“Design & Analysis of Z-Conveyor”

Mr. Rushikesh Venunath Gudade
Department of Mechanical.
Sanjivani College of Engineering,
Kopargaon, India.

Mr. Prathmesh Pravin Wadekar
Department of Mechanical.
Sanjivani College of Engineering,
Kopargaon, India.

Mr. Prajwal Jayant Durgude
Department of Mechanical.
Sanjivani College of Engineering,
Kopargaon, India.

Mr. Amol Rajendra Mohan
Department of Mechanical.
Sanjivani College of Engineering,
Kopargaon, India.

Prof. Sandip V. Fartale
Project Guide
Department of Mechanical.
Sanjivani College of Engineering,
Kopargaon, India.

❖ Abstract:

The design and analysis of a Z conveyor system for effective material handling in processing or industrial settings is the main goal of the study. The "Z" shaped conveyor is made up of two horizontal passages joined by a vertical or angled segment. For performance, stability, and longevity, the design parameters—such as frame construction, motor power, load capacity, and conveyor belt selection—are maximized. Consideration is given to important elements such as energy consumption, material properties, tension control, drive systems, load distribution, and speed regulation. Using both real-world case studies and modeling tools, the study assesses the system's performance and efficiency under various operating situations. For dependable and reasonably priced material handling solutions, the findings highlight the significance of meticulous design and maintenance procedures.

Key words: Z-type conveyor, SolidWorks simulation, CAD modeling, material selection, material handling, stress analysis, food industry conveyor, industrial automation, load capacity.

Introduction:

In material handling, a Z conveyor is a kind of conveyor system that moves materials or items in an inclined or vertical direction; it frequently takes the shape of the letter "Z." Because of its design, the conveyor may carry objects between different heights, for example, from lower to upper elevations or vice versa, while keeping the materials flowing continuously.

Typically, Z-conveyors consist of two horizontal portions joined by an inclined part. While the inclined portion raises or lowers the materials between the two horizontal levels, the horizontal sections are employed to transport materials from one location to another. These conveyors are frequently found in sectors that require vertical transport or have space restrictions, like manufacturing, packaging, and food processing.

Effective vertical goods transportation and space-saving design are two of Z-conveyors' primary advantages. They can manage vertical transport without taking up an excessive amount of floor area. Versatility: they can work with a variety of materials, such as fragile objects, bulk goods, and packages. Various belt kinds, speeds, and inclination degrees can be added to Z-conveyors based on the particular needs of the application.

In order to optimize important performance factors such load capacity, belt tension, frame stability, and energy consumption, this study focuses on the design and structural analysis of a Z conveyor system. To guarantee longevity, effectiveness, and safety, the design is assessed under various loading and operating circumstances using sophisticated CAD tools and simulation software. In order to satisfy various industrial needs, factors including motor selection, speed regulation, material compatibility, and drive mechanisms are also taken into account. The findings are intended to aid in the creation of dependable, reasonably priced, and highly effective material handling solutions.

❖ Literature survey:

With the addition of specialized conveyors made to satisfy the needs of contemporary businesses, material handling systems have significantly advanced. Conveyor system design, analysis, and optimization have been the subject of several studies in an effort to increase mechanical dependability and operational efficiency.

Patel et al. (2016) examined how belt conveyors behaved structurally under various load scenarios, highlighting the significance of belt tension control and frame design. Their research demonstrated the usefulness of simulation techniques for stress and deformation analysis.
Kadam and Gawande (2018) presented design calculations and performance assessments under various material loads with an emphasis on the construction of a Z-type bucket conveyor for agricultural applications.
A finite element analysis (FEA) of conveyor components by Shinde et al. (2019) demonstrated that material selection and frame stiffness are essential for long-term stability and vibration reduction.
In order to reduce energy losses, Kulkarni and Bhutada (2020) investigated the energy efficiency elements of conveyors and suggested motor power matching and drive system modifications.
After comparing several conveyor systems, Deshmukh et al. (2021) came to the conclusion that Z conveyors offer clear benefits in terms of handling elevation and space utilization.

❖ Problem Statement:

The following design specifications for the Z-conveyor for design, development, and analysis. Conveyor having design capacity 10 TPH for Medical Appliances. Also, selection of appropriate material to fit a FOS of 2 to 3. Speed of the conveyor will be 0.0833m/s, horizontal travel of 5m. And FEA analysis on shaft of conveyor, frame of conveyor and casing.

Following is some more relevant Data: -

Rated Capacity = 10TPH

Speed = 0.0833m/s

Material density = 7850kg/m^3

❖ Objective:

Using cutting-edge SolidWorks design tools and realistic manufacturing procedures; the project's goal is to create a Z conveyor system that is dependable, economical, and efficient. Z conveyors are vital in sectors where efficiency, accuracy, and durability are critical, such as manufacturing, packaging, and medical applications.
Conventional conveyor systems frequently face problems like high material costs, structural flaws brought on by ineffective designs, and difficult maintenance because of extensive welding. This project uses a methodical design and development strategy to address these issues.
We produced accurate 3D models and simulations using SolidWorks to verify functioning, spot possible defects, and expedite the manufacturing process. This strategy reduced the possibility of expensive manufacturing changes.
One major area of concern was structural reliability. We did this by reducing the amount of needless welding, which is frequently a cause of flaw in conventional designs. In order to increase assembly and maintenance flexibility without sacrificing durability, modular and bolted joints were used where practical.
Cost effectiveness was still another major priority. Through thorough cost research, we were able to optimize manufacturing processes and material choices, guaranteeing a balance between affordability and quality.
Additionally, the Z conveyor was used for conveying materials at significant incline, often close to vertical.

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In summary, the project effectively addressed industry challenges through creative design, structural optimization, and economical manufacture to produce a sturdy and application-specific Z conveyor system.

- To Increase capacity
- To make trough lightweight
- To Reduce deflection of pipe shaft assembly

❖ Scope:

Because a Z conveyor can effectively move goods between elevations while maximizing space, its variety of industrial applications is extensive. These are a few of its main scopes:

1. Management of Materials:
Bulk Material Transfer: Used in industries to transport large quantities of commodities such as food items, grains, aggregates, and powders. Handling Fragile Materials: Designed to transport fragile goods, such fruits, vegetables, or candies, with care and without causing any harm.

2. Optimization of Space:

Compact Design: Because the Z-shape enables both vertical and horizontal movement in a single system, it is perfect for facilities with limited space. Decline/Incline Transportation: Moves items between floors or levels efficiently without the need for extra equipment.

3. Uses in Industry:
Food and Beverage: Keeping food items clean and in compliance with safety regulations. Pharmaceuticals: Used to move raw ingredients or medications in a dust-free, hygienic manner. Manufacturing: Moving parts, leftover materials, or completed goods.

Moving coal, ore, and other raw materials vertically is known as mining and quarrying.

4. Customization Material Options:
Rubber, plastic, or stainless steel belts can be used to suit certain requirements. Attachments: To improve functionality, cleats, sidewalls, and hoppers can be attached.
5. Integration of Automation:
Enhances productivity and workflow by seamlessly integrating into automated manufacturing lines.

❖ Methodology :

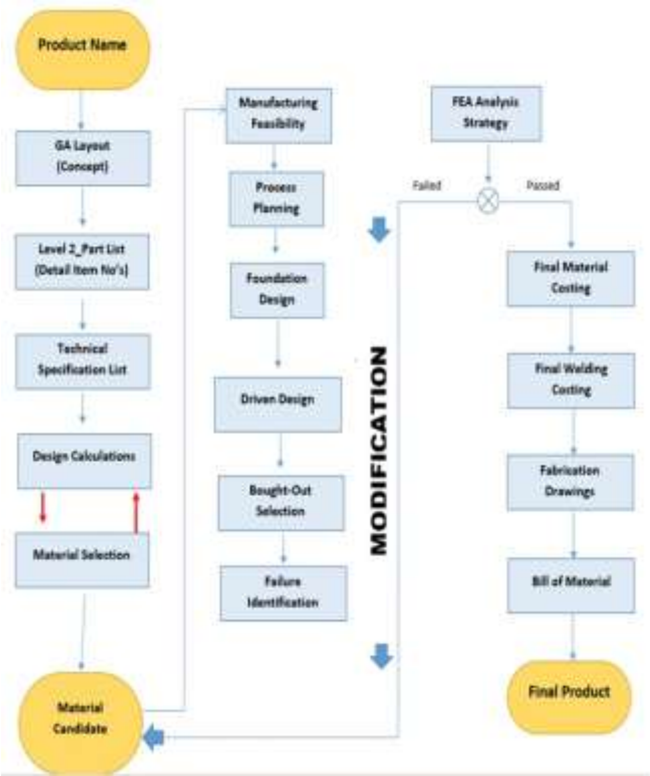


Figure 1: G.A.Layout

1. **G.A. LAYOUT:** The General Arrangement (GA) layout is a document that outlines the precise placement of the structural components that serve as the foundation for the structure's design. It makes an object's general makeup more clear.
2. **LEVEL 1 part LIST**: The basic item number, or Level 1 component list, is essentially a method of determining the number of sub-assemblies that make up the main assembly. For example, the motor, shaft, and chain are sub-assemblies found in the inclined Z-conveyor's main assembly.
3. **LEVEL 2 PART LIST:** Determining the number of subparts in the main assembly is essentially done through the Level 2-part list (Detail item no). For example, the shaft, roller, and bearing are subparts of the chain subassembly. It is essentially a summary of the design we are working on and the number of components we need to create. When creating a part list, we learn how many machining, fabrication, and bought-out items—items that we utilize ready-made rather than manufacturing—are there. For example, we buy the conveyor motor straight from the manufacturer rather than developing it.
4. **THE TECHNICAL SPECIFICATIONS LIST:** This is essentially the input that is provided. For instance: for our project's capability: Weight:

336.4 kg; carrying distance: 5 m (center to center); 10,000 kg/hour.

5. **DESIGN DETERMINATIONS AND MATERIAL CHOICE:** At the same time, material selection and design calculations are being made for things like shaft size, length, belt size, chain length, torque, and forces acting. Because we needed material input to do design calculations, and vice versa.

6. **MATERIAL CANDIDATE:** In Material Candidate, we identify the material based on requirements when choosing the materials for each component, such as a conveyor with a shaft. Therefore, the list of materials we are creating that are needed to make the shaft is referred to as the material contender.

7. **THE FEASIBILITY OF MANUFACTURING:** Manufacturing Feasibility: Suppose we have identified the five materials for the shaft. Next, we need to determine whether the manufacturing method is applicable to these five materials. For example, C45 is a material that may be used in shaft machines, but it is not available because of its high hardness.

8. **PROCESS PLANNING:** After determining the viability of production, we learn that only a small number of the chosen materials can really be manufactured. As a result, we dispose of the leftover materials and prepare the processes for the chosen ones. Thus, process planning essentially determines the amount of time needed to machine the component.

9. **COMPARATIVE COSTING:** This refers to the necessary component costs. Thus, we choose the machining cost that is the least expensive.

10. **FOUNDATION DESIGN:** The major components and the driving components must be identified in the part list we created in level 2. In the process of manufacturing the drive components, the major components are made initially.

11. **SELECTION BOUGHT OUT:** The Original Equipment Manufacturer (OEM) components must be chosen. For example, we may purchase motors from several manufacturers based on our desired specifications, pricing, and requirements. The 3D assembly is finished at this point.

12. **FAILURE IDENTIFICATION:** Following the 3D assembly's production, we need to consider which of these components could malfunction. For example, base frame and shaft may fail.

13. **FEA Analysis Strategy:** FEA analysis is the process of modeling systems and products in a virtual environment in order to identify and address possible (or current) structural or performance problems. Following the identification of the potentially defective parts, FEA analysis has been used to verify these parts.

14. **CASE 1)** If these components don't pass FEA analysis, you have to go back to the material candidate, choose a material, assess the production feasibility, and repeat the entire process. **CASE 2)** Then, if analysis is successful. FINAL MATERIAL & WELDING COSTING: Here, we determine the product's total weight, cost, and welding expenses.

15. **DESIGNS FOR FABRICATION:** Detail plans that convey design intent are called fabrication drawings. They provide fabricators the knowledge they need to create, construct, assemble, and install every part of a building. To build the component, we create the fabrication drawing.

❖ <u>Analytical Study</u>

1. Design Calculation: -

1. **Design Data :**

- Bell width 1800 mm
- Tensile Stength of belt : 200Mpa
- Horizontal Length of Conveyor :1.3mm
- C to C Conveyor length (L) : 6.1m
- Height of Head Pulley (H) : 5.2m
- Belt Speed (V) : 48m/s = 0.8m
- Conveyor Capacity (Q) : 3 Tan/hrs
- Application : Rice Package Box (Food Pack)

- Friction Factor (F) :

-F = 0.03 Belt Factor

-Lo = 49 Length Factor

- Weight of moving parts without material Carried : (W) 154

1. P1 Power req to move empty belt (kw)

= (0.06*F*V(L+Lo))/367 =0.63kw

2. P2 Power req to move load on bevel (Kw)

= (f*G (L+Lo)+W*15)/367 = 0.58kw

3. P3 Power lift to load (kw)

= (H*G*w)/367 = 6.55kw

Total Power = 7.14 kw

1. Effective Tension (Te) = (6120*p)/v

= 2913.12 kg

2. Slack Tension (T2) = Te*(1/e)

= 3320.36 kg

e = (during coeff. Factor = 1.14)

3. Slope Tension (T3) = w1(Ht – fxl)

= 63.52 kg

4. Sag Tension (T4) = 50/(8*lr*w1)

= 221.25 kg

Total Tension = 6518.85 kg

= 63.92 kn

Head Shaft Power = Total Tension * Speed /10

= 6518.85*15/10

= 2.71 hp

= 63.92*0.25/10

=1.59 = 2.5 hp

Gear Box = 95 %

= 1.59/0.95 = 1.67 =2.5 Hp (motor req)

❖ Material Selection

Selecting the appropriate material is a fundamental part of the engineering design process. It involves identifying a material that can effectively meet the mechanical, functional, and economic demands of a specific application. The process starts with defining the essential performance criteria such as load capacity, wear and corrosion resistance, thermal behaviour, and cost-effectiveness.

Once the requirements are clearly understood, a list of suitable material options is generated. These options are then examined to determine if they inherently meet the performance goals or if modifications, like surface treatment or compositional adjustments are needed. From this evaluation, the most appropriate material is selected based on its ability to satisfy the application needs while also being cost-efficient and easy to manufacture.A well-structured material selection process ensures the reliability and longevity of the final product. Making the wrong choice can lead to failures, increased maintenance, and higher production costs. Therefore, a strategic and analytical approach to material selection is vital for achieving a successful and sustainable design.

To aid in this decision-making, several standard methods are employed:

- **Cost per Unit Property Method**: Evaluates the efficiency of a material by analyzing the cost associated with achieving a specific performance characteristic.
- **Weighted Property Method**: Ranks materials by assigning importance to each required property and scoring materials accordingly.

Digital Logic Method: A logical approach that compares properties two at a time, using binary decisions to narrow down the most suitable material without subjective bias. Applying these methods helps designers balance technical performance with production cost, ultimately leading to a more efficient and dependable Z conveyor system.

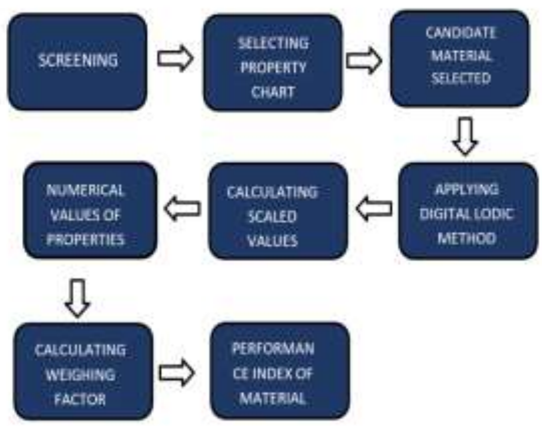


Fig.2. Material selection flowchart

Material Selection & Analysis:

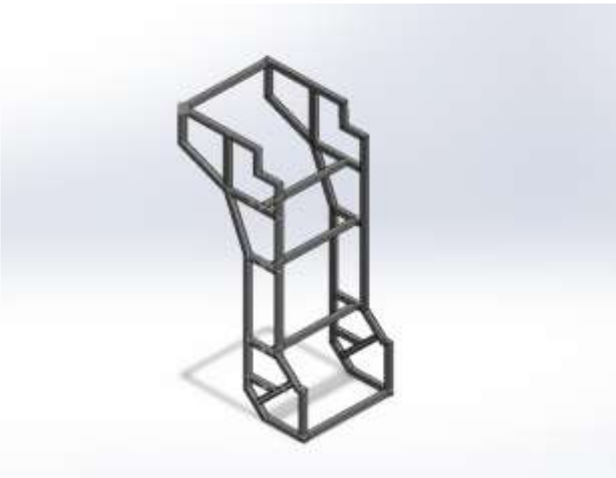
To help with material selection and guarantee the frame's capacity to support operational loads efficiently, a material analysis was carried out for the Z-Conveyor in SolidWorks Simulation. Mechanical characteristics, such as modulus of elasticity, yield strength, and tensile strength, were used to assess a variety of materials, including steel, aluminum, and composites.

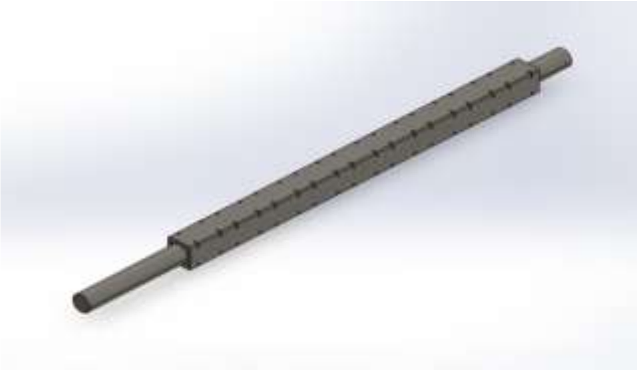
To find the ideal design that maximizes strength while reducing weight and material use, several area measurements of the frame were evaluated under load circumstances. In order to determine which dimensions and materials could support the imposed loads without going beyond safety limits, stress, strain, and deformation measurements were compared across different configurations. By choosing the best material and dimension combination, this iterative approach ensured the structural dependability, economy, and efficacy of the Z-frame.

Fig.3. Material Analysis

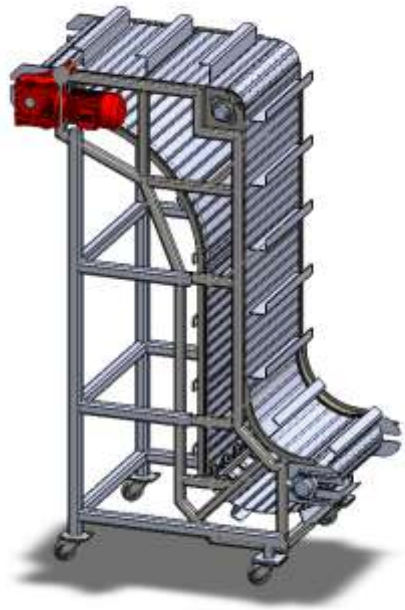
Material (Fixed)	Frame (Section)	Stress	Deformation	FOS	Weight	Cost
AISI 1020	100*100*5	90.35	0.93	3.89	191.12KG	22934 Rs
AISI 1020	80*80*5	102.40	0.97	3.43	143.70KG	17244 Rs
AISI 1020	60*60*5	172.40	1.01	2.04	135.50	16260 Rs
AISI 1020	**40*40*5**	**204**	**1.06**	**1.72**	**71.60**	**8592 Rs**
AISI 1020	35*35*5	249.38	1.23	1.41	50.40	6048 Rs
AISI 1020	20*20*5	408.60	1.92	0.86	36.12	4334 Rs

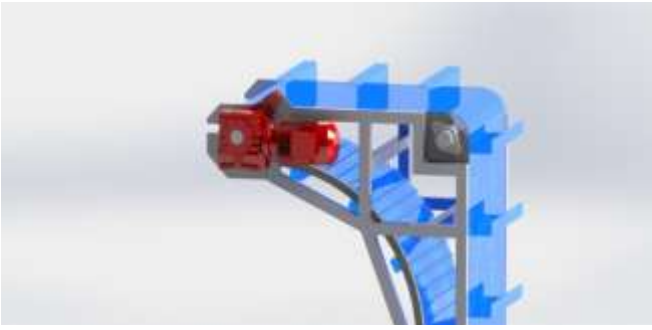
❖ Design Model Parts :

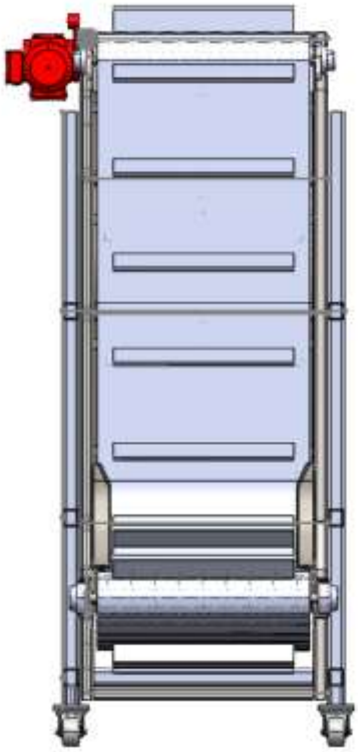




❖ **Design of Elevator:**







❖ <u>**Assembly: Z-Conveyor:**</u>

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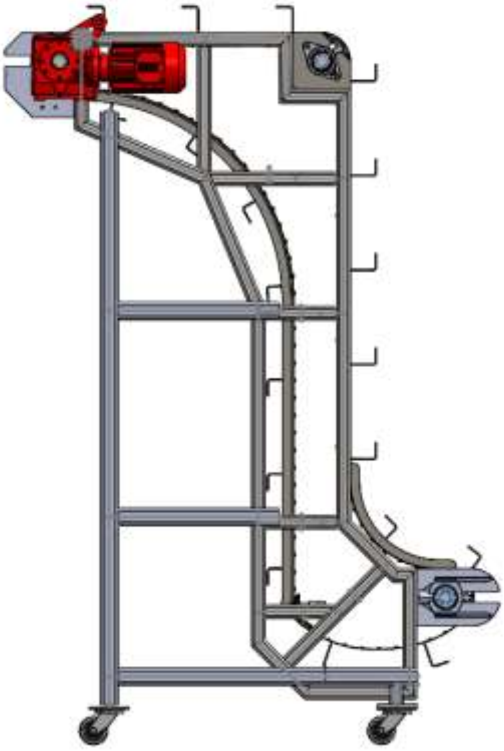
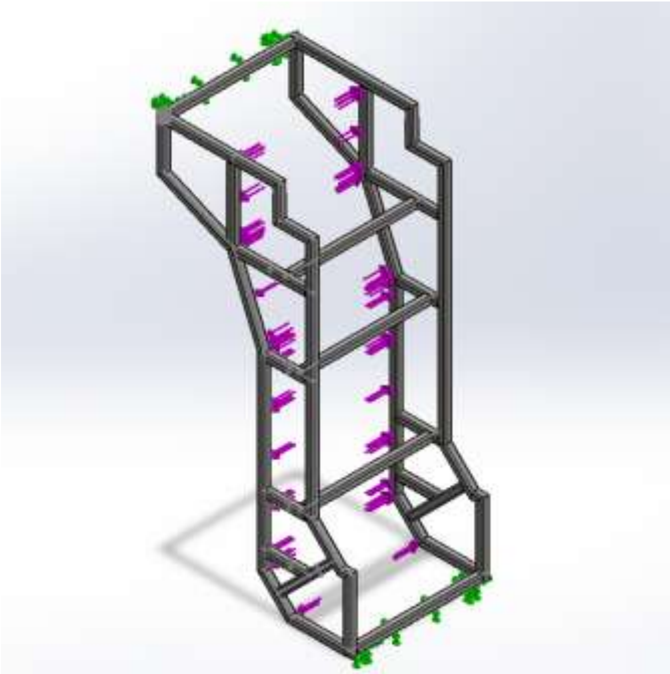


❖ Analysis Using Solidworks Simulation:

Using SolidWorks Simulation, the Z-conveyor's structural and functional performance under varied operating situations was thoroughly assessed. To ascertain the load-bearing capability of the frame, idler rollers, and inclined sections, stress and strain analysis was performed. We looked at the belt's alignment and tension to make sure materials moved smoothly and to reduce wear. By examining the relationship between moving parts such as pulleys, drive motors, and the belt, dynamic simulation was able to spot any misalignment or inefficiency.

To assess the conveyor's stress and strain performance under operating loading circumstances, the Z-frame was examined in SolidWorks Simulation. Finding regions of maximal stress, deformation, and possible failure spots under both static and dynamic loads was the main goal of the research. To mimic real-world circumstances, boundary constraints were implemented, including weight distribution, fixed supports, and outside pressures.

The simulation outcomes offered valuable insights into the structural performance of the Z-conveyor, particularly its ability to withstand applied loads and the response of materials under stress conditions. This analysis played a crucial role in refining the frame design, enhancing overall strength, and ensuring consistent stability throughout operational use.



STRESS

DISPLACEMENT

❖ Conclusion:

The development and evaluation of a Z conveyor system confirm its capability to efficiently transport materials across different elevations while maximizing space utilization. By thoughtfully selecting materials, belt configurations, drive systems, and structural elements, the system can be tailored for enhanced performance, long-term durability, and consistent reliability. Essential design factors such as load handling, speed regulation, energy use, and belt tension control play a key role in achieving stable and efficient operation.

The study also emphasizes the value of routine inspection and maintenance to sustain performance and extend the equipment's operational lifespan. Additionally, the integration of advanced simulation software and field-based performance data allows for customization based on specific industrial demands. In conclusion, the Z conveyor serves as a practical and adaptable solution for managing vertical and inclined material flow, helping industries improve efficiency, boost output, and lower operating expenses.

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