

# Structural Optimization of H-Type Press Table Design Parameters Using Taguchi Method and Finite Element Analysis

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## Abstract

*This study aims to analyse the influence of load variation, material type, and thickness on the Von Mises stress values of an H-type press table using Design of Experiments (DOE) based simulation approach. This study was conducted to determine the maximum strength of the press machine table design as an effort to prevent structural failure during the operation of the press machine. The “Smaller is Better” signal-to-noise (S/N) ratio criterion was applied to obtain the minimum stress value under loading conditions. Lower stress values indicate a safer load distribution, which can improve the safety factor of the H-type press machine table design. In this study, three load levels were used: 10, 20, and 30 tonnes; three material types: Mild Steel, High-Strength Steel, and Alloy Steel; and three variations in press table thickness: 30, 40, and 50 mm. The simulation results show that as the applied load increases, the Von Mises stress also increases. Changes in the thickness of the press table have the greatest influence on stability or response variation, while the material type has a relatively small influence compared to the other factors. Changes in thickness affect the Von Mises stress value depending on the material type, and vice versa. This indicates that the three parameters interact, meaning a change in one factor can produce different results depending on other conditions. The highest average stress value was obtained on the press table at 104.45 MPa for the combination of High-Strength Steel with a thickness of 30 mm and a load of 30 tonnes, while the lowest stress value of 21.97 MPa was obtained for Alloy Steel with a thickness of 50 mm and a load of 10 tonnes.*

**Keywords:** Design of Experiment, Von Mises Stress, Safety Factor

## 1. Introduction

Machinery and supporting systems are key factors in determining the capacity, precision and efficiency of manufacturing operations [1]. One example of a machine used in such processes is the hydraulic press. A hydraulic press is a machine used to apply compressive force to an object [2, 3]. The frame and cylinder are the main components of a hydraulic press

[4]. Press machines are used for the mass production of large quantities of goods quickly, accurately, and efficiently. This ranges from the cold working of low-carbon steel to other ductile materials [5]. A press machine consists of a frame, a table or support plate, and a reciprocating moving element called a ram, which applies force to the workpiece via specialized tools mounted on the ram and support plate. Press machines operate under

impact loads, so the frame and the structure are subjected to continuous tensile and bending stresses. Press machines are constantly subjected to stress, and as a result, structural failures frequently occur in the machine [6]. Analysis of the static stress distribution in a hydraulic press is essential for identifying potential critical areas at risk of material failure [7]. Structural analysis is also a vital part of identifying the design of a press machine [8].

The frame of a press machine serves a crucial function as the support point for various components therefore, it is essential to determine the stress distribution patterns and deflections caused by static loads on the frame [9]. Stress distribution can be calculated using analysis methods and the finite element method under different load conditions as considerations in the design process to obtain the optimal model [10]. Stress analysis using the finite element method in structural material simulation tests of the press machine frame are employed to analyse safety factors and loads to determine the maximum dynamic load that the press machine frame can withstand [11].

By using the stress analysis feature, which incorporates the Finite Element Analysis (FEA) method, outputs such as Von Mises stress, deflection (displacement), and safety factor can be determined [12]. This allows the critical values of the frame to be established, providing a reference to ensure it is safe for use [13]. This study combines the Taguchi Design of Experiment (DOE) method with Finite Element Analysis (FEA) to evaluate the interaction among three main parameters, namely loading variation, material type, and press table thickness, on the Von Mises stress value. The objective is to obtain the minimum possible stress distribution in the H-type press machine table design. This approach differs from previous studies, which mainly focused on analyzing stress distribution in the frame structure of press machines.

## 2. Methods

The research aims to determine the optimal design parameters for a press table using the Taguchi method, taking into account the effects of load variation, material type, and thickness by calculating the Von Mises stress values using the Finite Element Method (FEM).

From the finite element simulation data, the safety factor, stress, and displacement values were also obtained. It is hoped that the overall data generated will result in an optimal, efficient, and safe press table design for the applied working load. A flowchart is a diagram that serves to describe the sequence of operations in a working system [14]. The research flowchart used in this study is shown in Figure 1.

### 2.1. Taguchi

The Taguchi method is a technique designed to improve both product and process quality while minimising costs and resource usage. The Taguchi method is an example of fractional factorial design that utilises orthogonal arrays to reduce the number of experiments. The analytical tools used are ANOVA and the Signal-to-Noise Ratio. ANOVA is used to determine the factors influencing the response, while the Signal-to-Noise Ratio is used to determine the combination of factors affecting product performance to produce an optimal response [15].

The Taguchi method is frequently used to determine optimal quality in manufacturing processes with a single response [16]. The variables used in this study are three factors and three levels used to analyse the Von Mises stress values. As the objective of the optimisation is to minimise stress, the 'smaller-is-better' criterion for the Signal-to-Noise Ratio is employed. The three main factors influencing the Von Mises stress response are load, material type, and table

thickness. Each factor has three levels, as shown in Table 1.

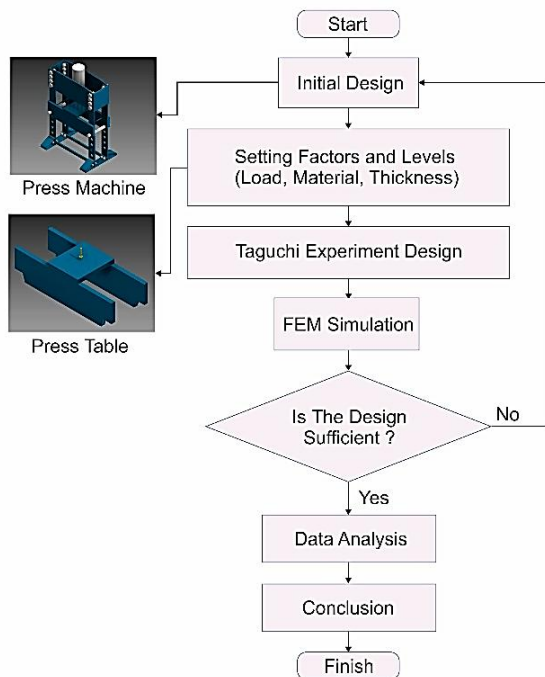


Figure 1. Research Flowchart.

Table 1. Design of Experiments (DOE)

Factor	Level 1	Level 2	Level 3
Load (t)	10	20	30
Material	Mild Steel	High-Strength Steel	Alloy Steel
Thickness (mm)	30	40	50

2.2. Finite Element Method (FEM)

Finite Element Method (FEM) is a numerical method aimed at obtaining an approximate solution to a partial differential equation. In the finite element method, the difficulties associated with numerical methods and the determination of boundary conditions can be overcome by dividing a continuum into small parts called elements, so that the solution in each small part can be expressed in a function that is far simpler than the function for the whole. These small

parts are mathematically linked to one another under conditions such that they are compatible and form a continuum between the small parts or elements [17].

Finite Element Analysis (FEA) is a computer-based numerical method used to solve problems such as calculating the strength and behaviour of engineering structures, including deflection, stress, vibration, bending behaviour and many other aspects. In Finite Element Analysis, the method employed involves breaking the structure down into small, simple elements [18]. In this study, the press machine design was created using an H-type configuration with a height of 1644 mm, a lateral width of 1000 mm and an internal width of 695 mm, with load points focused in two directions. The downward force direction refers to the press table, while the upward direction leads to the hydraulic section. These force directions can be seen in Figure 2.

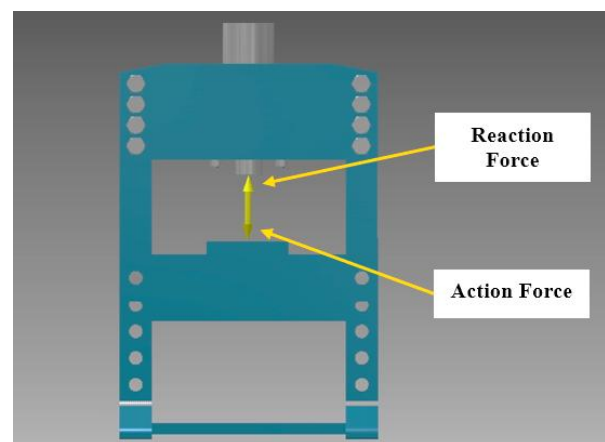


Figure 2. Press Machine Design.

The Von Mises stress is a process in which yielding occurs when the distortion energy or shear strain energy of the material reaches a critical value. The scalar stress value can be calculated from a strain gauge. In this case, the material is said to yield when the Von Mises stress reaches a critical value known as the yield strength [18]. If the Von Mises stress exceeds the material’s yield strength, the design will fail [19]. Displacement refers to the change in shape or deflection of a structure following the

application of a load [19]. Deformation occurs as a result of distributed forces, and when the load is removed, the shape returns to its original state. This is because, during the deformation process, the material absorbs energy due to the forces acting upon it under these conditions, physical deformation occurs as the object has reached its maximum strength. If the load continues to increase, the material appears to harden a phenomenon known as hardening strain which can lead to fracture [18]. The safety factor is a factor used to evaluate whether the design of a machine element or component is safe, by calculating the ratio of absolute strength or structural capacity to the actual load applied [18]. The range of safety factors is from 1 to 15 [19]. The safety factor must be greater than 1 for a design to be safe [20].

### 2.3 Material Properties

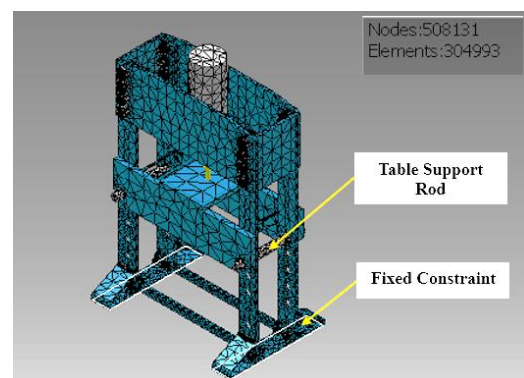
This study uses three different types of materials as comparison materials to determine the most optimal material during the testing process. This approach was carried out to evaluate the feasibility of the materials under loading conditions and to ensure the safety level of the H-type press machine table design. The mechanical properties of the three materials are presented in the following table:

**Table 2. Mechanical Properties**

Mechanical Properties	Material		
	Mild Steel	Alloy Steel	High-Strength Steel
Tensile Strength	345 MPa	400 MPa	448 MPa
Yield Strength	207 MPa	250 MPa	276 MPa
Young's Modulus	220 GPa	205 GPa	200 GPa
Poisson's Ratio	0,28	0,30	0,29
Density	7,86 kg/m <sup>3</sup>	7,72 kg/m <sup>3</sup>	7,86 kg/m <sup>3</sup>

In the finite element simulation, a fixed constraint was applied at the bottom support

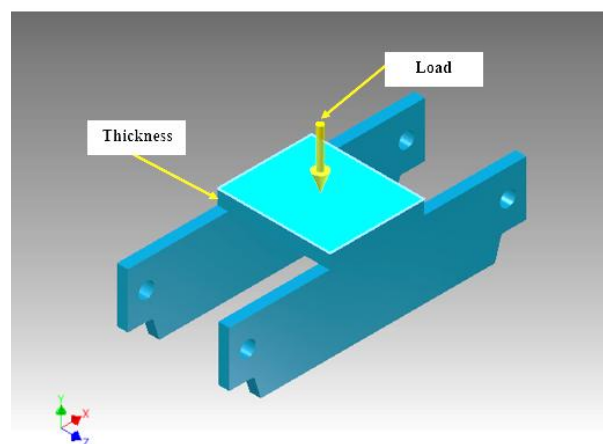
section of the press machine to represent the actual condition in which the press table is firmly mounted to the foundation and unable to move during the pressing process. Meanwhile, the load was applied in the form of a downward vertical compressive force on the surface of the press table. This condition was used to ensure that the simulation closely represented the real operating conditions of the press machine. The simulation employed a tetrahedral mesh with a total of 508,131 nodes and 304,993 elements.



**Figure 3. Meshing and Boundary Conditions**

### 3. Results and Discussion

The simulation was carried out by applying loads in two directions, the press table and the hydraulic system. However, this study focuses on the press table, varying the load, material and thickness of the press table. The press table measures 378 mm in length and 316 mm in width, with thicknesses varied to 30, 40, and 50 mm as shown in the Figure 4.



**Figure 4. Load Direction.**

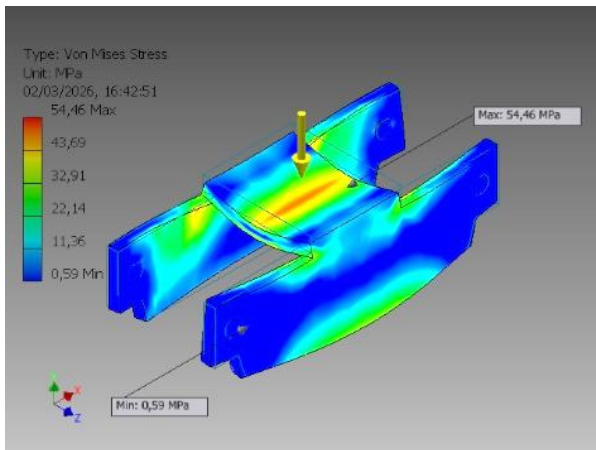


Figure 5. Von Mises Stress Value 1

load was concentrated at the center of the press table, resulting in structural deformation and generating several analysis outputs, including Von Mises stress, safety factor, and displacement. From the simulation carried out on the press machine using Inventor, the Von Mises stress value on the press table was obtained. Using this value, an analysis was performed using Minitab. The results were obtained using a Taguchi L9 array with three factors, nine runs, and two repetitions, as presented in Table 3.

Figure 5 presents the simulation results obtained using Autodesk Inventor software. The applied

Table 3. Von Mises Stress Value

No	Load (t)	Material	Thickness (mm)	Von Mises stress 1 (MPa)	Von Mises stress 2 (MPa)	Average (MPa)
1	10	Mild Steel	30	34.88	34.81	34.845
2	10	High-Strength Steel	40	27.22	27.24	27.23
3	10	Alloy Steel	50	21.92	22.02	21.97
4	20	Mild Steel	40	54.46	54.49	54.475
5	20	High-Strength Steel	50	43.91	44.11	44.01
6	20	Alloy Steel	30	69.52	69.52	69.52
7	30	Mild Steel	50	66.01	66.28	66.145
8	30	High-Strength Steel	30	104.6	104.3	104.45
9	30	Alloy Steel	40	81.67	81.68	81.675

To ensure that the values of the Von Mises stress data are valid, an analysis of the homogeneity of variance was conducted using Levene’s test and Bonett’s test, with a significance level of  $\alpha = 0.05$ , to confirm that the variance between data groups is equal (homogeneous). The results showed a *P-value* of 0.933 for Bonett’s test and 0.997 for Levene’s test. These values are greater than 0.05, so the null hypothesis is accepted this proves that the variation between data groups can be considered homogeneous. Consequently, further analysis using the Taguchi method can be carried out.

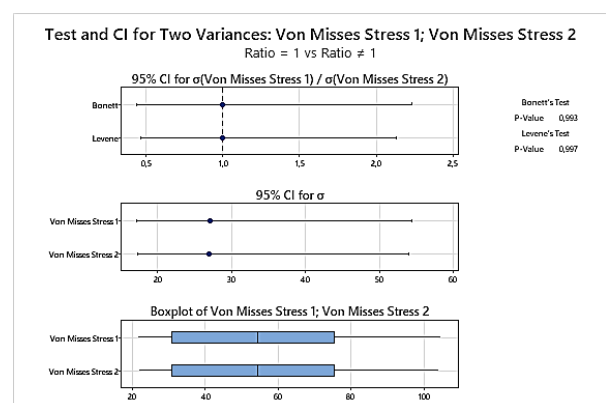


Figure 6. Homogeneity Test.

Stress analysis using the Von Mises stress criterion is used to predict the likelihood of a material undergoing plastic deformation when subjected to loading. The “Smaller-is-Better” criterion is used to ensure that the resulting

stress is as low as possible, thereby avoiding the risk of material failure. Based on the Signal-to-Noise Ratio analysis of the Von Mises stress values for the compression table, the following values were obtained:

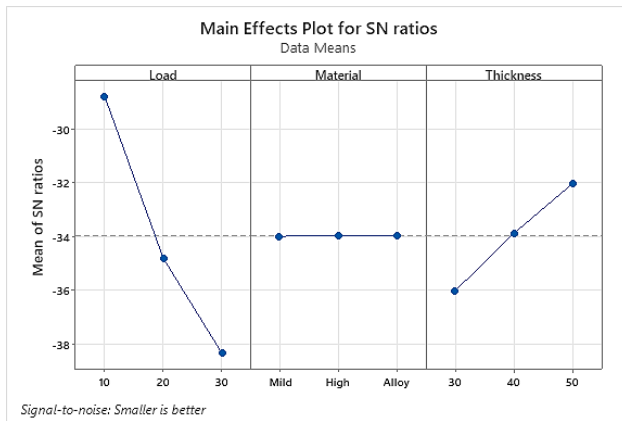


Figure 7. Main Effects Plot for S/N Ratios.

From the graph, the results indicate that the load values at levels 1, 2, and 3 are -28.79, -34.81, and -38.34. The material values are -33.99, -33.98, and -33.97 whereas the thickness values are -36.02, -33.89, and -32.04. Analysis of the Delta difference values is used to determine the influence of each factor on the Von Mises stress value. From these calculations, it was found that the largest Delta difference was for the load factor at 9.55, followed by the thickness factor at 3.98 and the material type at 0.02. Thus, the load factor has a significant influence, ranking first, followed by thickness and material. The slope on the Main Effects Plot for S/N ratios graph indicates the influence of each factor on the response. The figure shows that the greatest change in slope is observed for the load factor, confirming that the load factor is the most dominant variable influencing the response value.

The thickness factor of the press table has a more significant influence on the Von Mises stress response compared to the material type. This occurs because variations in thickness directly affect the structural stiffness and the effective cross-sectional area of the press table.

As the thickness increases, the moment of inertia of the structure also increases, improving the table's ability to resist deformation and distribute the applied load more effectively. Consequently, the stress concentration occurring in critical areas can be significantly reduced. In contrast, material variation has a relatively smaller effect on stress changes. This is because the three materials used in this study belong to the same category of metallic materials with relatively similar elastic modulus characteristics. Therefore, the stress distribution caused by loading is influenced more by the structural geometry than by the material properties themselves.

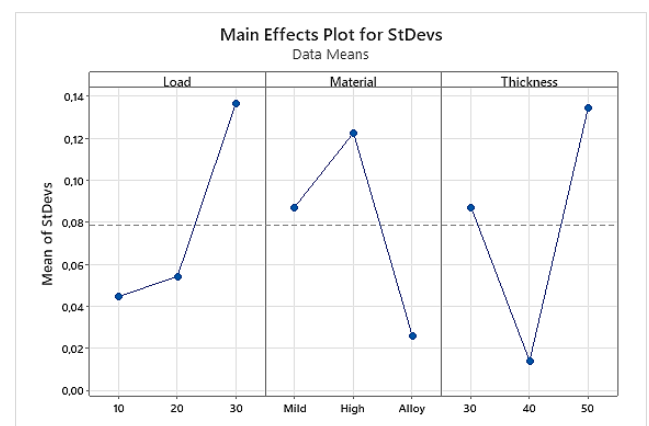


Figure 8. Main Effect Plot for Standard Deviations.

From the graph above, the results indicate that the load values at levels 1, 2, and 3 are 0.04478, 0.05421, and 0.13671. The material values are 0.08721, 0.12257, and 0.02593 whereas the thickness values are 0.08721, 0.1414, and 0.13435. From this data, the results indicate that the thickness factor has a delta of 0.12021, the material type 0.09664 and the load factor 0.09192. This demonstrates that changes in thickness have the greatest influence on stability or response variation; the load factor is more dominant in determining the magnitude of the response, while the material type has a relatively small influence compared to the other factors.

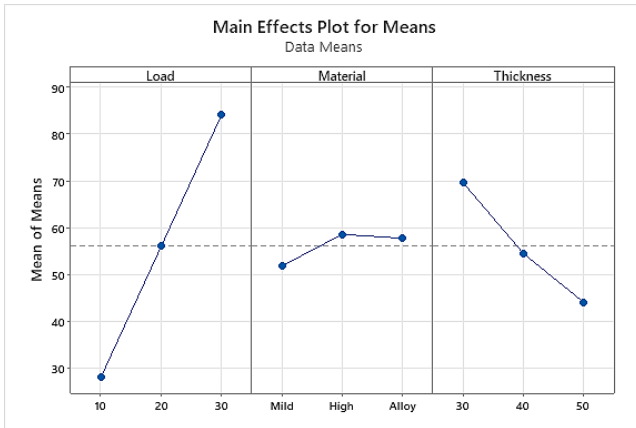


Figure 9. Main Effects Plot for Means.

From the graph, the results indicate that the load values at levels 1, 2 and 3 are 28.01, 56.00, and 84.09. The material values are 51.82, 58.56, and 57.72, while the thickness values are 69.61, 54.46, and 44.04. From this data, it is evident that the load factor has a delta of 56, making it the primary factor with the most significant influence on the response value. The thickness factor has a delta of 25.56, ranking second in terms of influence on the response value, whereas the material type has the least influence on the response value with a delta of 6.74. Based on this, the combination of parameters yielding the best conditions is load level 1, material level 1, and thickness level 3.

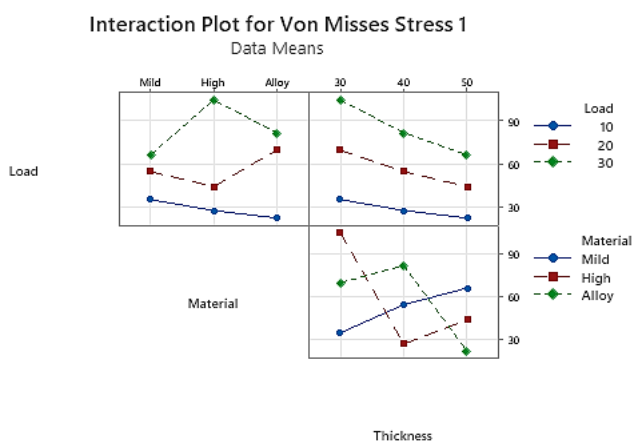


Figure 10. Interaction Plot for Von Mises Stress 1.

The graph above provides an overview of the relationship between load factor, material type and thickness in relation to the Von Mises stress value. The parallel lines for the load and material types indicate that there is no

interaction between these factors, whereas the intersecting lines for the material and thickness factors indicate that there is an interaction. Based on the patterns formed by the lines for Mild Steel, the stress values continue to increase with increasing thickness, while for high-strength steel there is a significant change: the stress is significantly higher at 30 mm, then drops considerably at 40 mm, and rises again at 50 mm. For Alloy Steel, the graph shows an increase in stress values from a thickness of 30 mm to 40 mm, but a considerable decrease occurs at a thickness of 50 mm. The intersection of the lines between the material and thickness factors indicates an interaction between these two factors this can be interpreted to mean that changes in thickness will influence the Von Mises stress value depending on the material type, and vice versa.

In the study conducted by A. F. Andri et al., it was found that stress distribution is influenced by loading variations and structural characteristics. Similar results were also obtained in this study, where increasing the applied load significantly increased the Von Mises stress value. The study by F. Arifin et al. also showed that increasing the load leads to a reduction in the safety factor and the emergence of critical areas at the structural joints. These findings support the results of the present study, in which a 30-ton load produced the highest stress value of 104.45 MPa at a thickness of 30 mm. In contrast, the combination of 50 mm thickness and Alloy Steel material produced the lowest stress value of 21.97 MPa, indicating that increasing the thickness is effective in reducing stress concentration. The main difference between this study and previous studies lies in the application of the Taguchi method to evaluate the effects of loading, material type, and thickness simultaneously. Previous studies mainly focused on stress and deformation

simulations without performing statistical optimization of the design parameters. By applying the Taguchi method, this study was able to identify the most dominant parameter as well as the optimal parameter combination for achieving minimum stress in the H-type press machine table.



Figure 11. Average Von Mises Stress.

The average Von Mises stress shows the variation in the average Von Mises stress values across test combinations 1 to 9. In general, this graph indicates that the Von Mises stress values are influenced by the combination of parameters used in each test. Certain combinations can produce low stress, while others produce significantly higher stress. The lowest value for Von Mises stress was obtained in the third test, with an average value of 21.97 MPa, and the highest value in the eighth test, with an average of 104.45 MPa.

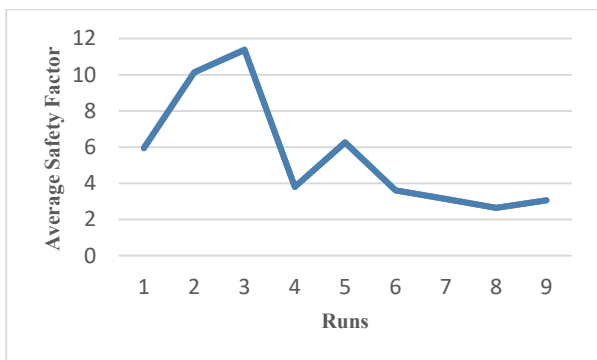


Figure 12. Average Safety Factor.

The average safety factor graph illustrates how the average safety factor varies with load, thickness and the effect of changes in material. In experiments 1 to 3, the results indicate that the average safety factor continues to increase,

reaching its peak in the third experiment at 11.38, before falling again in the fourth experiment to 3.8 and reaching its lowest point in the eighth experiment at 2.68. As the lowest safety factor value is still greater than 1, the design is deemed safe.

In this study, the optimal parameter combination was obtained at a loading variation of 98,100 N (10 tons), using Alloy Steel material and a press table thickness of 50 mm. This combination produced a Von Mises stress value of 22.21 MPa, a safety factor of 11.25, and a maximum displacement of 0.0902 mm. The obtained safety factor was the highest among all parameter combinations, indicating that the press table structure possesses an excellent level of structural safety. Under the highest loading condition of 294,300 N (30 tons), using Mild Steel material with a thickness of 30 mm, the Von Mises stress reached 101.4 MPa with a safety factor of only 2.04, although it still remained above the minimum structural safety limit. These results indicate that structural thickness plays a very important role in improving the stiffness and stability of the press table. Increasing the thickness allows the load to be distributed more effectively throughout the structure. In addition, material selection also affects the structural capability to withstand high loading conditions. Therefore, the combination of high-strength material and adequate thickness becomes a key factor in producing a safe press machine table design.

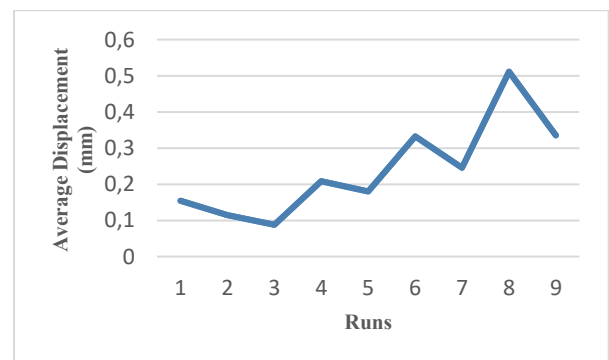


Figure 13. Average Displacement.

The graph shows fluctuations in each parameter; the highest average displacement was recorded in run 8 at 0.5113 mm, while the lowest value occurred in run 3 at 0.0878 mm. The highest average displacement indicates a high level of deformation, while the lowest displacement value indicates optimal conditions with minimal deformation. Overall, the fluctuating average displacement values demonstrate a significant influence of the parameter combination on the mechanical behaviour of the tested structure.

#### 4. Conclusion

The results of the Main Effects Plot for S/N ratios show that the largest difference in Delta values is for the load factor at 9.55, followed by the thickness factor at 3.98 and the material type at 0.02. Thus, the load factor has the most significant influence, followed by the thickness factor and the material type, in affecting the Von Mises stress on the table of an H-type press machine. As the load increases the resulting stress will also increase. Conversely, increasing thickness plays a role in reducing stress. Thus, thicker structures are better able to withstand loads safely. The influence of material type is not always consistent across all conditions, as it is highly dependent on the combination with load and thickness. From the Interaction Plot for Von Mises stress, it is evident that changes in thickness affect the Von Mises stress value depending on the material type, and vice versa. This indicates that the three parameters interact, meaning that a change in one factor can yield different results depending on the other conditions.

The optimal parameter combination was obtained at a loading condition of 10 tons (98,100 N), using Alloy Steel material with a thickness of 50 mm. This combination resulted in a minimum Von Mises stress of 22.21 MPa, a maximum displacement of 0.0902 mm, and a safety factor of 11.25. These results indicate

that the press table design is in a very safe condition and is practically feasible for use, since the working stress remains far below the material strength limit. This study only focused on static loading conditions; therefore, the actual operating conditions of the press machine, which involve repetitive pressure and varying loads during operation, have not been fully represented. In addition, the simulation was limited to variations in material type and press table thickness without considering other factors, such as the quality of the bolted joints used in the structure. For future research, it is recommended to conduct experimental testing under actual working conditions using a press machine prototype so that the simulation results can be directly compared with real field conditions.

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