ANALYSIS OF THE EFFECT OF LOAD VARIATIONS ON THE LEAF SPRING OF THE L300 VEHICLE USING SOLIDWORKS SOFTWARE

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Abstract. *This study aims to analyze the effect of load variations on the performance of the leaf spring in the Mitsubishi L300 vehicle using SolidWorks software through the Finite Element Analysis (FEA) method. Various load conditions were applied to observe changes in stress distribution, deformation, and safety factor on the leaf spring structure. A three-dimensional model was developed based on actual specifications, followed by meshing and the applications of boundary condition to ensure accurate and representative simulation results. The analysis shows that increasing the applied load significantly raises the maximum Von Mises stress and deformation values. Furthermore, several critical points were identified as potential areas of initial structural failure. These findings provide valuable insights for design improvements, material selection, and optimization of the suspension system in light commercial vehicles to enhance safety and reliability.*

Keywords: *Finite Element Analysis; Leaf Spring; Load Variation; Mitsubishi L300; Solidworks.*

1. INTRODUCTION

Suspension is one of the main systems in a vehicle that functions to improve comfort, stability, and safety during driving. The suspension system works by absorbing vibrations from the road surface to maintain vehicle stability and ensure driver safety. One important component in the suspension system of commercial vehicles such as the Mitsubishi L300 is the leaf spring (Budynas & Nisbett, 2020). The leaf spring is responsible for supporting the load, resisting vertical forces, and reducing vibrations during vehicle operation.

In real operating conditions, commercial vehicles often carry loads exceeding the standard capacity, causing the leaf spring to experience higher stresses and potentially leading to permanent deformation or structural failure (Singh & Kumar, 2020). Therefore, analyzing the strength of the leaf spring under load variations is highly important.

Analytical calculation methods are often used to determine basic stress and deflection; however, these methods are limited in describing stress distribution in components with complex geometries (Dewangan et al., 2020). For this reason, the use of Finite Element Analysis (FEA) has increasingly developed as an accurate and efficient numerical simulation method (Moaveni, 2022).

According to SolidWorks Corporation (2024), the FEA module in SolidWorks is capable of presenting stress distribution, deformation, and safety factor under realistic loading conditions. This enables researchers to understand structural responses to load variations without conducting time-consuming physical testing.

This study analyzes the effect of load variations of 1500 kg, 1700 kg, 2000 kg, and 2300 kg on the Mitsubishi L300 leaf spring using SolidWorks simulation, thereby obtaining information on Von Mises stress, maximum deformation, and safety factor under each loading condition.

1.1 Problem Formulation

a. How do load variations of 1500 kg, 1700 kg, 2000 kg, and 2300 kg affect the Von Mises stress in the leaf spring?
b. How does the maximum deformation change under each load variation?
c. Is the leaf spring still safe based on the safety factor value under loads up to 2300 kg?

1.2 Research Benefits

This study provides benefits in academic, technical, and industrial aspects, in accordance with recommendations from recent studies on material and structural research (Kaushik, Singh, & Bansal, 2021; Sharma & Kumar, 2023).

2. LITERATURE REVIEW

2.1 Leaf Spring

A leaf spring is a suspension spring consisting of multiple steel layers arranged in series to support the vehicle load (Rao, 2021). This component is commonly used in commercial vehicles because it has a high load-carrying capacity, a simple structure, and is easy to maintain.

The mechanical behavior of a leaf spring is influenced by the material type, number of leaves, thickness, and leaf length (Wong, 2020). AISI 5160 steel is frequently used as a leaf spring material due to its high tensile strength and good resistance to repeated loading (ASM International, 2021). Spring steel such as AISI 5160 is widely applied because it can withstand high stress and exhibits good elastic properties.

2.2 Finite Element Analysis (FEA)

FEA is a numerical method that divides a structure into smaller elements (finite elements) to calculate stress, strain, and deformation (Moaveni, 2022). This method is highly useful for complex structures that cannot be accurately analyzed using manual approaches alone. The main advantages of FEA include the ability to model complex geometries, apply various boundary conditions, and provide visual results in the form of stress contour plots (SolidWorks Corporation, 2024).

2.3 Von Mises Stress

Von Mises stress is a parameter used to predict the failure of ductile materials based on the distortion energy theory. A material is considered to fail when the Von Mises stress exceeds its yield strength (Budynas & Nisbett, 2020).

2.4 Several Relevant Studies Include:

1. Dewangan et al. (2020) analyzed the static loading of a leaf spring using FEA.
2. Kaushik et al. (2021) performed optimization of a composite leaf spring.
3. Tiwari & Patel (2022) compared the stress characteristics of steel and composite leaf springs.
4. Sharma & Kumar (2023) conducted static and dynamic analyses of leaf springs in commercial vehicles.
5. SolidWorks Corporation (2024) updated the simulation module with a more accurate meshing algorithm.
6. These studies indicate an increasing trend in the use of FEA as a primary method for structural evaluation and performance assessment.

3. RESEARCH METHODS

3.1 Type of Research

This study is a quantitative study based on numerical simulation using the Finite Element Analysis (FEA) approach. The simulation was conducted to evaluate the structural response of the leaf spring under static loading conditions using key parameters, namely Von Mises stress, total deformation (displacement/URES), and safety factor. The FEA method is applied because it is capable of modeling and analyzing complex structures through element discretization, allowing stress and deformation responses to be obtained numerically and visually (Moaveni, 2022).

3.2 Software and Equipment

a. The geometric modeling was performed using the following software: SolidWorks 2019 for 3D modeling. SolidWorks Simulation for FEA analysis (static analysis).
b. SolidWorks Simulation was selected because it provides a structural analysis module based on the finite element method for calculating stress**,** deformation, and safety factor (SolidWorks Corporation, 2024).

The supporting equipment used in this study was a laptop/PC with sufficient specifications to perform FEA computations.

3.3 Research Object

The object of this study is the leaf spring of a Mitsubishi L300 vehicle under varying loads, modeled as a 3D solid based on the actual dimensions of the leaf spring used in the vehicle.

3.4 Material Properties

The leaf spring material is defined as spring steel based on the SolidWorks material database and/or relevant literature references. The material properties used in the simulation include:

a. Elastic modulus (E).
b. Poisson's ratio (v).
c. Density (ρ).
d. Yield strength.

Accurate material definition is required to ensure that the simulation results represent the true mechanical characteristics of the component (ASM International, 2021).

3.5 Boundary Conditions

The determination of boundary conditions aims to represent the actual operating conditions of the leaf spring on the vehicle. In this study, the following boundary conditions were applied:

a. The ends of the leaf spring were given support constraints in accordance with their mounting conditions on the vehicle.
b. The support reactions were defined to restrict certain displacements to prevent rigid body motion.
c. The load was applied vertically to the main working area of the leaf spring (the axle seat region or central part according to the model).

Proper boundary conditions are essential because they influence the distribution of stress and deformation in the simulation results. In structural analysis, incorrect boundary conditions can lead to stress results that do not accurately represent real operating conditions (Moaveni, 2022; SolidWorks Corporation, 2024).

3.6 Loading Variations

The loading was applied statically with the following mass variations:

a. 1500 kg → 14,715 N

b. 1700 kg → 16,677 N
c. 2000 kg → 19,620 N
d. 2300 kg → 22,563 N

The load mass was then converted into force (N) using the equation:

$$F = m \times g$$

where:

- m = load mass (kg).
- g = gravitational acceleration (9.81 m/s^2)

Thus, the applied forces obtained were:

- 1500 kg → 14,715 N.
- 1700 kg → 16,677 N.
- 2000 kg → 19,620 N.
- 2300 kg → 22,563 N

Static loading was used to observe the initial structural response of the leaf spring to vertical forces without considering inertia effects due to vehicle dynamics (Moaveni, 2022).

3.7 Simulation Procedure

The simulation was carried out through the following steps:

a. 3D modeling of the 5-leaf spring configuration.
b. Material property assignment
c. Application of boundary conditions
d. Load application based on load variations
e. Mesh generation
f. Simulation execution
g. Extraction of Von Mises stress, deformation, and FoS results

The simulation procedure followed the standard workflow of static analysis in SolidWorks simulation to ensure that the results were consistent with the input parameters (SolidWorks Corporation, 2024).

3.8 Output Parameters (Analysis Results)

The simulation results were evaluated based on the following parameters:

a. Von Mises stress (σ_{vm}) to identify the distribution of equivalent stress and the location of maximum stress concentration in the structure.
b. Total displacement (URES) to determine the maximum deformation occurring in the leaf spring.
c. Safety factor (FoS) to assess the safety level of the structure against the material’s yield limit.

Von Mises stress and safety factor are commonly used in the evaluation of ductile material structures, particularly to assess whether the working stress remains below the material’s yield strength (Budynas & Nisbett, 2020).

3.9 Data Analysis Method

The simulation results were presented in the form of:

a. Recapitulation tables of maximum and minimum values.
b. Simulation result contours (Von Mises stress, displacement, and safety factor).
c. Graphs showing trends of result changes with load variations.

These results were then analyzed to examine the effect of load variations on the structural response of the leaf spring and to identify critical areas in each leaf configuration.

4. RESULTS AND DISCUSSION

4.1 Profile/Dimension of the Mistubishi L300 5-Leaf Spring

Parameter	Symbol	Value	Unit	Description
Number of leaves	N	5	layers	5-leaf spring
Total length (eye to eye)	L	1200	mm	Overall spring length
Leaf width	B	70	mm	Same width for each leaf
Leaf thickness	T	8	mm	Thickness of each leaf
Length of leaf 1 (main leaf)	L_1	1200	mm	Longest leaf
Length of leaf 2	L_2	1050	mm	Second leaf
Length of leaf 3	L_3	900	mm	Third leaf
Length of leaf 4	L_4	750	mm	Fourth leaf
Length of leaf 5	L_5	600	mm	Shortest leaf
Eye diameter (spring eye hole)	D_{eye}	35	mm	Pin/shackle hole
Camber (arch height)	H	90	mm	Spring curvature height
Distance to axle seat center	Lc	600	mm	Load applied at center
Center bolt diameter	D_β	10	mm	Bolt binding the leaves

Table 4.1 Profile/Dimensions of the Mitsubishi L300 5-Leaf Spring

Material Property	Symbol	Value	Unit
Material type	–	Spring Steel (AISI 5160)	–
Elastic modulus	E	200	GPa
Poisson's ratio	ν	0.30	–
Density	ρ	7850	kg/m³
Yield strength	σ_y	1100	MPa
Ultimate tensile strength	σ_u	1300	MPa

Table 4.2 Material Properties of the Leaf Spring (Spring Steel / AISI 5160)

4.2 Von Mises Stress Analysis

The simulation was conducted to analyze the Von Mises equivalent stress response of the Mitsubishi L300 leaf spring with a 5-leaf configuration under load variations of 1500 kg, 1700 kg, 2000 kg, and 2300 kg. The Von Mises stress was used as the main parameter to evaluate stress distribution and to identify critical areas that could potentially become initiation points for failure in ductile materials (Budynas & Nisbett, 2020). The Von Mises analysis results are presented in the form of recapitulation tables, contours, and trend graphs to facilitate interpretation. A summary of the maximum Von Mises stress values for each load variation is presented in Table 4.1

Load (kg)	Von Mises max (MPa)
1500	80,42
1700	91,04
2000	107,08
2300	107,08

Table 4.3 Maximum Von Mises stress of 5-leaf spring under load variations (1500–2300 kg).

The visualization of stress distribution in the form of contours is shown in **Figure 4.1**

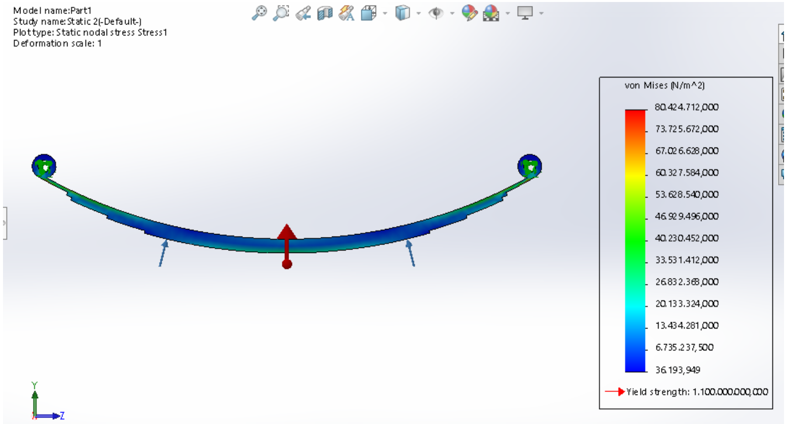


Figure 4.1 Von Mises Contour at 1500 kg

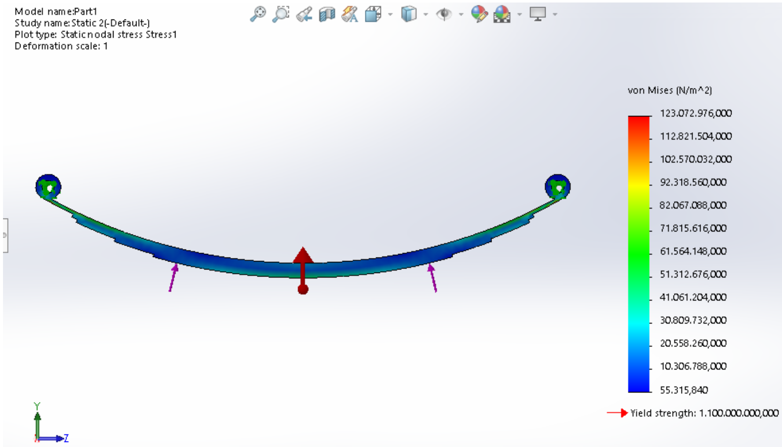
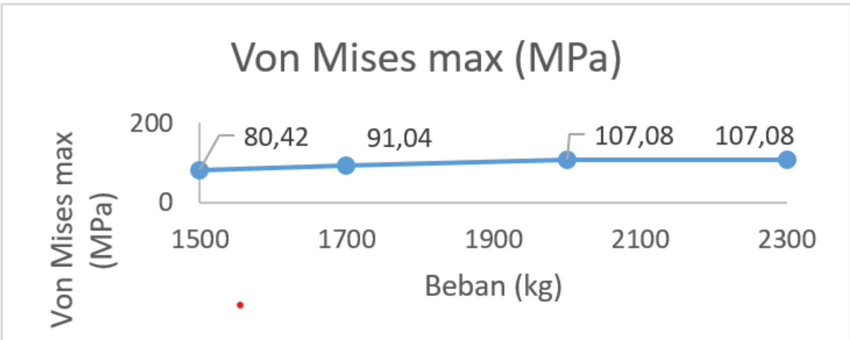
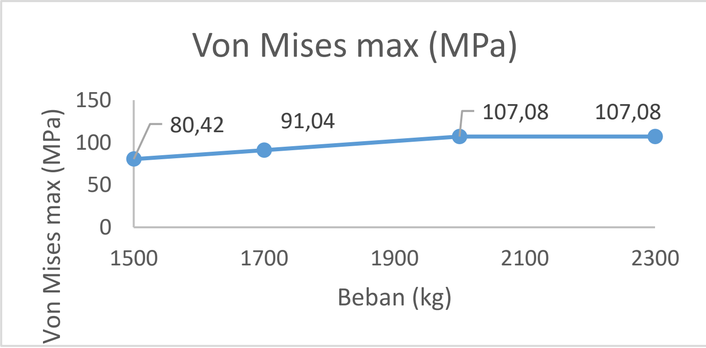


Figure 4.2 Von Mises Contour at 2300 kg.

To clarify the trend of stress changes due to increasing load, the data are visualized in Graph 4.1.



Graph 4.1 Relationship between applied load and maximum Von Mises stress for the 5-leaf spring.



Graph 4.1 Relationship between applied load and maximum Von Mises stress for the 5-leaf spring.

Based on the simulation results, the maximum Von Mises stress increases with the increase in load from 1500 kg to 2000 kg, then tends to remain constant at a load of 2300 kg. At a load of 1500 kg, the maximum Von Mises stress obtained is 80.42 MPa, increasing to 91.04 MPa at 1700 kg, and reaching its highest value of 107.08 MPa at loads of 2000–2300 kg. This pattern indicates that higher loads generate greater bending moments in the leaf spring, leading to an increase in equivalent stress (Moaveni, 2022).

The Von Mises contour distribution shows that stress is not uniformly distributed throughout the leaf spring but is concentrated in certain areas as maximum stress concentration zones. Regions with the highest contour levels (red–orange) represent critical points that require attention because they have the potential to experience the greatest deformation or become initiation sites for damage if the load increases or cyclic loading occurs. This stress concentration phenomenon is consistent with the characteristic behavior of leaf spring structures that primarily operate under bending conditions, where maximum stress tends to occur in areas subjected to the highest loads and/or experiencing geometric changes (Wong, 2020).

4.3 Displacement (Deformation) Analysis

The analysis of total deformation (total displacement/URES) was conducted to determine the magnitude of deflection of the 5-leaf spring under varying loading conditions. A summary of the maximum displacement values is presented in Table 4.2.

Load (kg)	Displacement max (mm)
1500	0,3
1700	0,34
2000	0,4
2300	0,4

Table 4.4 Maximum Total Displacement (URES) of the 5-Leaf Spring under Load Variations (1500–2300 kg).

The deformation contour is shown in Figure 4.2, and the trend of displacement changes due to load variations is visualized in Graph 4.2.

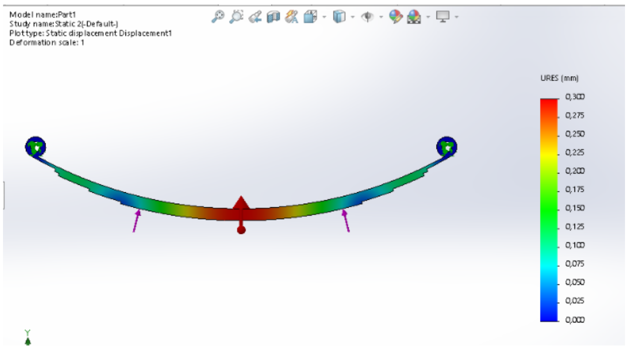


Figure 4.3 Displacement Contour at 1500 kg

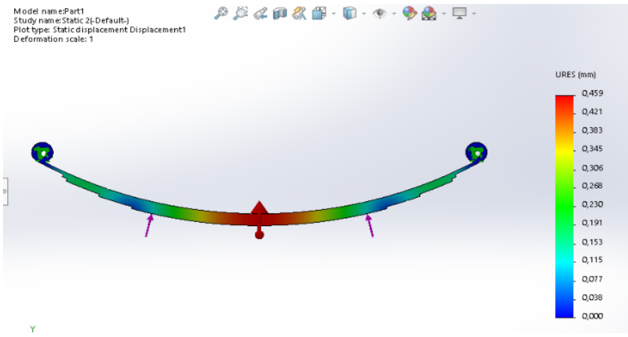
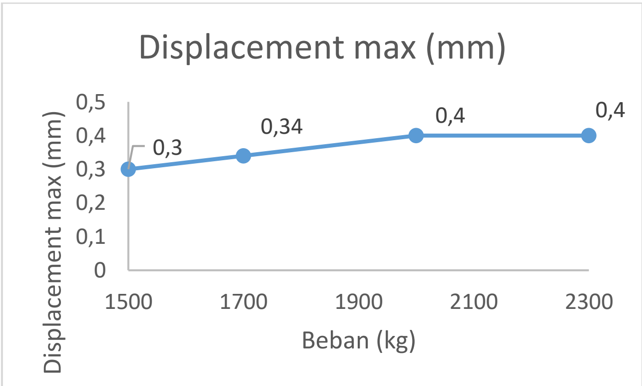


Figure 4.4 Displacement Contour at 2300 kg



Graph 4.2 Relationship between applied load and maximum displacement (URES) for the 5-leaf spring.

The simulation results show that the maximum displacement value increases with increasing load. At a load of 1500 kg, the maximum displacement is 0.30 mm, increasing to 0.34 mm at 1700 kg, and reaching a maximum value of 0.40 mm at loads of 2000–2300 kg. This increase in deformation indicates a direct relationship between the applied load and the bending response of the leaf spring. The greater the vertical force applied, the greater the resulting deflection as an elastic response of the suspension system (Moaveni, 2022).

The displacement contour shows that the maximum deformation occurs in the main working area of the leaf spring (generally the central or loading region), while the minimum deformation is located in the constrained areas. This pattern is consistent with bending principles, where the greatest deflection typically occurs in regions experiencing the maximum bending moment (Wong, 2020). Therefore, displacement can be used as an important indicator in evaluating the stiffness of a 5-leaf spring under high loading conditions.

4.4 Safety Factor Analysis

The evaluation of the safety factor (FoS) was conducted to assess the safety level of the 5-leaf spring against the material's yield stress under various loading conditions. A recap of the minimum safety factor values is presented in Table 4.3.

Load (kg)	FoS min
1500	13,68
1700	12,08
2000	10,27
2300	10,27

Table 4.5 Minimum safety factor (FoS) of 5-leaf spring under load variations (1500–2300 kg).

Meanwhile, the contour distribution of the safety factor is shown in Figure 4.3, and the trend of its variation is visualized in Graph 4.3

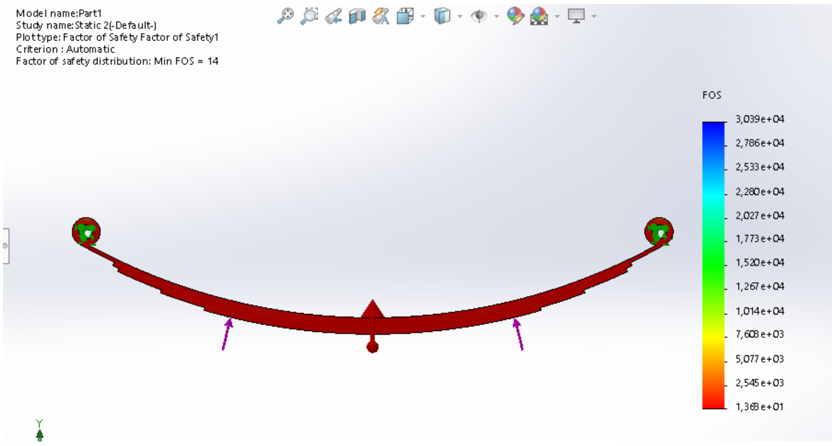


Figure 4.5 FoS contour 1500 kg

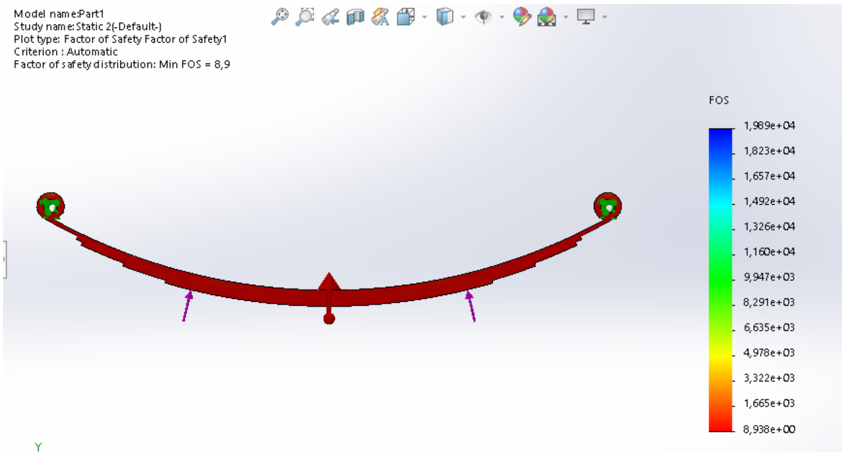
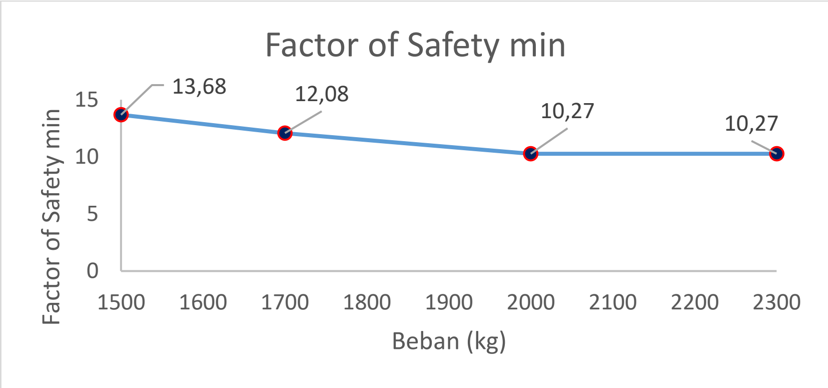


Figure 4.6 FoS contour 2300 kg



Graph 4.3 Minimum safety factor (FoS) of 5-leaf spring under load variations (1500–2300 kg).

The analysis results indicate that the safety factor tends to decrease as the load increases. At a load of 1500 kg, the minimum safety factor obtained is 13.68, which then decreases to 12.08 at 1700 kg, and reaches a minimum value of 10.27 at loads of 2000–2300 kg. This reduction in safety factor indicates that the margin of safety decreases as the load becomes larger, because the working stress approaches the material's strength limit (Budynas & Nisbett, 2020).

The safety factor contour shows that the minimum values are concentrated in the same area as the location of the maximum Von Mises stress. This confirms that the critical region of the structure is the main point experiencing the highest stress response, which influences the safety level of the component. Overall, although the safety factor decreases under high loads, its value remains above 1, indicating that the leaf spring is still in a safe condition with respect to the material's yield stress.

4.5 Discussion (General Trend of Load Variation)

Based on the three simulation result parameters—Von Mises stress, displacement, and safety factor—it can be concluded that variations in loading have a significant effect on the structural response of the 5-leaf spring. An increase in load leads to higher Von Mises stress and deformation, as well as a reduction in the safety factor. Mechanically, this is caused by the increase in vertical force, which raises the bending moment on the leaf spring, thereby increasing bending stress and deflection (Wong, 2020; Moaveni, 2022).

The contour results also reveal a concentration of response in certain critical areas, making these regions the primary focus of structural strength evaluation. These findings are consistent with previous studies stating that high loading on leaf springs increases stress and deformation and elevates the risk of failure if subjected continuously to extreme loading conditions (Agrawal et al., 2020; Sharma & Kumar, 2023).

CONCLUSION

Based on the Finite Element Analysis (FEA) results of the Mitsubishi L300 5-leaf spring (5 layers) under load variations of 1500 kg, 1700 kg, 2000 kg, and 2300 kg, the following conclusions can be drawn:

1. The maximum Von Mises stress increases as the applied load increases. The maximum values obtained are 80.42 MPa (1500 kg), 91.04 MPa (1700 kg), and reaching the highest value of 107.08 MPa (2000–2300 kg). This indicates that higher loading leads to higher bending stress on the leaf spring structure.
2. The maximum total displacement (URES) also increases with increasing load. The displacement values are 0.30 mm (1500 kg), 0.34 mm (1700 kg), and reaching 0.40 mm

(2000–2300 kg). This confirms that the leaf spring deformation grows with increasing vertical load.

3. The minimum safety factor (FoS) decreases with increasing load. The minimum FoS values obtained are 13.68 (1500 kg), 12.08 (1700 kg), and 10.27 (2000–2300 kg). Although FoS decreases at higher loads, the values remain above 1, indicating that the leaf spring is still within a safe range based on yield strength criteria.

Overall, load variation significantly affects the structural response of the L300 5-leaf spring. The highest load condition (2300 kg) produces the highest stress and deformation while resulting in the lowest safety factor; therefore, this load case represents the most critical operating condition for the evaluated leaf spring configuration.

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