World Academy of Science, Engineering and Technology
International Journal of Mechanical and Materials Engineering
Vol:18, No:10, 2024

Modelling and Enhancing Engineering Drawing and Design Table Design by Analyzing Stress and Advanced Deformation Analysis Using Finite Element Method

Nitesh Pandey, Manish Kumar, Amit Kumar Srivastava, Pankaj Gupta

Open Science Index, Mechanical and Materials Engineering Vol:18, No:10, 2024 publications.waset.org/10013859.pdf

***Abstract*—**The research presents an extensive analysis of the Engineering Drawing and Design (EDD) table's design and development, accentuating its convertible utility and ergonomic design principles. Through the amalgamation of advanced design methodologies with simulation tools, this paper explores and compares the structural integrity of the EDD table, considering both linear and nonlinear stress behaviors. The study evaluates stress distribution and deformation patterns using the Finite Element Method (FEM) in Autodesk Fusion 360 CAD/CAM software. These analyses are critical to maximizing the durability and performance of the table. Stress situations are modeled using mathematical equations, which provide an accurate depiction of real-world operational conditions. The research highlights the EDD table as an innovative solution tailored to the diverse needs of modern workspaces, providing a balance of practical functionality and ergonomic design while demonstrating cost-effectiveness and time efficiency in the design process.

***Keywords*—**Parametric modelling, Finite element method, FEM, Autodesk Fusion 360, stress analysis, CAD/CAM, computer aided design, computer-aided manufacturing.

I. INTRODUCTION

IN the modern world, where drawing, designing, and painting are integral parts of various professions and hobbies, and to do so, people need furniture, the design of furniture plays an important role in increasing productivity, comfort, and health for any user. Traditional tables are widely used, but they are not ergonomically designed. Any user needs adaptability and ergonomic support for long-term work without causing discomfort or strain on their body.

In today's era, users require furniture that offers adaptability and ergonomic support for extended periods of use, ensuring comfort and minimizing strain on the body [11]. With the evolving nature of workspaces and environments, like flexible arrangements and multiple modes, the need for furniture that can smoothly adjust to different needs and preferences has become vital. To do so, the EDD table stands out as a versatile solution [3], [9].

In today's market, there are multiple tables available, but they are not ergonomically designed and are highly adjustable for multiple uses and users. To resolve this issue, the EDD table's ergonomic design and convertible feature help the user do their tasks for longer durations with comfortable support, creating an insightful environment [5].

Drawing, designing, and painting require a stable and comfortable surface that supports the creative process without causing discomfort or fatigue. The ergonomic design of the table fulfils these needs by providing a workspace that adapts to the user's posture. The convertible feature of these tables allows them to fit in less space after usage. Every professional has dedicated tools for their specific tasks. The modelling of the EDD table is considered for those professionals. In addition, the convertible feature adds the comfort of convenience and flexibility, especially for those who prefer to work while sitting [10].

This research paper explores the design and development of the EDD table, focusing on its ergonomic principles and convertible functionality with its structural analysis to analyze the strength of the model. This table is a combination of innovative design and practical functionality. It represents a significant advancement in workspace furniture, giving a diverse advantage to professionals and enthusiasts.

II. DESCRIPTION

The objective is to create a versatile and inclusive solution. Within the sketch, integration is needed for various components. Specific spaces were designated for accessories, ensuring easy access and organization for users. The required features with ergonomic principles are considered while modelling.

A. Ideation

The ideation process for the EDD table began by identifying the challenges prevalent in traditional workspace tables, such as limited adaptability, insufficient storage options, discomfort during extended use, and organizational inefficiencies. This initial analysis paved the way for a comprehensive understanding of user needs, encompassing ergonomic requirements, versatile functionality, efficient storage solutions, and a clutter-free workspace to maximize usability. Through a series of brainstorming sessions, ideas were generated to address these challenges, leading to concepts that provide adjustability, ergonomic comfort, integrated storage,

Nitesh Pandey, Student, Manish Kumar, Student, Dr. Amit Kumar Srivastava, Assistant Professor, Dr. Pankaj Gupta, Assistant Professor are with the Jaypee University of Engineering and Technology, Guna, Madhya Pradesh, India (e-mail: niteshpandey46974@gmail.com).

and intuitive organization of tools and materials for different workspaces [3], [10].

Modelling and user testing played a crucial role in refining these concepts and ensuring that the final design of the EDD table meets real-world usability standards. Material selection focused not only on durability and functionality but also on sustainability, with an emphasis on eco-friendly options like wood with carbon sequestration properties. That's why wood, aluminum, steel, and plastic are the main components of a table. The integration of technology, consideration of aesthetic appeal, and standards into an iterative design process further enriched the ideation journey, resulting in a well-documented and optimized solution [2].

B. Conceptual Drawing and Sketching

The conceptual drawing and sketching process for the EDD table as shown in Fig. 1, began by gathering all essential components needed in the table. The sketch for the EDD table was guided by a clear vision, each requirement had to be met with precision.

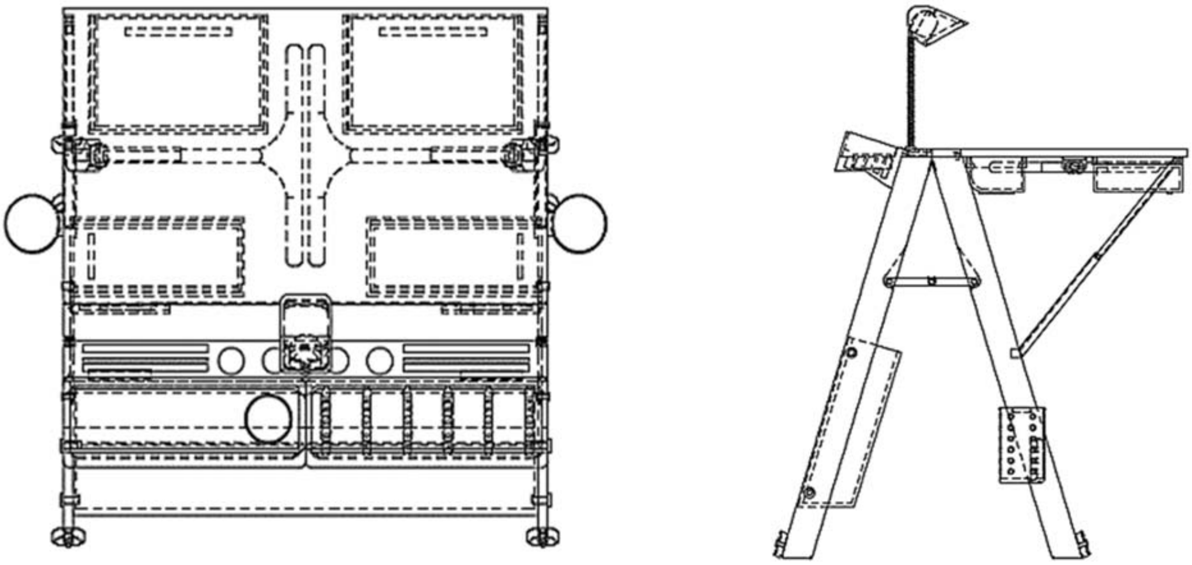


Fig. 1 Line Diagram of table

C. Design and Feature Integration

The EDD table is crafted using Autodesk Fusion 360 software, known for its capabilities in 3D modelling, simulation, and animation. The goal is to seamlessly translate intricate designs into a functional and visually appealing product by prioritizing quality and durability and selecting materials that meet the standards of luxury furniture. Using Fusion 360's color presets, each component of the table is represented in different colors, aiding in visual differentiation during the design process [1], [2].

The EDD table is innovatively designed furniture that combines ergonomic functionalities to create a comfortable and efficient workspace. This desk features four legs, each attached to wheels, which allows the table for easy movement and repositioning. When the legs are folded vertically, the table can be easily moved to different locations, occupying very little space to move and being easily movable in compact spaces with the help of wheels, making it ideal for dynamic work environments in confined areas. The EDD table offers mobility and flexibility without compromising on functionality or strength [3]-[5]

The addition feature of the EDD table includes an attached cabinet section with front legs, offering convenient storage for various items such as bags, books, and other stationary accessories. Moreover, the desk's writing area is externally connected to a mechanism that enables it to fold up to 90 degrees, which makes the desk fold seamlessly from a horizontal to a vertical position, which is a great help for space optimization.

More features of the EDD table include various spaces to carry necessary things while working, like a bottle stand, pen-and-pencil stand, brush stand, etc., which help users organize their workspace efficiently. The desk also includes a study lamp as a light source, which ensures efficient lighting for working or studying [3].

Furthermore, the upper part of the desk is detachable and can be converted into a study table for those who like to work while sitting on the ground or in beds. Its unique design provides users with a comfortable and ergonomic workspace even in unconventional settings. This feature enhances the desk's usability, allowing it to adapt to different environments and user preferences. Additionally, two foldable legs underneath the desk provide additional stability when working while sitting, ensuring a secure and comfortable experience. This detachable table explicitly contains drawers, which makes this table unique [3], [11].

Open Science Index, Mechanical and Materials Engineering Vol:18, No:10, 2024 publications.waset.org/10013859.pdf

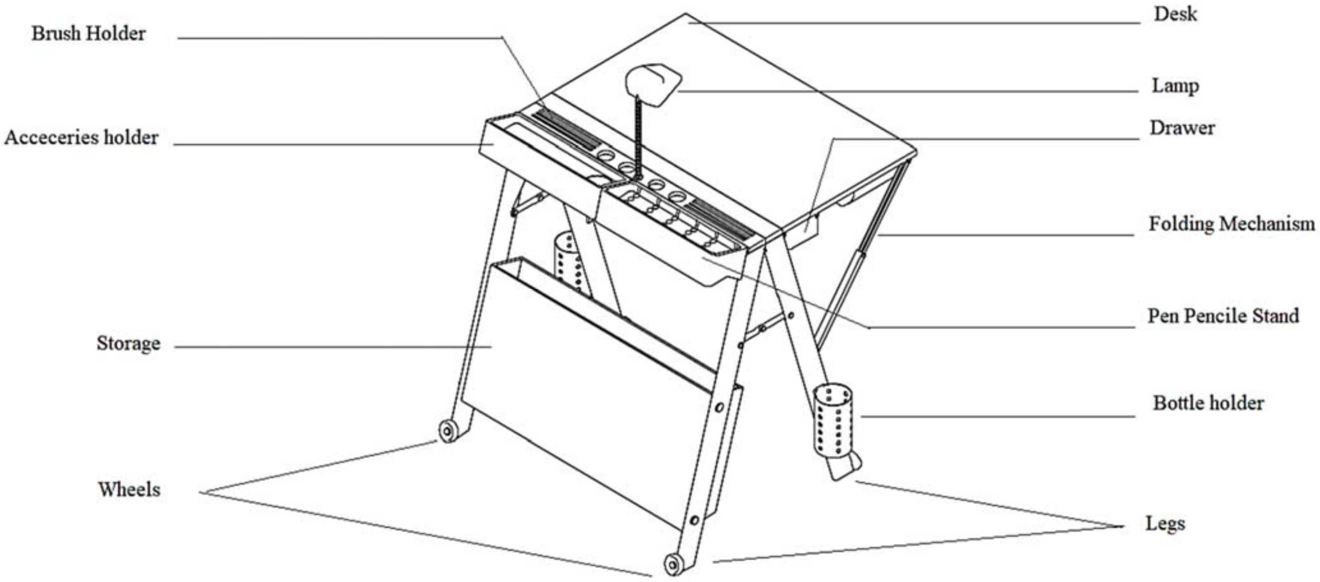


Fig. 2 Labelled diagram of table

III. METHODOLOGY

A. *Procedure for Finite Element Analysis and Design Optimization*

Finite Element Analysis (FEA) is a critical tool in developing the EDD Table, ensuring its structural integrity and optimal performance across various conditions. This analysis method is essential for evaluating the table's behavior, identifying potential weaknesses, and making informed design choices.

The process of utilizing FEA in the EDD Table's development starts with a deep understanding of the problem at hand. This step lays the groundwork for generating innovative ideas that evolve into solid design concepts. Understanding the problem involves identifying key requirements like load-bearing capacity, durability, and ergonomic considerations.

Translating these ideas into tangible concepts is facilitated by digital tools such as Autodesk Fusion 360 CAD/CAM software. These tools enable designers and engineers to create detailed 3D models of the EDD Table, incorporating various design elements and functionalities.

FEA is instrumental during the design phase, providing a thorough analysis of the table's structural behavior. This analysis covers crucial aspects such as stress distribution, deformation patterns, and load-bearing capacities, enabling designers to assess the table's performance under real-world conditions.

An advantage of FEA is its ability to simulate different materials and geometries. Materials like steel, aluminum, and plastic are typically considered, with each material offering unique properties. Simulating these materials in FEA allows designers to optimize performance while minimizing material usage and production costs.

The FEA process begins by importing the CAD model into the simulation environment. Designers then select appropriate analysis types, such as static stress or nonlinear stress analysis, based on project requirements. Suitable materials are chosen for analysis, and mesh analysis is conducted to accurately define the simulation elements.

FEA also allows designers to apply constraints like load and boundary conditions, replicating real-world scenarios accurately. This ensures that the analysis results are reliable and reflective of actual usage conditions.

Autodesk Fusion 360 CAD/CAM software is preferred for conducting FEA analysis for the EDD Table due to its advanced modelling and simulation capabilities. This software enables designers to gain a comprehensive understanding of the table's performance, contributing to a systematic and rigorous product design approach.

Overall, integrating FEA into the EDD table's development ensures structural robustness, performance optimization, and cost-effectiveness, culminating in a high-quality product for end users.

B. *Applying FEA on Table*

All the table components are introduced, and the initial design as shown in Fig. 4 is presented for FEA. The goal is to optimize the design for enhanced structural performance, usability, and deformation of material.

C. *FEA Defining Procedure*

To begin a Finite Element Analysis (FEA) in Fusion 360, we start by launching the software and opening the design file. In the Simulation workspace, we initiate the FEA by selecting "New Study" or "New Material Study." For the analysis type, "Static Stress" is chosen to evaluate the structural behavior under static loads. For scenarios requiring more complexity, "Nonlinear Static Stress" is selected to account for non-linear material properties or large deformations. Static analysis is commonly used to examine how a structure responds to applied loads, without considering the effects of time or the rate of loading. It is suitable for analyzing steady-state conditions where the applied loads do not vary significantly over time.

Open Science Index, Mechanical and Materials Engineering Vol:18, No:10, 2024 publications.waset.org/10013859.pdf

That is why it is necessary for applying on EDD table. While on the other hand nonlinear analysis is used when the behavior of the material or structure shows nonlinear characteristics, such as large deformations, material yielding, or contact interactions, this analysis is useful to know how table will perform in real scenario.

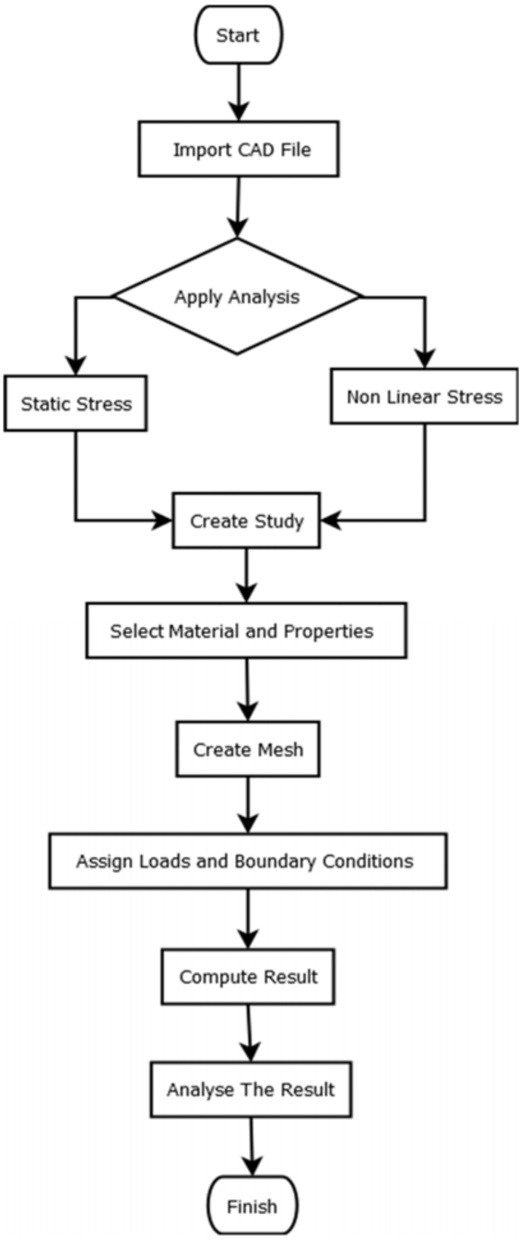


Fig. 3 Work Flow Chart

Next, we assign the material for the study, making sure to accurately represent it by assigning key material properties like Young's Modulus and Poisson's Ratio. We introduce external forces by applying loads, such as a vertical structural load on the table desk. To specify the load magnitude, we convert the weight to Newtons, taking gravitational acceleration into account. Additionally, we include the effects of gravity by applying a downward load based on the gravitational acceleration of 9.8 m/s², as shown in Fig. 5.

Fig. 4 EDD Table Design

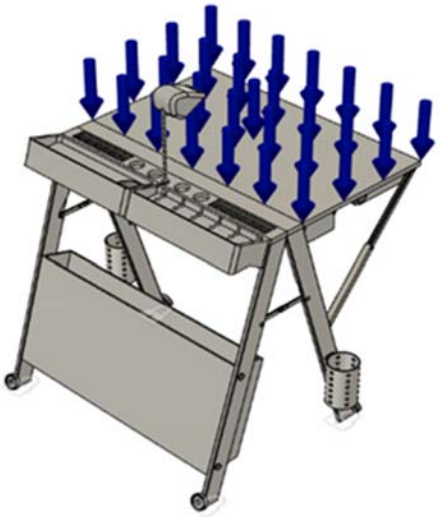


Fig. 5 Structural load

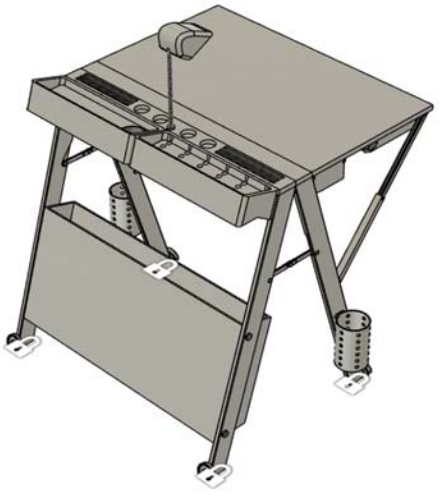


Fig. 6 Structural constraints

Once the analysis is complete, we compile a detailed report summarizing the FEA results, highlighting key findings, and offering recommendations for design improvements if needed. Following this systematic approach ensures a detailed and well-documented record of the FEA conducted in Fusion 360.

IV. MATHEMATICS

A. Linear Stress Analysis Equation

The stress (σ) experienced by a material due to an applied force (F) over its cross-sectional area (A) can be represented by [6]:

$$\sigma = F/A \tag{1}$$

B. Nonlinear Stress Analysis Equation (Von Mises Criterion)

$$\sigma VM = \sqrt{\frac{3}{2}\sum_{i=1}^{13}(\sigma_i - \sigma_{avg})^2} \tag{2}$$

The von Mises stress (σVM) is calculated using the von Mises criterion, which assesses material failure based on the principal stresses (σ_i) and their average (σ_{avg}) [7].

C. First Principal Stress (Maximum)

$$\sigma_1 = \frac{\sigma_{max}{++}\ \sigma_{min}}{2} + \sqrt{(\frac{\sigma_{max}{++}\ \sigma_{min}}{2})^2 + \tau^2{}_{max}} \tag{3}$$

The maximum principal stress (σ_1) is determined using the maximum and minimum normal stresses ($\sigma_{max} + + \sigma_{min}$) along with the maximum shear stress (τ_{max}).

D. Third Principal Stress (Minimum)

$$\sigma_3 = \frac{\sigma_{max}{++}\ \sigma_{min}}{2} - \sqrt{(\frac{\sigma_{max}{++}\ \sigma_{min}}{2})^2 + \tau^2{}_{max}} \tag{4}$$

The minimum principal stress (σ_3) is calculated similarly to the first principal stress equation, using the same principles.

E. Deformation Equation (Linear Elasticity)

Strain (ε) experienced by a material due to a change in length (ΔL) relative to its original length (L) under linear elasticity assumptions is given by [8]:

$$\varepsilon = \frac{\Delta L}{L} \tag{5}$$

F. Linear Deformation (Hooke's Law)

Hooke's Law describes the linear relationship between stress (σ) and strain (ε) within the elastic limit of a material:

$$\sigma = E.\varepsilon \tag{6}$$

where σ: Stress applied to the material (in Pa or N/m²), ε: Resulting strain (dimensionless), E: Young's modulus or elastic modulus of the material (in Pa or N/m²).

G. Non-linear Deformation

Non-linear deformation occurs when the material behavior deviates from Hooke's Law, typically beyond the elastic limit. The stress-strain relationship can be expressed using the Ramberg-Osgood equation:

$$\sigma = K.\varepsilon^n \tag{7}$$

where σ: Stress applied to the material (in Pa or N/m²), ε: Resulting strain (dimensionless), K: Material constant (in Pa or N/m²), n: Strain-hardening exponent, representing the material's resistance to deformation.

H. FEA Equation

In Finite Element Analysis (FEA), the relationship between nodal displacements ([u]), the global stiffness matrix ([K]), and applied nodal forces ([F]) is expressed as:

$$[K].[u] = [F] \tag{8}$$

This equation is used to solve for nodal displacements, providing insights into structural deformation and behavior [6].

I. Error Rate Calculation

$$\text{Error} = \frac{\text{Experimental Value} - \text{Theoretical Value}}{\text{Theoretical value}} \times 100 \tag{9}$$

where Theoretical Value: the value predicted by the FEA analysis, Experimental Value: the value obtained from physical testing or real-world observation.

The EDD table's structural behavior, stress distribution, and deformation patterns can all be thoroughly analyzed and understood thanks to these equations, which makes it easier to optimize the table's performance and design.

V. RESULT AND DISCUSSION

A. Stress Analysis

The Fusion 360 analysis for the static stress of the EDD table design provided crucial information about its structural behavior under specific conditions. The study focused on a 1:1 simulation model, utilizing materials such as aluminum, plastic, and steel. Steel, known for its density of 7.850E-06 kg/mm³, Young's modulus of 210,000.00 MPa, Poisson's ratio of 0.30, and yield strength of 207.00 MPa, was chosen for its strength and suitability for structural applications. The analysis aimed to evaluate the table's performance and safety under various loads and constraints, which helped find the deformation point in the table. In addition to experiencing significant deformation or loading conditions that may lead to nonlinear material behavior, Nonlinear analysis is also applied to the table, which allows consideration of material nonlinearities such as plasticity, large deformations, and contact, which can be crucial for accurately predicting the structural response of the table.

B. Mesh

To understand how the table responds to stress, parameters like mesh need to be configured. The average element size, designated as 10% of the overall model size, plays a key role in determining the analysis's level of detail and precision. The decision not to scale mesh size per part simplifies the meshing process, maintaining uniformity. Employing parabolic elements improves the accuracy of the mesh representation,

Open Science Index, Mechanical and Materials Engineering Vol:18, No:10, 2024 publications.waset.org/10013859.pdf

especially for complex geometries.

TABLE I
MESH OUTCOME

Average Element Size (% of model size)	
Solids	10
Scale mesh size per part	No
Average element size (absolute value)	-
Element order	Parabolic
Create curved mesh elements	No
Max. Turn angle on curves (deg.)	60
Max. Adjacent mesh size ratio	1.5
Max. Aspect ratio	10
Minimum element size (% of average size)	20

While not creating curved mesh elements, allowing curves to bend up to 60 degrees ensures that the mesh conforms well to curved surfaces. The maximum adjacent mesh size ratio of 1.5 enables a gradual transition between different mesh densities, enhancing the overall mesh quality. A maximum aspect ratio of 10 prevents excessive element stretching, maintaining mesh integrity.

Setting the minimum element size to 20% of the average size prevents the generation of overly small elements that could impact analysis accuracy. This analysis does not employ adaptive mesh refinement, as indicated by zero refinement steps, which simplifies the meshing process without sacrificing accuracy.

TABLE II
ADAPTIVE MESH REFINEMENT

Number of Refinement Steps	0
Results Convergence Tolerance (%)	20
Portion of Elements to Refine (%)	10
Results for Baseline Accuracy	von Mises Stress

The convergence tolerance for results is set at 20%, ensuring that the analysis concludes when results are within this percentage of convergence. In a scenario involving mesh refinement, 10% of the elements would undergo refinement based on the results. Prioritizing von Mises stress as the baseline accuracy parameter acts as a primary indicator of potential material failure under applied loads.

C. Material

The material specifications used in the Fusion 360 analysis, particularly for the table design, are important for understanding its structural response to stress. The chosen materials include steel, aluminum, and plastic, each with unique properties. Steel has a density of 7.850E-06 kg/mm³, Young's Modulus of 210,000.00 MPa, Poisson's Ratio of 0.30, yield strength of 207.00 MPa, ultimate tensile strength of 345.00 MPa, thermal conductivity of 0.056 W/(mm°C), thermal expansion coefficient of 1.200E-05/°C, and specific heat of 480.00 J/(kg°C). Aluminum features a density of 2.700E-06 kg/mm³, Young's Modulus of 68900.00 MPa, Poisson's Ratio of 0.33, yield strength of 275.00 MPa, ultimate tensile strength of 310.00 MPa, thermal conductivity of 0.23 W/(mm°C), thermal expansion coefficient of 2.360E-05/°C, and specific heat of 897.00 J/(kg°C). Plastic, on the other hand, has a density of 1.290E-06 kg/mm³, Young's Modulus of 709.00 MPa, Poisson's Ratio of 0.40, yield strength of 30.00 MPa, ultimate tensile strength of 40.00 MPa, thermal conductivity of 2.500E-04 W/(mm°C), thermal expansion coefficient of 4.190E-05/°C, and specific heat of 1750.00 J/(kg°C). Steel, aluminum, plastic are necessary components for manufacturing the EDD table, mainly tradition table are made with woods which are strong but not that durable, as the technology grows new materials are introduced because of their properties, while in case of EDD table all the material which are chosen are affordable, strong, easily available and maintainable, in addition they are high durable and strong.

The meshing process utilized an average element size of 10% of the model size for solids, resulting in 439190 nodes and 235449 elements. The study, set for static stress analysis, incorporated contact tolerances of 0.10 mm and gravitational effects with a magnitude of 9.807 m/s² in the downward direction.

TABLE III
STEEL PROPERTIES

Density	7.850E-06 kg/mm^3
Young's modulus	210000.00 MPa
Poisson’s ratio	0.30
Yield strength	207.00 MPa
Ultimate tensile strength	345.00 MPa
Thermal conductivity	0.056 W/(mm °C)
Thermal expansion coefficient	1.200E-05/°C
Specific heat	480.00 J/(kg °C)

TABLE IV
ALUMINUM PROPERTIES

Density	2.700E-06 kg / mm^3
Young's modulus	68900.00 MPa
Poisson’s ratio	0.33
Yield strength	275.00 MPa
Ultimate tensile strength	310.00 MPa
Thermal conductivity	0.23 W / (mm C)
Thermal expansion coefficient	2.360E-05 / C
Specific heat	897.00 J / (kg C)

TABLE V
PLASTIC PROPERTIES

Density	1.290E-06 kg / mm^3
Young's modulus	709.00 MPa
Poisson’s ratio	0.40
Yield strength	30.00 MPa
Ultimate tensile strength	40.00 MPa
Thermal conductivity	2.500E-04 W / (mm C)
Thermal expansion coefficient	4.190E-05 / C
Specific heat	1750.00 J / (kg C)

These material characteristics are vital inputs for the FEA, determining how each material behaves under various conditions. They influence mass, elasticity, deformation under stress, resistance to permanent deformation, maximum stress endurance, and the material's response to temperature changes. Accurate material properties enhance the simulation's precision, providing valuable insights into the table's structural integrity and performance under static stress conditions.

D. Load Case1

Constrains

In Fusion 360 analysis, Load Case 1 involves fixed constraints denoted as Fixed1, aiming to replicate immobility within structural elements. These constraints are set as fixed in the X, Y, and Z directions. The imposition of these constraints in the FEA ensures an accurate portrayal of static stress conditions, enabling a realistic simulation of the table's response to applied loads. This methodology enhances analytical precision, facilitating a comprehensive exploration of structural integrity and potential stress points inherent in the design.

Gravity

In Fig. 7, a gravity load of 9.807 m/s^2 is applied to simulate the impact of gravitational forces on the table structure. Specified as acting in the negative Z-direction, this load type accurately represents the acceleration due to gravity.

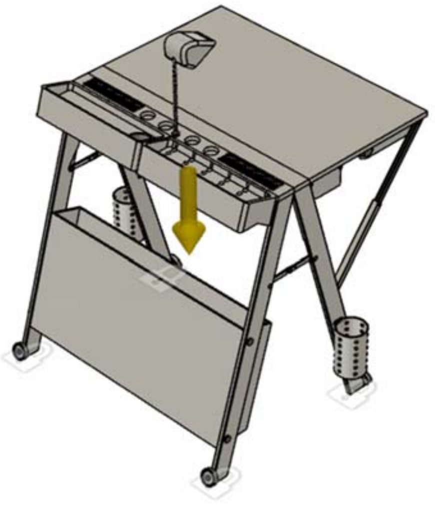


Fig. 7 Selected entity for gravity

TABLE VI
Brief Description of Gravitational Load

Type	Gravity
magnitude	9.807 m/s^2
x value	0.00 m/s^2
y value	0.00 m/s^2
z value	-9.807 m/s^2

This inclusion in the FEA ensures a realistic assessment of the table's response to external forces, contributing to the precision of the simulation under static stress conditions. By mimicking real-world gravitational effects, this approach enhances the overall accuracy of the analysis, providing valuable insights into the structural behavior of the table when subjected to varying loads.

Force

In the Fusion 360 analysis, a force load is implemented to simulate a vertical force on the table's desk area, as seen in Tables VIII and IX. To get more accuracy about the strength of the table, a magnitude of 294.00 N and 600N force applied in the negative Z-axis direction mimics an external load acting downward.

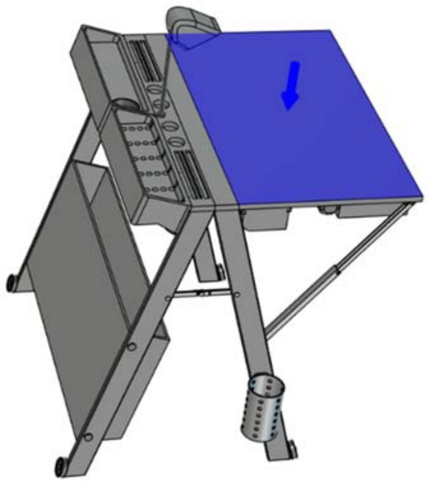


Fig. 8 Selected entity for applied force

TABLE VII
Brief Description of Applied Force (30 kg)

Type	Force
magnitude	294.00 N
x value	0.00 N
y value	0.00 N
z value	-294.00 N
Force Per Entity	No

TABLE VIII
Brief Description of Applied Force (60 kg)

Type	Force
magnitude	600.00 N
x value	0.00 N
y value	0.00 N
z value	- 600.00 N
Force Per Entity	No

In both scenarios, weights of 30 kg and 60 kg are applied to the table to assess its strength. The 30 kg weight represents the average load that a person might exert on the table during regular use, either directly or indirectly. The 60 kg weight is used to evaluate the table's deformation under heavier loads, ensuring it can withstand more significant stress without compromising its structural integrity.

E. Result Summary

The Fusion 360 analysis results offer extensive insights into the table's structural performance under various stress conditions, including static and nonlinear static stress. The safety factor, a crucial measure of structural robustness, is graphically represented in Fig. 9 and ranges from 0.044 to 15.00.

Open Science Index, Mechanical and Materials Engineering Vol:18, No:10, 2024 publications.waset.org/10013859.pdf

A safety factor of 15.00 indicates a substantial margin of safety, reflecting a high level of confidence in the structure's safety and reliability. Conversely, a safety factor of 0.044 raises significant concerns, indicating potential weaknesses that must be addressed to ensure the structure's safety and reliability.

These findings underscore the necessity of conducting thorough structural analyses using advanced tools like Fusion 360. By assessing safety factors and pinpointing areas for enhancement, designers can effectively improve the table's structural integrity and overall performance, ensuring its long-term durability and safety.

In Fig. 10 stress analysis, represented by von Mises stress and principal stresses, unveils the distribution of forces within the table's structure. In Fig. 10 (a), blue denotes minimal stress, red signifies high pressure (up to 4678.371 MPa). For nonlinear static stress range is from 0.00 MPa to 694.571 MPa in Fig 10 (b).

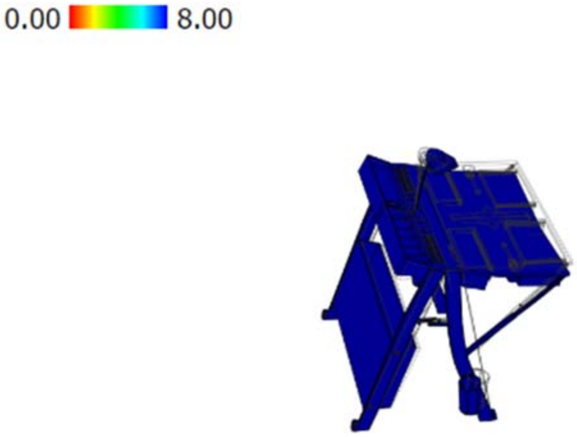
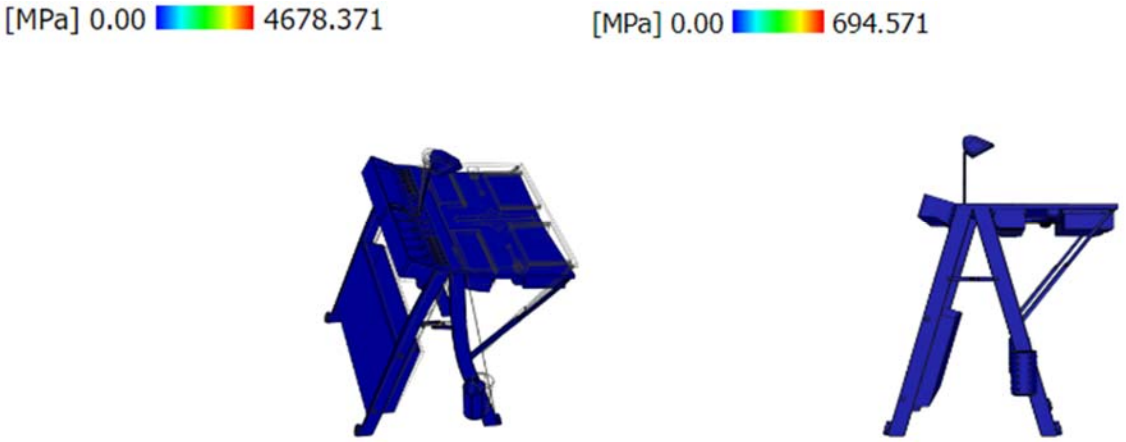
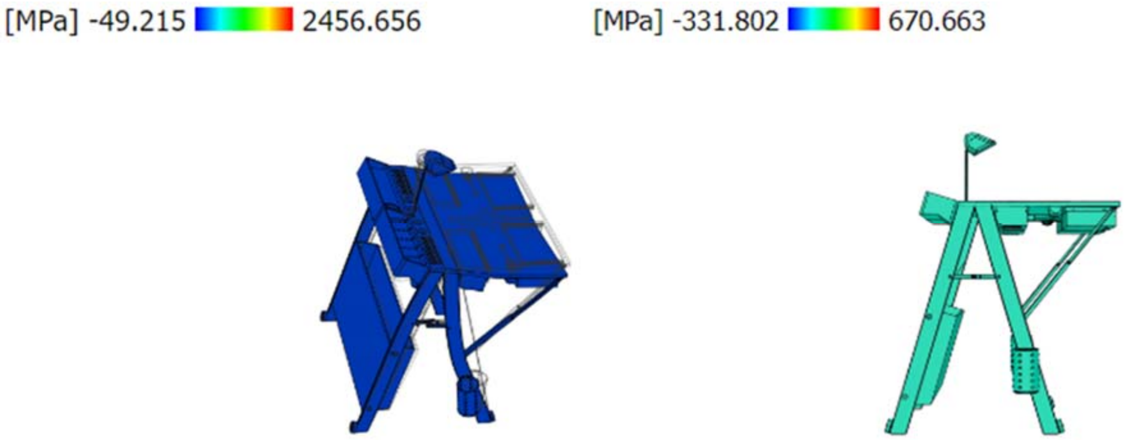


Fig. 9 Safety Factor (Per body)



(a) (b)

Fig. 10 (a) Most affected areas are desk and legs which makes table to bend downward and in forward direction, and 10 (b) Von stress

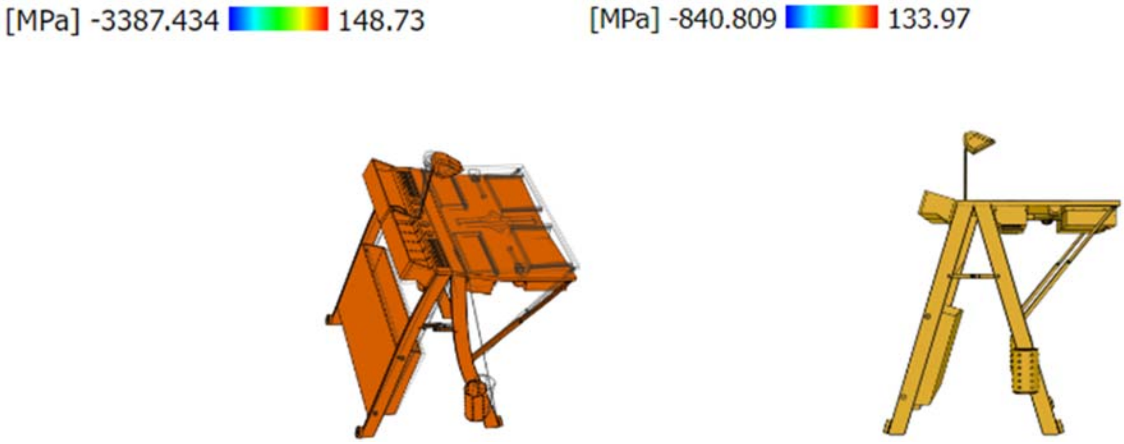


(a) (b)

Fig. 11 (a) Most affected areas are desk and legs which makes table to bend downward and in forward direction, and 11 (b) 1st Principal

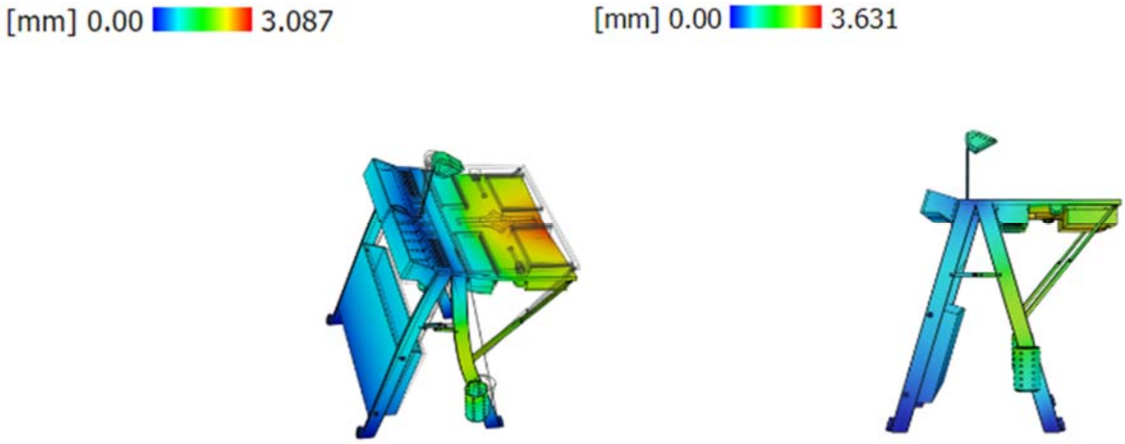
Fig. 11 (a) illustrates 1st Principal stress ranging from -49.215 MPa to 2456.656 MPa. Here blue indicates minimum stress and red indicates maximum stress. But here table, as shown in the figure, shows a different color which is mixture of blue and cyan gives an increased stress then minimum and the area with max load is surface and legs. The nonlinear static stress range extends from -331.802 MPa to 670.663 MPa, as illustrated in Fig. 11 (b). This range is depicted by a mixture of yellow and green colors, indicating a median stress level between the minimum and maximum values.

In Fig. 12 (a), the 3rd Principal stress values range from -3387.434 MPa (minimum) to 148.73 MPa (maximum). The table's stress distribution, shown in a mixture of red and yellow, indicates stress levels below the maximum, resulting in an orange coloration and max affected areas are desk and legs. For the nonlinear static stress in Fig. 12 (b), the range extends from -840.809 MPa to 133.97 MPa. The stress is above the median value, as indicated by the predominant yellow color uniformly throughout the structure.



(a) (b)

Fig. 12 (a) Most affected area of table, (b) 3rd Principal



(a) (b)

Fig 13 (a) Most affected area of table, (b) Displacement

In Fig. 13 (a), displacement values indicate the degree of deformation, with total displacement ranging from 0.00 mm to 3.087 mm in various directions. And in Fig. 13 (b), the nonlinear range is from 0.00 mm to 3.631 mm. In Fig. 13, the front part of the table is shown in blue and cyan, indicating minimum stress in this area, while the desk area indicates maximum displacement in the center part and less in the corners, as indicated by transitions of red, yellow, and green. As we move downward, the color transitions to yellow, green, and blue, signifying progressively less displacement on the edges and more displacement on the center of the leg.

These results, depicted in detail in Table IX, provide a thorough overview of the table's FEA results, giving us valuable insights into how it handles different loads. The safety factor, ranging from 0.022 to 15.00, shows how well the design can handle applied loads, ensuring there's a safety margin. A higher safety factor means a stronger design with more safety against potential issues. The von Mises stress, ranging from 0.00 MPa to 4678.371 MPa, is crucial for understanding material strength. The values for the 1st and 3rd principal stresses, along with normal and shear stresses, explain how stress is distributed within the table. Negative principal stresses indicate areas under compression. Displacement values, from 0.00 mm to 3.087 mm, tell us how much the table deforms under the applied loads. Detailed data along the X, Y, and Z axes help us understand the direction and number of deformations. Reaction forces at different points of the chair, along the X, Y, and Z axes, show how the table responds to external loads. These values give insights into the forces exerted on the table's structure. Strains showing material deformation are presented as equivalent, principal, and normal strains. These values help assess the extent of material deformation. Contact pressure, ranging from 0.00 MPa to 1534.714 MPa, reveals how pressure is distributed at contact points. Contact forces along the X, Y, and Z axes help understand interactions between different parts, which is crucial for spotting stress concentration and potential failure points. These detailed numerical data give a clear picture of how the table reacts to external forces. The safety factor ensures a safety margin, stress distribution identifies critical points, displacement reveals deformations, reaction forces show load-bearing capacity, strain assesses material deformation, and contact pressure and force unveil crucial contact points. These results empower designers to enhance the table's design for better structural performance and reliability.

F. Deformation

The analysis of deformation in the table design has resulted in five different images, each depicting the table's response to different levels of deformation. These visuals are invaluable in comprehending how the table behaves under various conditions, offering crucial insights for design decisions and structural optimization.

The initial image, labelled "Actual" in Fig. 14 (a), represents the table's baseline deformation without any adjustments. This serves as a reference point for comparing the impacts of different deformation levels. In contrast, Fig. 14 (b) displays the table's response to 0.5 times the baseline deformation, labelled "Adjusted 0.5x." Here, a slight downward bend indicates a moderate response to deformation.

Moving forward, Fig. 14 (c), labelled "Adjusted," illustrates the table's behavior with standard deformation, providing clarity on its typical structural response under normal conditions.

Fig. 14 (d), labelled "Adjusted 2x," exhibits the table's reaction to twice the baseline deformation, displaying a more noticeable downward bend and a significant response to increased deformation levels. Lastly, Fig. 14 (e), labelled "Adjusted 5x," reveals the table's behavior under five times the baseline deformation, highlighting a substantial downward bend and increased vulnerability to deformation.

These visual representations provide a critical understanding of how the table structure reacts to varying deformation levels. They equip designers with essential insights for informed decisions regarding reinforcement or optimization strategies. Through thorough analysis of these images, designers can pinpoint areas where the table may require strengthening or modifications to ensure stability and structural integrity, ultimately improving the overall quality and durability of the table design.

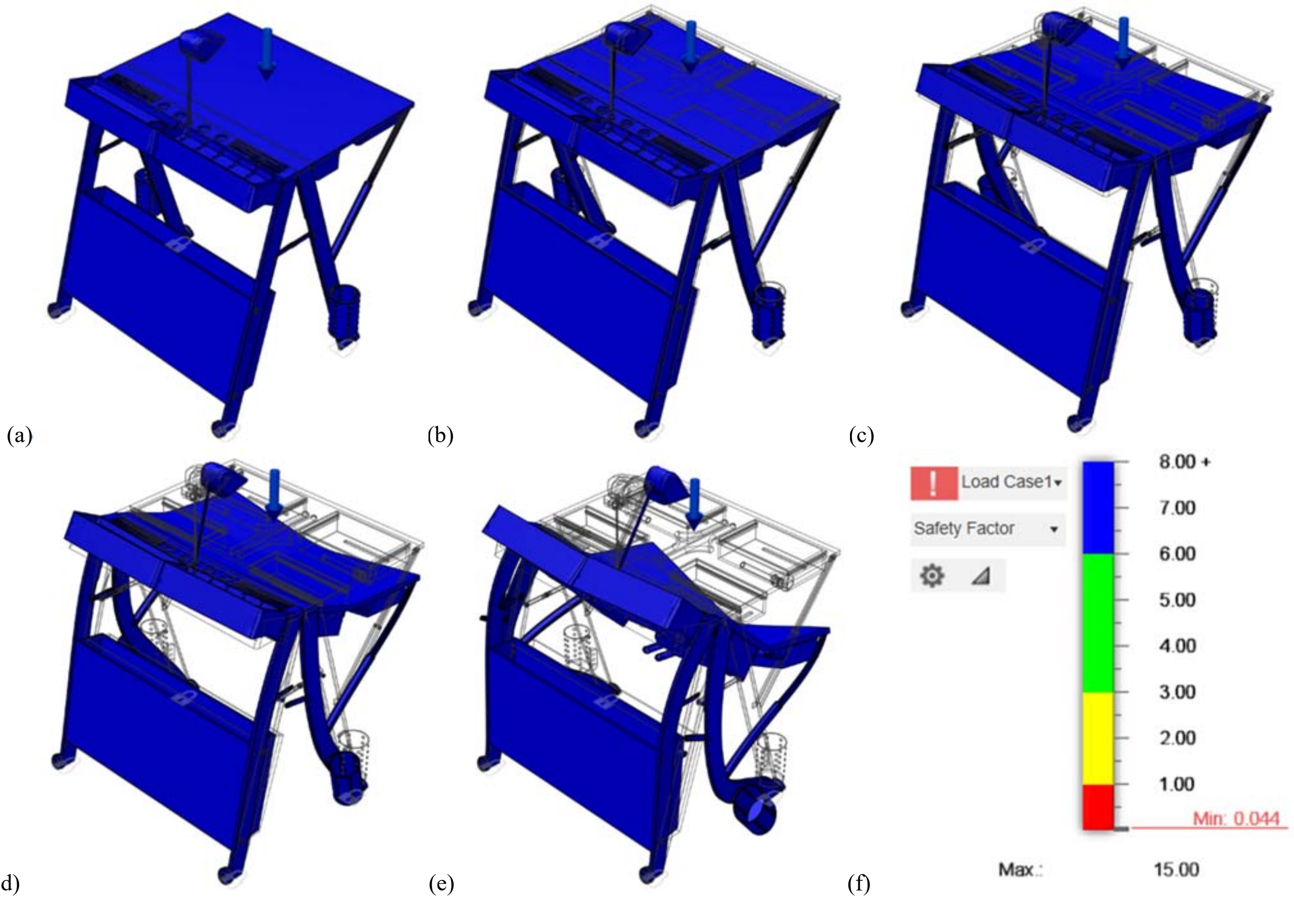
VI. CONCLUSION

The conclusions drawn from this research are summarized as follows since it is focused on identifying the need of the convertible table and modelling and innovative product:

TABLE IX
BRIEF DESCRIPTION OF RESULT OUTCOME

Name	Minimum	Maximum
	safety factor	
safety factor (per body)	0.022	15.00
	Stress	
von mises	0.00 MPa	9547.757 MPa
1st principal	-100.44 MPa	
3rd principal	-6913.178 MPa	303.532 MPa
normal xx	-1949.053 MPa	1050.256 MPa
normal yy	-870.847 MPa	1886.496 MPa
normal zz	-861.31 MPa	909.809 MPa
shear xy	-5344.053 MPa	5473.322 MPa
shear yz	-270.624 MPa	521.48 MPa
shear zx	-1651.008 MPa	1674.979 MPa
	displacement	
total	0.00 mm	6.301 mm
x	-1.407 mm	1.436 mm
y	-3.764 mm	2.795 mm
z	-6.296 mm	1.507 mm
	reaction force	
total	0.00 N	56.30 N
x	-6.909 N	6.08 N
y	-3.779 N	2.525 N
z	-28.335 N	56.245 N
	strain	
equivalent	0.00	0.078
1st principal	-7.128E-06	0.066
3rd principal	-0.071	7.246E-06
normal xx	-0.007	0.005
normal yy	-0.005	0.006
normal zz	-0.013	0.008
shear xy	-0.066	0.068
shear yz	-0.012	0.016
	contact pressure	
total	0.00 MPa	3132.092 MPa
x	-2000.787 MPa	3103.65 MPa
y	-2084.931 MPa	164.281 MPa
z	-678.754 MPa	354.639 MPa
	contact force	
total	0.00 N	1858.08 N
x	-680.73 N	939.446 N
y	-1737.268 N	1722.343 N
z	-1049.165 N	839.395 N

1. Leveraged FEA to analyze the structural integrity of the EDD table, ensuring its durability, materials, geometries and performance under various loading conditions and providing valuable insights into stress distribution, deformation patterns, and load-bearing capacities ensuring compliance with necessary standards.
2. Employed advanced deformation analysis techniques to comprehensively assess the EDD table's response to varying loads and usage scenarios, revealing insights into its deformation behavior under different conditions.
3. Safety factors ranging from 0.044 to 15.00 were achieved, affirming the structural robustness and providing a considerable margin of safety.



(a) (b) (c) (d) (e) (f)

Fig. 14 Deformation

4. Von Mises stress ranged from 4.426E-05 MPa to 21.219 MPa, unveiling forces within the structure and aiding in pinpointing areas of stress concentration.
5. EDD table deformations were examined during push/pull tests from 0.5x to 5x. Increasing force resulted in visible downward bending, guiding design enhancements for strengthened areas.
6. The wide range of 1st principal stress (-49.215 to 2456.656 MPa) indicates significant variation in structural response under different loading conditions. Nonlinear static stress range (-331.802 to 670.663 MPa) underscores the complex behavior, emphasizing the need for comprehensive analysis to ensure structural integrity and safety across scenarios.
7. The wide range of 3rd principal stress (-3387.434 to 148.73 MPa) and nonlinear static stress (-840.809 to 133.97 MPa) suggests diverse structural responses, with stress exceeding the median value. This highlights the complexity of behavior under varying conditions, necessitating careful consideration for structural integrity and safety.
8. Displacement ranges from 0.00 mm to 3.087 mm, and in non-linear analysis, it extends up to 3.631 mm.
9. Successfully employed EDD table to enhance productivity and comfort in various professional and hobbyist settings, recognizing its pivotal role in facilitating drawing, designing, and artistic activities

ACKNOWLEDGMENT

Funding: The present work has received no funds in any manner from any organization.

Conflicts of interest: The authors declare that they have no involvement in any organization or entity with any financial interest.

REFERENCES

[1] Mahto, H. K., Pandey, N., Mahalik, V., Shrivastava, A., Pandey, A., Tewari, P., ... & Gupta, P. Design and Analysis of the Component of Glass Cleaning Robot Using Generative Designing Module.
[2] Gupta, P., Srivastava, A., Pandey, N. (2024). 'Enhancing Hand Efficiency of Smart Glass Cleaning Robot through Generative Design Module'. World Academy of Science, Engineering and Technology, Open Science Index 206, International Journal of Mechanical and Industrial Engineering, 18(2), 29 - 36.
[3] Pandey, N., Kumar, M., Gupta, P., Srivastava, A. (2024). 'Modelling and Dimension Analysis of a Multipurpose Convertible Laptop Table Using Autodesk Fusion 360'. World Academy of Science, Engineering and Technology, Open Science Index 207, International Journal of Industrial and Manufacturing Engineering, 18(3), 93 - 102.
[4] Fariz, N., Amarta, Z., Hutasoit, N., & Amalia, D. (2023). Analysis Of Stress and Deformation in Parametric Furniture Using the Finite Element Method. In E3S Web of Conferences (Vol. 465, p. 02032). EDP Sciences.
[5] Staneva, N., Genchev, Y., & Hristodorova, D. (2017). FEM analysis of deformations and stresses of upholstered furniture skeleton made of scots pine and OSB. Int. J.—Wood Des. Technol, 6, 31-37.
[6] Prabowo, A. R., Ridwan, R., Tuswan, T., & Imaduddin, F. (2022). Forecasting the effects of failure criteria in assessing ship structural damage modes. Civil Engineering Journal, 8(10), 2053-2068.
[7] Dzulfiqar, M. F., Prabowo, A. R., Ridwan, R., & Nubli, H. (2021).

Assessment on the Designed Structural Frame of the Automatic Thickness Checking Machine–Numerical Validation in FE method. Procedia Structural Integrity, 33, 59-66.

[8] Bacthiar, M., Ridwan, B., & Prabowo, A. R. (2023, March). An Overview of Railway Damage with the Finite Element Analysis. In International Conference on Railway and Transportation (ICORT 2022) (pp. 3-12). Atlantis Press.

[9] Kassim, N. (2023). Development of Convertible Table and Shelf. Multidisciplinary Applied Research and Innovation, 4(4), 153-160.

[10] Astonkar, D. V., & Kherde, D. S. M. (2015). Development in various multipurpose furniture's by using space saving approach. on IRJET, 2(6), 257-264.

[11] Cheng, H. Y., Ng, P. K., Nathan, R. J., Saptari, A., Ng, Y. J., Yeow, J. A., & Ng, K. Y. (2021). The Conceptualisation and Development of a Space-Saving Multipurpose Table for Enhanced Ergonomic Performance. Inventions, 6(4), 67.