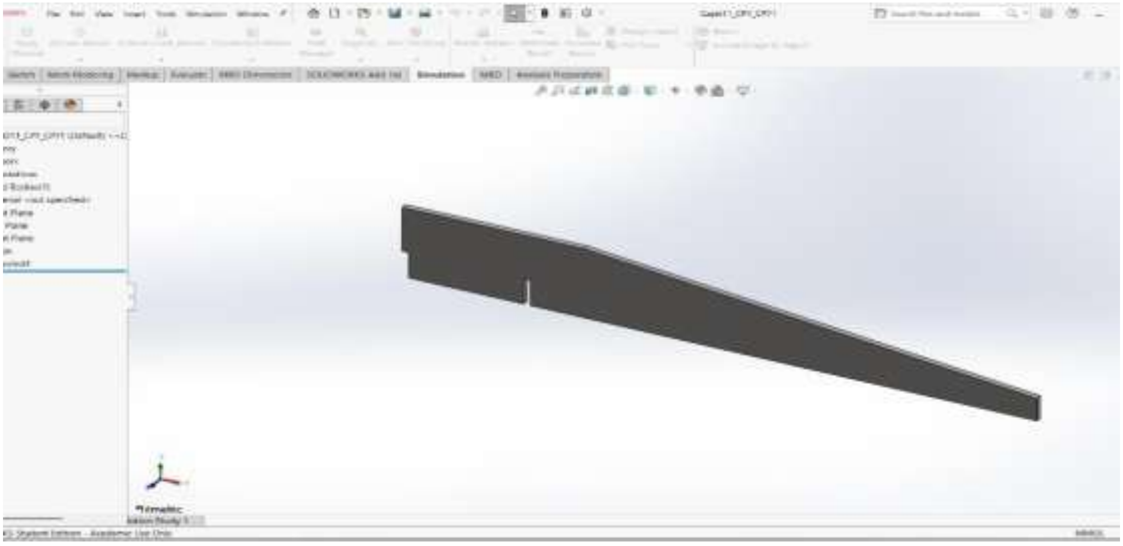

Fig 4.4 side plate

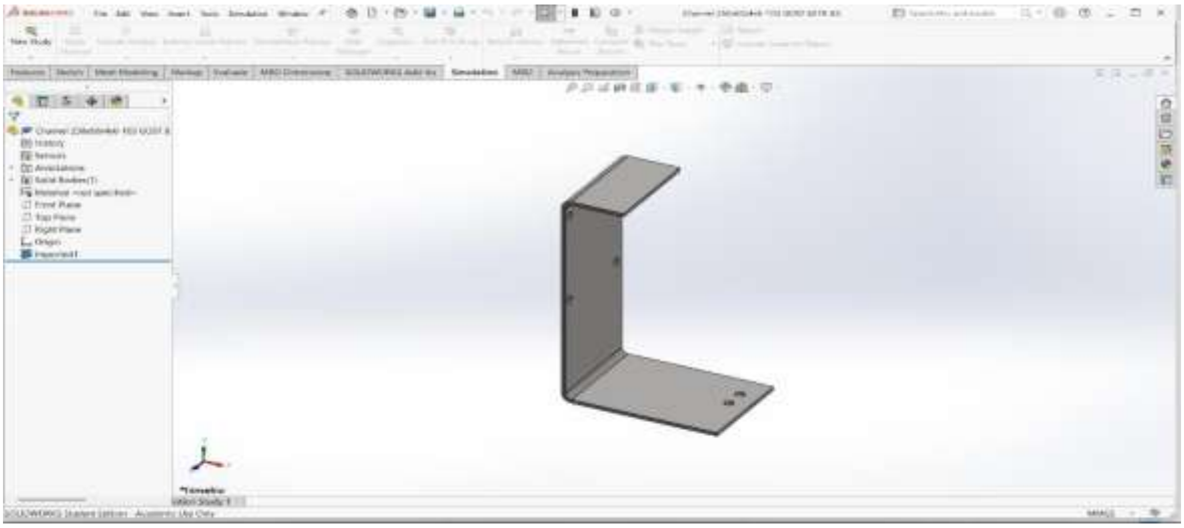

Fig 4.5 support bracket.

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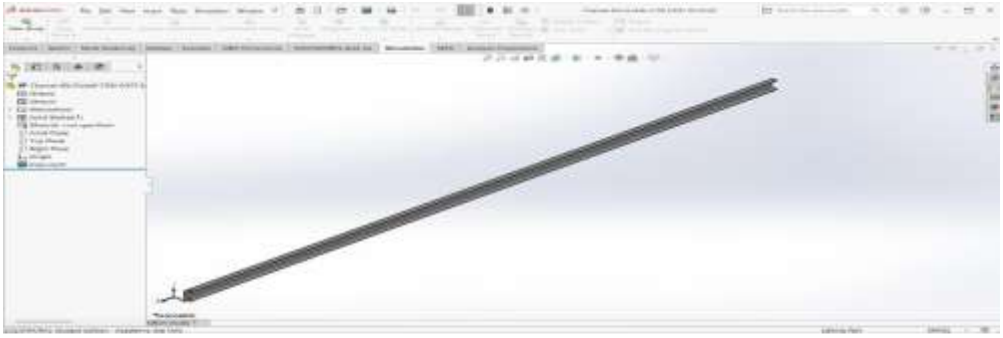


Fig 4.6 support channel.

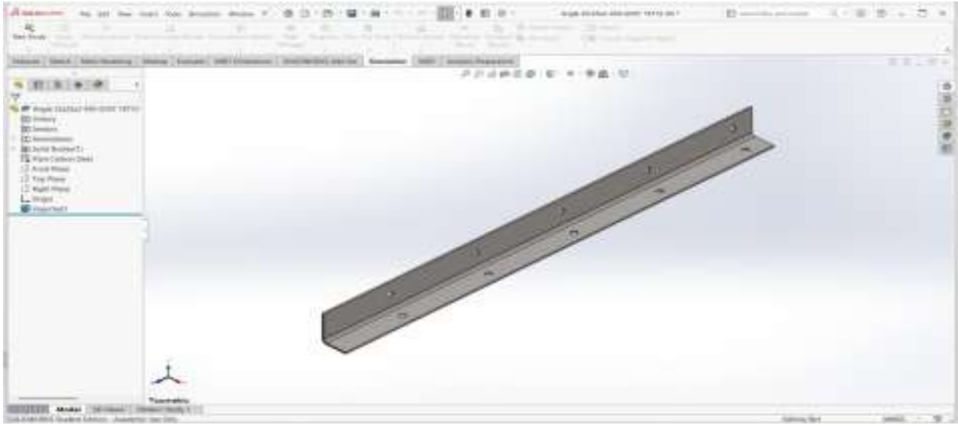
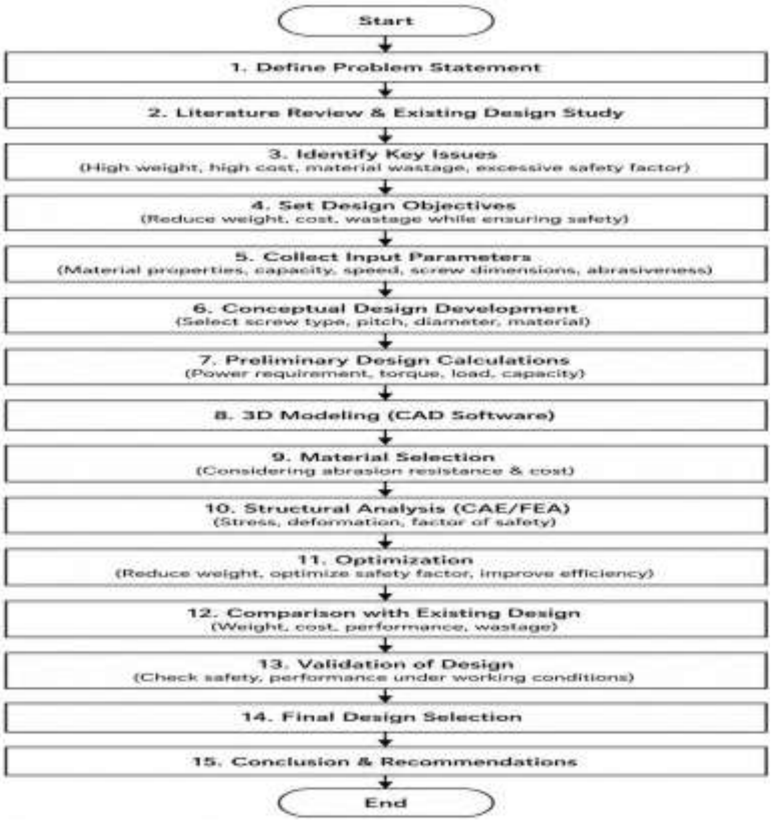


Fig 4.7 L type support

VI. WORKING FLOW CHART



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VII. ANALYSIS OF BASE PLATE AND ROLLER SUPPORT

1.Base Plate

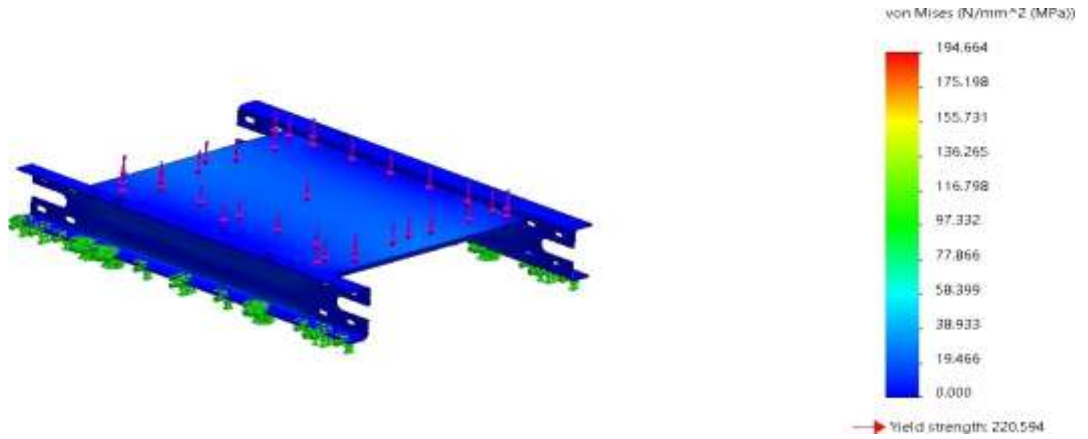

Fig 6.1 Yield strength analysis of base plate .

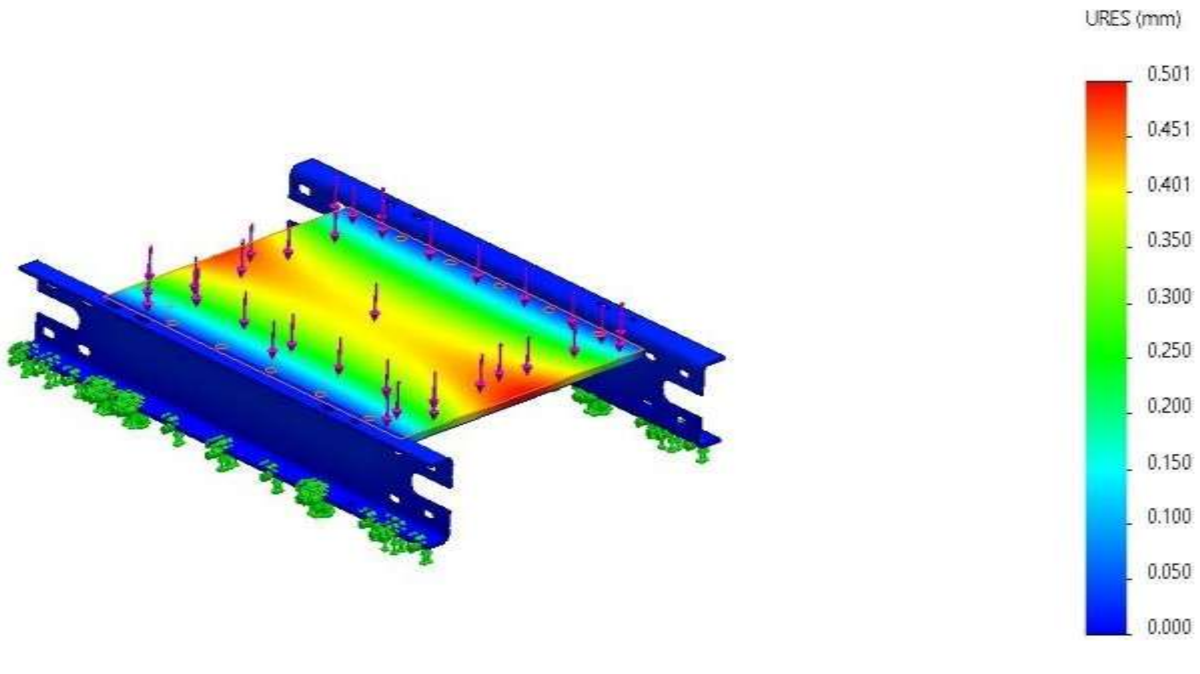

Fig 6.2 Stress analysis of base plate.

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1. Roller support

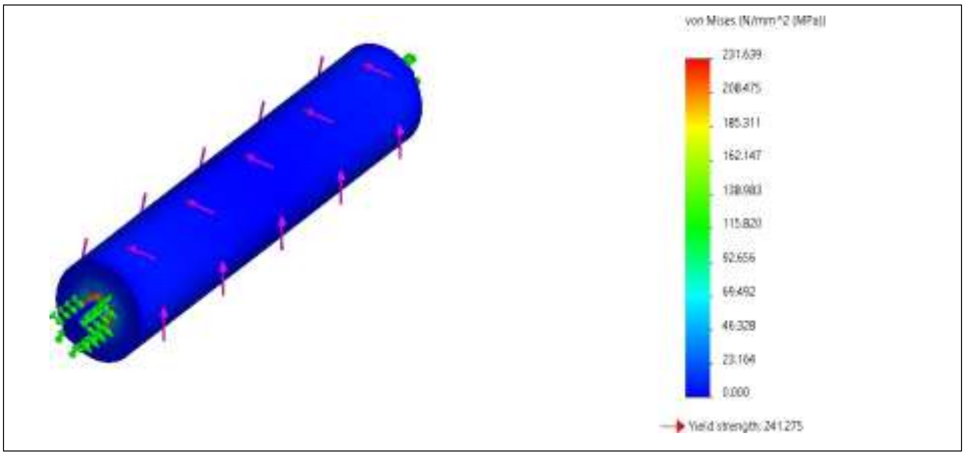

Fig 6.3 Yield strength analysis of roller support.

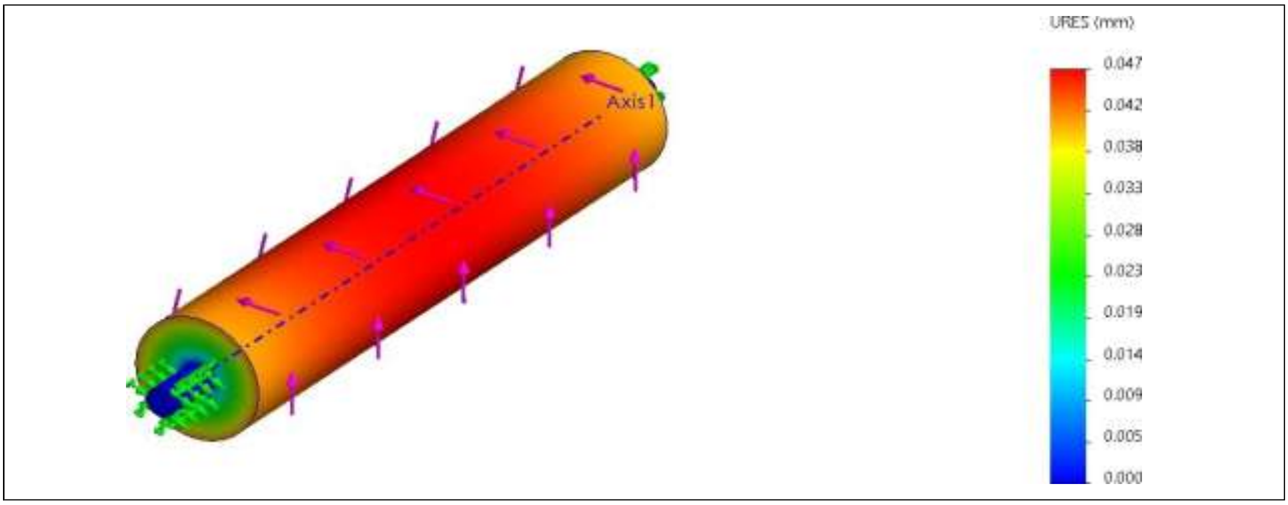

Fig 6.4 Strength analysis of roller support.

VIII. RESULT TABLE

Initial Design		Final Design	
Material	SS304	Material	Plain Carbon Steel
Weight	42kg	Weight	26kg
Material Cost	350Rs./kg	Material Cost	290Rs./kg
Total Cost	14700Rs	Total Cost	2400 Rs
F.O.S	3.5	F.O.S	1.2

Cost Reduction = Initial Cost – Final Cost
= 14700 – 2400
= 12277 Rs.

Reduced Cost :- 12360.2 Rs.

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IX. CONCLUSION

In this project, the design and analysis of a elevator system conveyor for plastic resin application has been successfully carried out. By changing the material from SS404 to mild steel and modifying the design dimensions, a significant reduction in weight and cost has been achieved.
The key outcomes of the project are:
Weight reduction from 42 kg to 26 kg
Material cost reduction from ₹350/kg to ₹90/kg
Optimized factor of safety reduced from 3.5to 1.2 , suitable for abrasive material handling Safe stress and displacement values obtained from SolidWorks Simulation Reduction in material wastage during conveying
The simulation results confirm that elevator system safe and efficient under working conditions. Hence, the proposed design meets all objectives and proves to be economical, lightweight, and reliable for industrial application.

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