# Design Optimisation of Nanjing Cabinet Sheet Slider Machine

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## Abstract

The Nanjing Cabinet Trolley in & out Machine plays a crucial role in the manufacturing process of body components for Whirlpool products. This sophisticated machinery automates the shaping and assembly of sheet metal and various materials to create the product's body. Understanding the Nanjing Cabinet production line and its significance in Whirlpool's manufacturing process is paramount for anyone interested in the appliance industry and the production of large household goods.

In the scope of this project, we conducted a comprehensive analysis, both numerical and experimental, of the machine's structural performance under applied loads. Our primary objective was to optimize the design by iteratively refining it within minimal spatial constraints. As a result of our efforts, we achieved a remarkable 10% reduction in deformation, aligning with our targeted optimization level.

**Keywords**: Nanjing Cabinet line machine, Machine structure, Static analysis, Double integration numerical analysis, ANSYS Work bench, Deflection, Deformation & Stress strain.

## 1. Introduction

The Nanjing Cabinet line machine finds application in various industrial processes involving the handling of sheets. It performs tasks such as lifting, transporting to the designated location, and releasing the sheets at regular intervals within the specified output range. Renowned for its sheet-handling capabilities, this machine is particularly employed in the sheet metal industry, contributing to the fabrication of household items such as washing machines and refrigerators. These products are typically crafted from galvanized iron sheets of diverse sizes to meet specific requirements. The schematic view depicted in Figure 1 illustrates the established Nanjing cabinet machine used in the industry

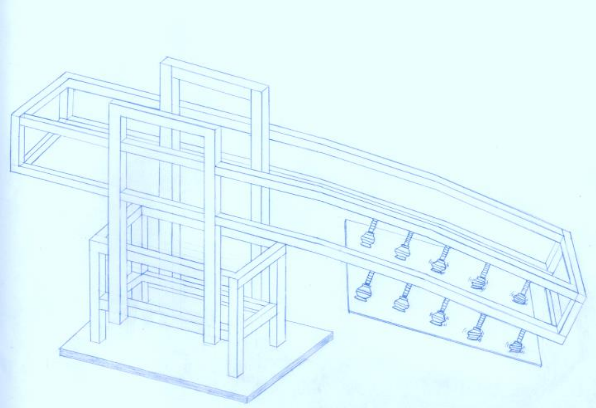
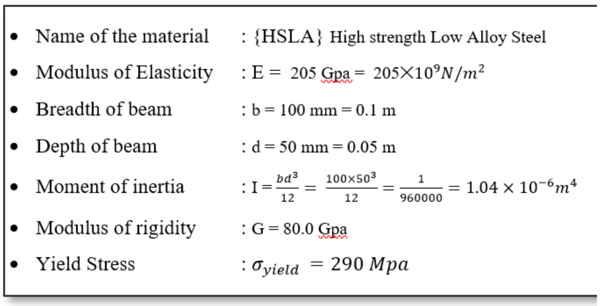


**Fig 1 Representation of existing Nanjing cabinet machine**

The Nanjing cabinet line machine has a diverse range of applications for handling sheets, as previously mentioned. Constructed from HSLA (High Strength Low Alloy) steel, the machine possesses specific properties detailed in Fig. 2 below. Additionally, this equipment is outfitted with mobilizing agents and a vacuum mechanism, facilitating the movement of sheets and securely holding them in place until they reach their designated location



- Name of the material : {HSLA} High strength Low Alloy Steel
- Modulus of Elasticity : E = 205 Gpa = $205 \times 10^9 N/m^2$
- Breadth of beam : b = 100 mm = 0.1 m
- Depth of beam : d = 50 mm = 0.05 m
- Moment of inertia : $I = \frac{bd^3}{12} = \frac{100 \times 50^3}{12} = \frac{1}{960000} = 1.04 \times 10^{-6} m^4$
- Modulus of rigidity : G = 80.0 Gpa
- Yield Stress : $\sigma_{yield} = 290\ Mpa$

**Fig. 2 machine structure property**

The vacuum mechanism of the Nanjing cabinet machine features vacuum cups on both sides, as illustrated in Figure 3 below. These cups secure the sheet firmly, preventing slippage during displacement. However, it's important to note that the load being carried is distributed across the machine's frame, leading to deflection and a slight slope in the sheet. This deflection can result in a minor opening of the vacuum holders, potentially causing slipping and a non-uniform distribution of stress within the vacuum holder.

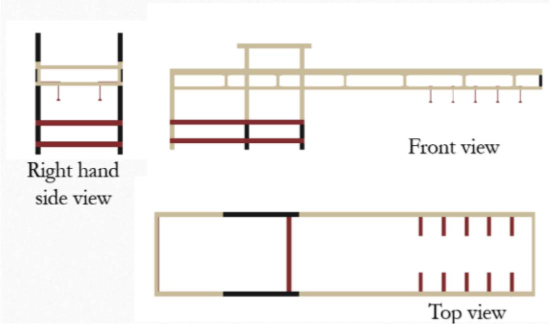


**Fig. 3 Representation of vacuum cups in existing model of Nanjing cabinet machine**

The primary focus of this project revolves around addressing the deflection issues in the structure of the machine. The approach involves an iterative design process, incorporating numerical and experimental analyses with references to various literature reviews. The numerical analysis employs the double integration method, while computer-aided analysis, specifically utilizing ANSYS Workbench software, is conducted for experimental analysis.

In the computer-aided analysis, the static analysis tool is utilized to identify and optimize the design. The goal is to achieve a reduction in deflection of approximately 10%, bringing it down to the range of 2-4 mm. This reduction is crucial to mitigate air gaps that occur due to deflection in the vacuum cups. The integration of both numerical and experimental approaches aims to enhance the efficiency of the design while addressing structural concerns in the Nanjing cabinet machine.

## 2. Literature review

Computer-Aided Design (CAD) has brought about a transformative impact on the realm of structural engineering by furnishing sophisticated instruments and proficiencies for the conceptualization and assessment of edifices. The objective of this comprehensive survey is to delve into the realm of investigations and progressions concerning the development and evaluation of structures through the employment of CAD. Encompassing a wide array of dimensions, this analysis encompasses modeling methodologies, assessment approaches, fine-tuning algorithms, and the harmonious fusion with alternative software frameworks. The assessment underscores pivotal innovations, obstacles, and forthcoming trajectories within this domain.

### FORKLIFTING FEA ANALYSIS OF BASE FRAME USING ANSYS

This literature explains FEA Analysis of base frame for forklift lifting loading condition. This journal briefs about geometry cleanup like Midsurface extraction, weld and connection for base frame along with FEA meshing and deck preparation for forklift load case. It also discusses the results like deformation and stresses for forklift.

- **R. SOEGIARSO (2003)**

The given edifice experiences wind loading in accordance with the Uniform Building Code (UBC), coupled with vertical loads arising from both permanent and dynamic loads. To expedite convergence, a scaling technique is devised. This method is then applied to optimize the weight of four expansive high-rise steel structures, ranging from 20 to 81 stories in height, and encompassing 1,920 to 9,245 individual components. When comparing the designs of spatial moment-resisting frameworks based on the AISC LRFD code versus those grounded in the AISC Allowable Stress Design (ASD) code, the former yields a more lightweight configuration in the provided instances. In contemporary architectural practice, simplicity prevails in the shaping of structures, often adopting cubic forms and geometric volumes. This tendency is primarily driven by the structural systems employed within buildings, which dictate the achievable design configurations. This juncture signifies a period of revival for architectural shapes, forms, and spatial arrangements. In regions prone to seismic activity, the imperative for earthquake-resistant structural systems necessitates designs that guarantee enhanced resilience and stability in construction.

- **SHILINDONGA (2012)**

In a study conducted by SHILINDONGA (2012), the application of prestressing technology and creative structural concepts emerges as intimately interconnected with present-day spatial frameworks. These encompass a range of architectural configurations, including composite space trusses, open-web grid structures, polyhedron space frame structures, partial double-layer lattice shells, cable-stayed grid structures, tree-type structures, and prestressed segmental steel structures, among others. This work provides an insightful overview of the unique structural characteristics and practical applications specific to the context of China. The discussed frameworks span a spectrum from contemporary rigid spatial constructions to flexible spatial designs, showcasing the innovative integration of both rigid and flexible spatial elements

- **DISHA SAHADEVAN1, MEGHAVIJAYAN (2017)**

The collaborative work by DISHA SAHADEVAN1 and MEGHAVIJAYAN (2017) delves into an examination of critical parameters including maximum displacement, storey drift, and stiffness within regular and irregular buildings. These structures feature varying column shapes—square, circular, and specially shaped columns. Notably, the study reveals a reduction of maximum displacement within G+9 stories, ranging from 20% to 30%. Furthermore, in the context of G+9 stories, Z-shaped columns exhibit a storey drift reduction of 20% - 40% when compared to their square and circular counterparts. Additionally, the stiffness of Z-shaped columns in G+9 stories surpasses that of equivalent square and circular columns by 60%. The distinctive Z-shaped column configuration emerges as an effective approach to achieving these improvements across the specified categories.

- **MANMOHAN SINGH THAKUR1, DR.SUMAN SHARMA (2017)**

The research by MANMOHAN SINGH THAKUR1 and Dr. SUMAN SHARMA (2017) centres around the objective of investigating the vibration characteristics of two distinct frame types: square frames and tubular frames. The study aims to compare the natural frequencies of vibration between these two frame designs, with the intention of drawing meaningful conclusions. Through meticulous analysis, the research seeks to elucidate the vibrational behavior of motorcycle frames featuring diverse cross-sections. The study employs two materials—aluminum and steel—for its analysis, contributing insights into the intricate dynamics of vibration across varied structural configurations.

## 3. Methods

**Numerical analysis:**

The existing machine structure underwent numerical analysis through the utilization of the double integration method. In this process, the frame was transformed into a beam to facilitate the examination of a simplified representation, as depicted in Fig. 4 below. The values for slope and deflection were subsequently derived.

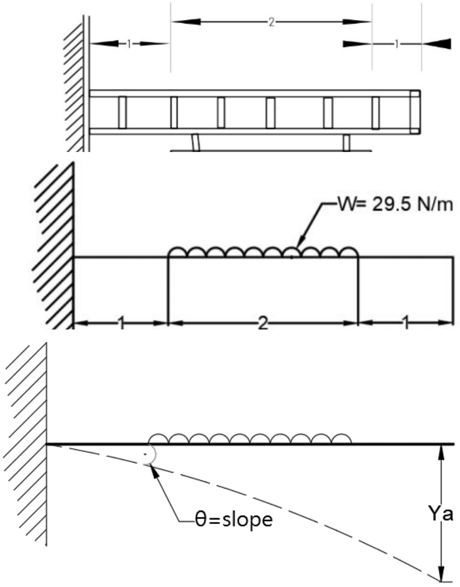


**Fig. 4 Representation of slope and load on beam**

By iteratively analyzing the obtained deflection and slope from the existing case, the line diagram of the optimized design was generated. This diagram was anticipated to fulfill the project's objectives. The subsequent numerical analysis, employing the double integration method, guided the step-by-step procedure showcased in Figure 5 below. This process outlined the progression from the initial design to the optimized line design and its subsequent conversion into the structure of the machine.

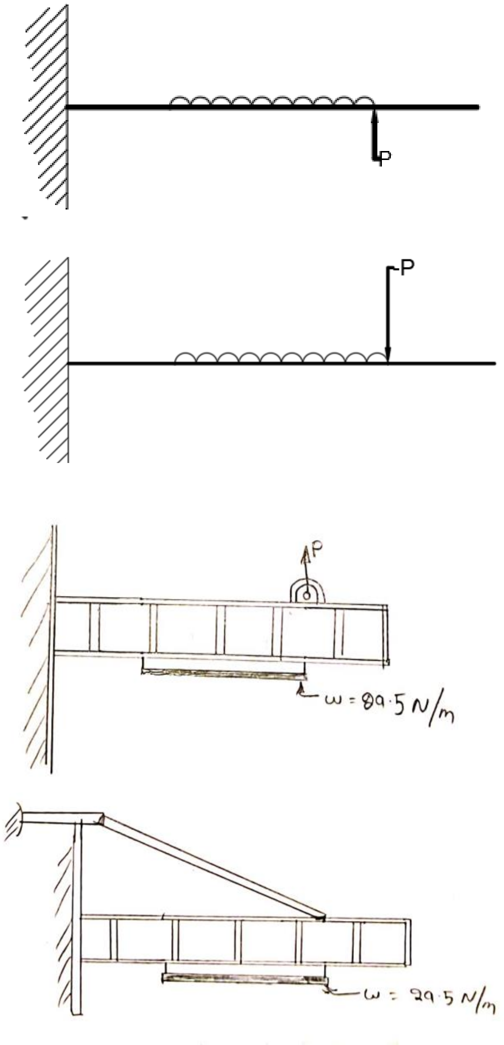


**Fig. 5 Representation of obtaining optimized line design and development of structure**

The final design of structure thus obtained by developing the optimized line design is shown in below figure no. 6

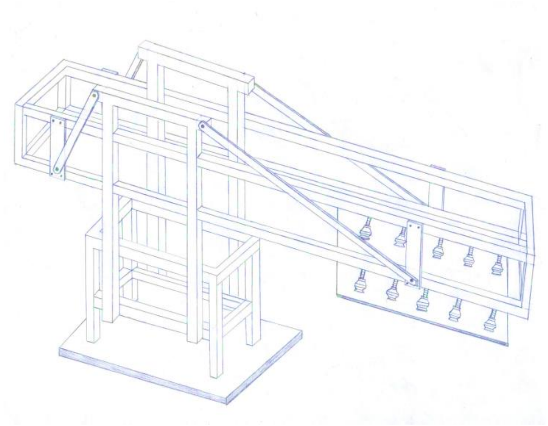


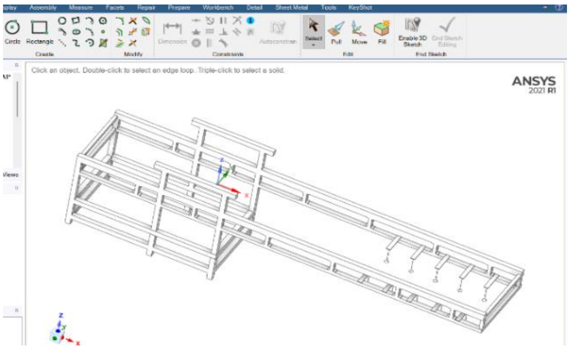
**Fig. 6 Final design structure obtained from optimized line design using double integration**

**Experimental analysis (Computer aided analysis and simulation)**

The 3D model was first created using AutoCAD software and subsequently imported into ANSYS Workbench software. In ANSYS Workbench, the model underwent mesh generation, wherein it was divided into smaller nodes. Following this, the process involved defining boundary conditions, applying loads, specifying material properties, and configuring the solver for both the existing and optimized designs.

A comprehensive analysis was conducted, covering aspects such as deformation, stress analysis, directional deformation, principle stresses, and more. The obtained results from both designs were then systematically compared to assess the variations and improvements achieved through the optimization process.

The below figure 7 shows the procedures and all method followed in experimental analysis



Click an object. Double-click to select an edge loop. Triple-click to select a solid.

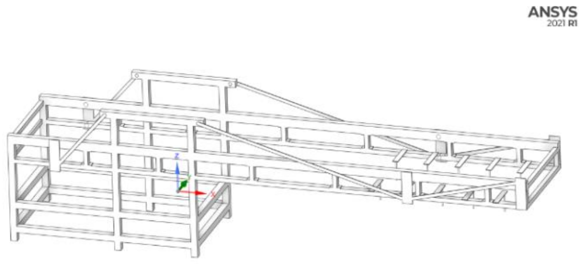
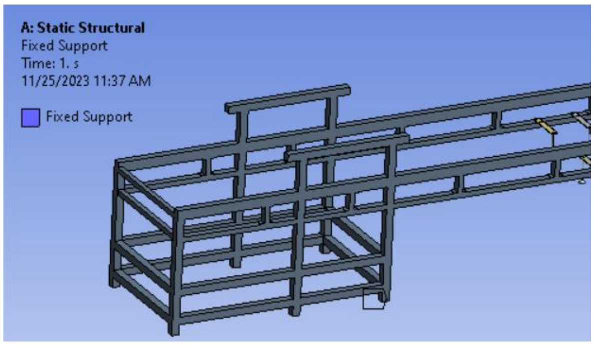


**Fig.7 Importing of geometry of both existing and optimized case**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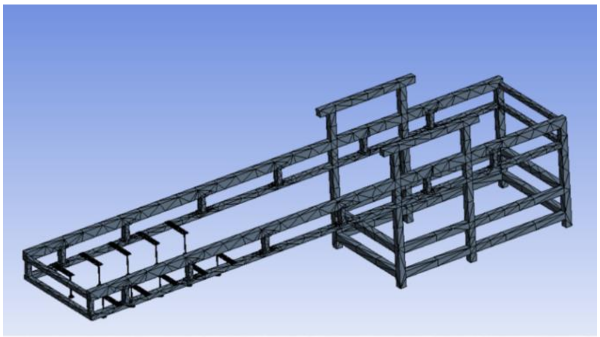
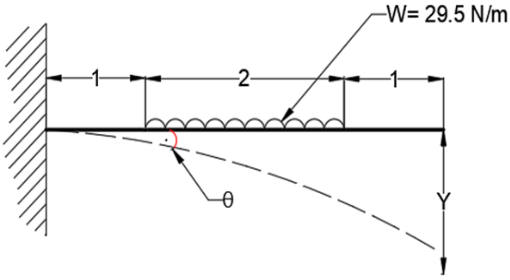


**Fig 7(a) Meshing the structure**
**fig. 7(b) Representation of boundary condition**

## Result and Discussion

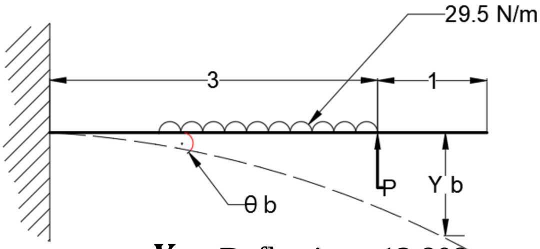
### Numerical Analysis

The numerical analysis of the existing case using double integration gave a result of slope and deflection as following:



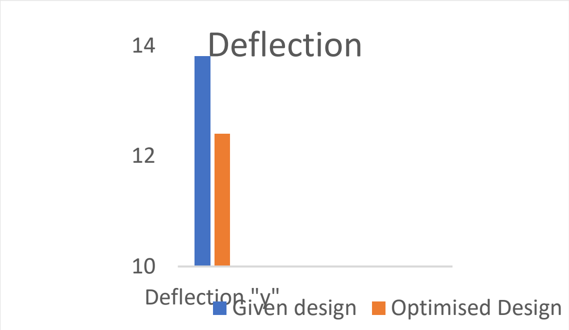
$$Y = \text{Deflection} = 13.808$$
$$\theta = \text{Slope} = 22.41^\circ$$

The numerical analysis of optimized case using double integration method gave and solution as represented below.



$$Y_b = \text{Deflection} = 12.808$$
$$\theta_b = \text{Slope} = 17.41^\circ$$

| | Given design | Optimised design | % of optimisation | Reduction in Dimension |
|---|---|---|---|---|
| **Deflection "y"** | 13.8 mm | 12.4 mm | 10.1% | 1.4 mm |
| **Slope "θ"** | 22.4° | 17.8 ° | 20.55% | 4.6° |



### Experimental analysis

Both the existing and optimized design structures were created using AutoCAD and subsequently imported into ANSYS Workbench. Load and boundary conditions were specified, and a static analysis was conducted. The resulting values for deformation, directional deformation, and stresses were obtained and then compared between the two designs. The comparative analysis, as illustrated in the figures below, confirmed the project's success in achieving its objectives. The optimization effectively reduced slipping and minimized stress concentration on the vacuum cups, enhancing their ability to securely hold sheets.

The below fig. 8 represents the various computer aided analysis which was carried out using Ansys work bench software.

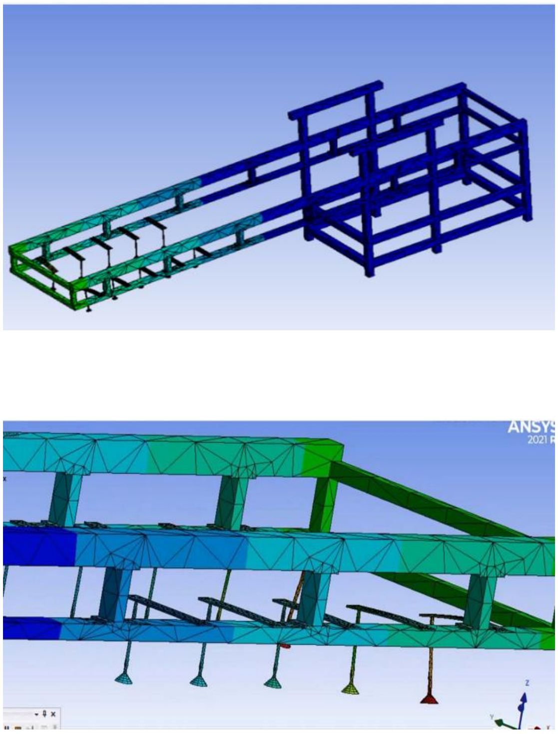


**Fig. 8 representation of deflection and deformation in existing design**

Total Deformation = $Y = 1.1614 \times 10^{-3} m = 1.1614\ mm$

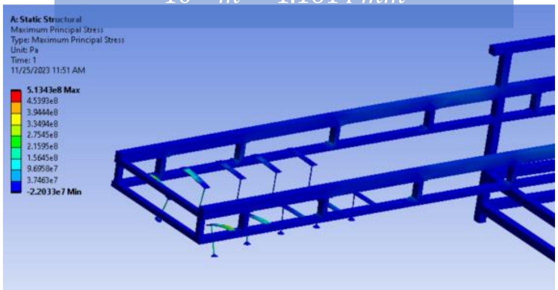


**Fig. 9 Representation of stress disorderly developed in vacuum cups in existing case**

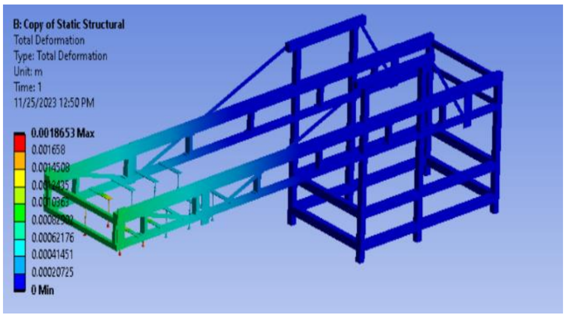
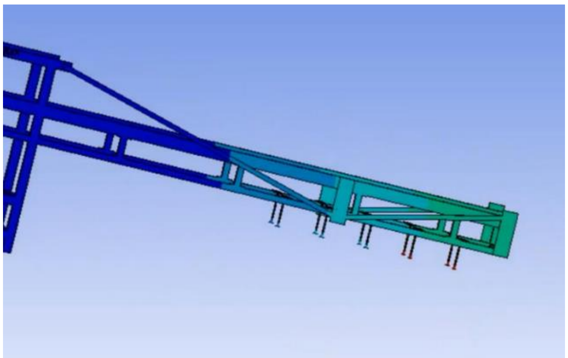


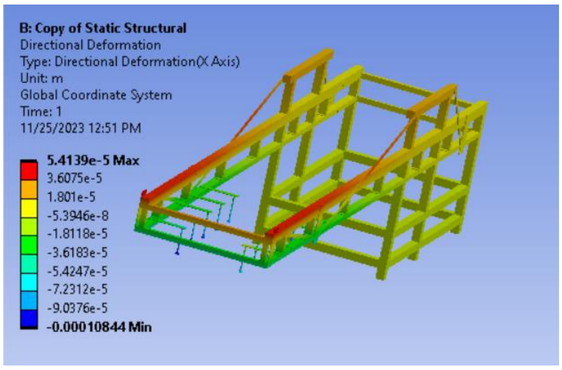
**Fig. 10 Representation of deformation in machine structure of optimized design**



Total Deformation = Y = 1.051 $mm$

**The result of deformation in shifting the total sheets of 10 nos by the both machines gives the values as plotted in below table.**

| | Case "a" | Case "b" | % of Optimisation | Difference in Dimension |
|---|---|---|---|---|
| **Total Deformation** | 11.61 $mm$ | 10.51 | 9.47% | 1.06mm |



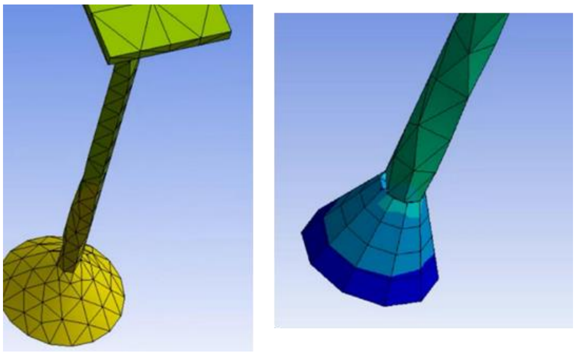
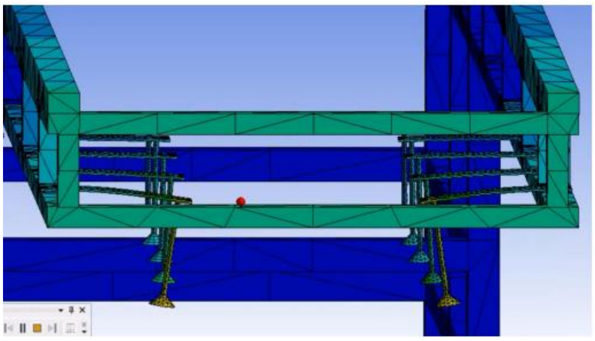


**Fig. 11 Directional Deformation Representation**

**Fig. 12 Deformation of pre and post optimised analysis of vacuum cups**



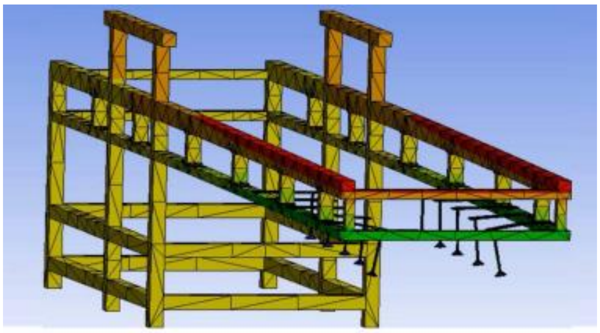


**Fig. 13 Schematic representation of structural deformation thus obtained**

**Similarly, the result of experimental analysis which was carried on and it obtained values of deformation and stresses are shown in below figures.**

## 4. Conclusion

**In conclusion, the combined results of both numerical and experimental analyses indicate that the optimized design, obtained through the double integration method, successfully achieved the project's objective. By reducing deflection, the optimized design effectively addressed the need to decrease stress concentration, thereby eliminating air gaps in the vacuum cups. This improvement mitigated the issue of sheet slipping during the transition from the source to the destination.**

**THUS THIS IS THE APPROVED OPTIMIZED DESIGN WE ACHIEVED BY ANALYSIS.**

**Fig. 14 3D Model of optimized design model obtained**

**Fig. 15 3D Model of optimized design model obtained back view**

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