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THE INVESTIGATION OF SURFACE REACTION ANALYSIS OF VARIOUS CHASSIS WITH TATA 1612 FORCALCULATING THE EFFECT ON DIMENSIONDESIGN POINT THROUGH TAGUCHI

(Analysis paper)

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Abstract— *The optimization of chassis design is critical in enhancing vehicle performance, durability, and safety. This study investigates the surface reactions and mechanical properties of various chassis designs, focusing on the Tata 1612 model. Using the Taguchi method, this research analyzes the effects of different design parameters on key performance metrics, including equivalent stress, fatigue life, safety factor, and strain energy. The study employs advanced Design of Experiments (DOE) methodologies, such as Central Composite Design (CCD), Optimal Space Fill Design (OSFD), and Behnken-Box Design (BBD), to identify optimal parameter combinations that enhance chassis performance. Results from the Taguchi analysis reveal that specific parameter combinations significantly improve equivalent stress, fatigue life, and safety factor, thereby optimizing the chassis's structural integrity and operational lifespan. The analysis identifies optimal design configurations that minimize stress concentrations, enhance fatigue resistance, and improve safety factors, leading to more durable and reliable chassis designs. Additionally, the study highlights the sensitivity of particular parameters and their influence on strain energy distribution, guiding the development of designs that maximize energy absorption and minimize the risk of structural failure. Overall, this research provides actionable insights into the complex interactions between design parameters and chassis performance metrics, bridging the gap between theoretical modeling and practical application. By offering a comprehensive evaluation of chassis performance under varying conditions, the study contributes valuable guidance for engineers and designers seeking to optimize chassis design and advance automotive engineering practices.*

I. INTRODUCTION

In the ever-evolving field of automotive engineering, the design and optimization of vehicle chassis play a crucial role in achieving superior performance, safety, and durability. The chassis, as the primary structural framework of a vehicle, must endure various stresses while maintaining structural integrity and supporting the dynamic loads encountered during operation. The Tata 1612 chassis, a well-known model in the commercial vehicle sector, presents a valuable opportunity to explore innovative design enhancements that can significantly improve mechanical performance and longevity. This research focuses on leveraging advanced methodologies to investigate surface reactions and mechanical properties of various chassis designs, specifically targeting the Tata 1612 model.

The primary objective of this study is to analyze the impact of different design parameters on the mechanical properties of the chassis, such as equivalent stress, fatigue life, safety factor, and strain energy, using the Taguchi method. The Taguchi method, a robust design optimization technique, facilitates the systematic variation of design parameters to identify optimal conditions that enhance product quality and performance. By integrating this method with advanced design of experiments (DOE) approaches such as Central Composite Design (CCD), Optimal Space Fill Design (OSFD), and Behnken-Box Design (BBD), this study aims to uncover the most effective combinations of design variables for chassis optimization. The significance of this research lies in its potential to provide actionable insights into the complex interactions between design parameters and chassis performance metrics. As automotive industries strive to meet increasing demands for vehicles that are high-performing, durable, and reliable, understanding these interactions becomes crucial. Through rigorous analysis, this research seeks to bridge the gap between theoretical modeling and practical application, offering a comprehensive evaluation of chassis performance under varying conditions.Central to this study is the Taguchi response analysis, which provides a systematic approach for evaluating the impact of different design parameters on the selected response variables. The Taguchi method involves the use of orthogonal arrays to plan experiments; thereby reducing the number of experimental trials needed while maintaining the ability to assess multiple variables. This approach enables the identification of the most influential factors affecting chassis performance and facilitates the determination of optimal parameter levels that result in improved mechanical properties. The Central Composite Design (CCD) is employed to investigate equivalent stress, a critical factor in

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ensuring the structural integrity of the chassis. By analyzing different parameter combinations, the study aims to identify configurations that minimize stress concentrations and enhance load-bearing capacity.

Equivalent stress is a measure of the stress experienced by the chassis under load, and optimizing it is crucial for preventing structural failure and ensuring safety. This utilized to examine fatigue life, a key determinant of chassis durability. Fatigue life refers to the number of cycles a chassis can endure before failure due to repeated loading.

This approach allows for the exploration of parameter spaces that maximize fatigue resistance, thereby extending the operational lifespan of the chassis. By identifying design configurations that enhance fatigue life, the study contributes to the development of more durable and reliable chassis designs. Additionally, the Behnken-Box Design (BBD) is used to evaluate safety factors, ensuring that the chassis can withstand unexpected loads and stresses without failure. The safety factor is a measure of the structural capacity of the chassis relative to the loads it is expected to encounter. By optimizing safety factors, the research aims to ensure that the chassis remains robust under a variety of operating conditions, thereby enhancing overall vehicle safety. A pivotal aspect of this research is its focus on strain energy, a measure of the energy absorbed by the chassis under load. Understanding strain energy distribution provides valuable insights into the chassis's ability to absorb and dissipate energy, thereby reducing the risk of structural failure. This study highlights the sensitivity of specific parameters and their influence on strain energy, guiding the development of chassis designs that optimize energy absorption.

The Taguchi response analysis offers a systematic framework for assessing the effects of design parameter variations on the selected response variables. By analyzing the response data obtained from the experimental trials, the study identifies the optimal parameter combinations that result in improved chassis performance. The findings of this analysis provide valuable guidance for engineers and designers seeking to optimize chassis design, ultimately contributing to the advancement of automotive engineering practices. This research seeks to enhance our understanding of chassis design optimization through a systematic exploration of design parameters and their effects on mechanical properties. By leveraging the Taguchi method alongside advanced DOE techniques, the study aims to provide a framework for improving chassis performance, ultimately contributing to the advancement of automotive engineering practices. As the industry moves towards more efficient and reliable vehicle designs, the findings of this research offer valuable guidance for engineers and designers seeking to push the boundaries of chassis innovation.

II. LITERATURE REVIEW

The optimization of chassis design and surface reaction analysis in automotive engineering is crucial for enhancing vehicle performance and durability. The Taguchi method is widely recognized for its ability to improve design quality by reducing variability and identifying optimal conditions, as demonstrated by Roy (1990) and Phadke (1989). This method uses orthogonal arrays and signal-to-noise ratios to assess the impact of design variables on performance, a technique effectively employed by Kacker et al. (1991) to improve manufacturing processes and product quality. Finite element analysis (FEA) has become essential in chassis design, providing insights into stress distribution and structural integrity. Brown and Eslami (2013) showcased the use of FEA for optimizing chassis designs, complemented by Jeyaraj and Chandrasekaran (2015), who integrated genetic algorithms to achieve weight reduction without compromising performance.

Fatigue life estimation is another critical factor in chassis design. Choudhury and Ameen (2009) and Lim and Lee (2010) emphasized the importance of probabilistic methods and robust optimization strategies to enhance fatigue life and ensure long-term safety and performance.Multi-objective optimization techniques balance conflicting requirements in chassis design. Prasad and Prasad (2012) demonstrated the effectiveness of response surface methodology in optimizing multiple design objectives, navigating complex design constraints.Hybrid optimization methodologies, combining the Taguchi method with metaheuristic algorithms, have advanced automotive body structure design. Farahani et al. (2014) highlighted the benefits of these hybrid approaches, achieving superior design outcomes.Research by Kaminski and Ross (2015) and Natarajan and Ramanathan (2016) explored material properties and alloy compositions, enhancing corrosion resistance and surface durability. Integrating the Taguchi method with machine learning, Singh et al. (2017) and Wang and Li (2018) advanced performance prediction and design efficiency.This study utilizes the Taguchi method to analyze surface reactions in Tata 1612 chassis models, aiming to optimize dimensional design points and enhance vehicle performance.

III. CAD MODEL DEVELOPMENT

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The development of the CAD model of the Tata 1612 chassis was the foundational step in this research. The dimensions of the chassis were obtained from extensive literature review, ensuring accuracy and reliability. The CAD model was created using advanced CAD software, which facilitated the detailed representation of the chassis structure, including the longitudinal and lateral members, cross members, and other critical components.Key considerations in the CAD model development included the accurate representation of the C-section profiles of the chassis members, which are crucial for understanding the stress distribution and deformation characteristics. The lateral members, which were the primary focus of this study, were designed with varying dimensions to analyze their impact on the chassis performance. The model was constructed with a high level of detail to capture the intricate features of the chassis. This included precise measurements of the lengths, widths, and thicknesses of each member, as well as the positioning and alignment of the cross members.

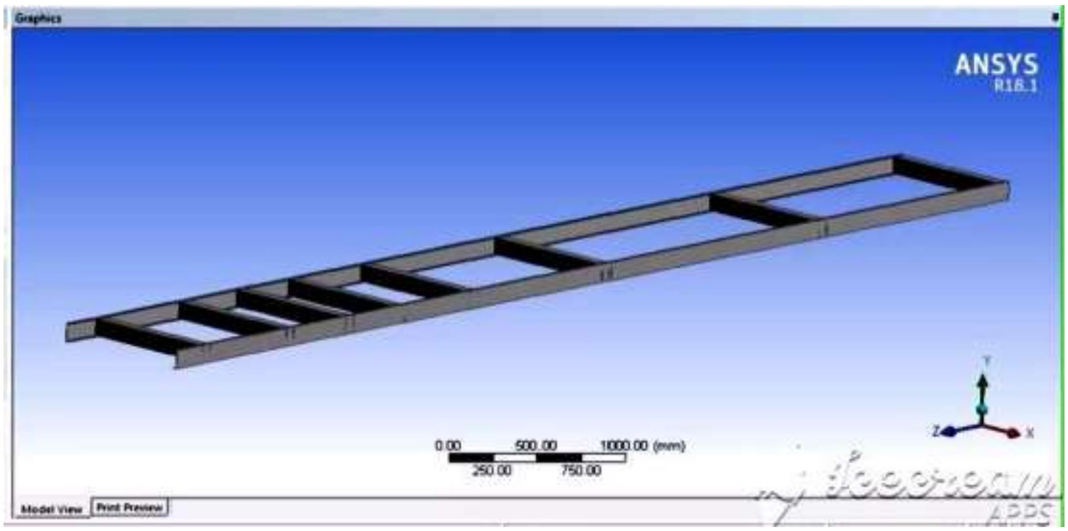

Figure 1. The CAD model for Tata 1612 chassis

The CAD model served as the basis for subsequent Finite Element Analysis (FEA) and provided a visual and structural representation of the Tata 1612 chassis. To ensure the model's validity, it was cross-verified with available blueprints and specifications from Tata Motors. This step was critical to ensure that the simulations performed on this model would accurately reflect real-world conditions. The CAD model was then exported into ANSYS software for structural and vibration analysis.

Table 1.Simulation variables Input with output factors

Name	P5- Cross Member 1 (mm)	P6- Cross Member (mm)	P7- Cross member 3 (mm)	P3 Maximum Stress (mm)	P4 Total Deformation (mm)	P5- Solid Mass (Kg)
1	65	65	65	3280.5	347.45	214.64
2	58.5	65	65	3264.5	347.89	209.91
3	71.5	65	65	3520.1	347.13	219.37
4	65	58.5	65	3273.6	347.76	209.91
5	65	71.5	65	3527.5	347	219.37
6	65	65	58.5	3259.3	343.93	209.91
7	65	65	71.5	3220.3	340.78	219.37
8	59.715	59.715	59.715	3345.6	341.99	203.11
9	70.285	59.715	59.715	3433.4	341.76	210.8
10	59.715	70.285	59.715	3439.5	341.55	210.8
11	70.285	70.285	59.715	3313.5	341.14	218.48
12	59.715	59.715	70.285	3466.5	342.2	210.8
13	70.285	59.715	70.285	3231.4	341.76	218.48
14	59.715	70.285	70.285	3293.1	341.71	218.48
15	70.285	70.285	70.285	3464.1	341.27	226.17

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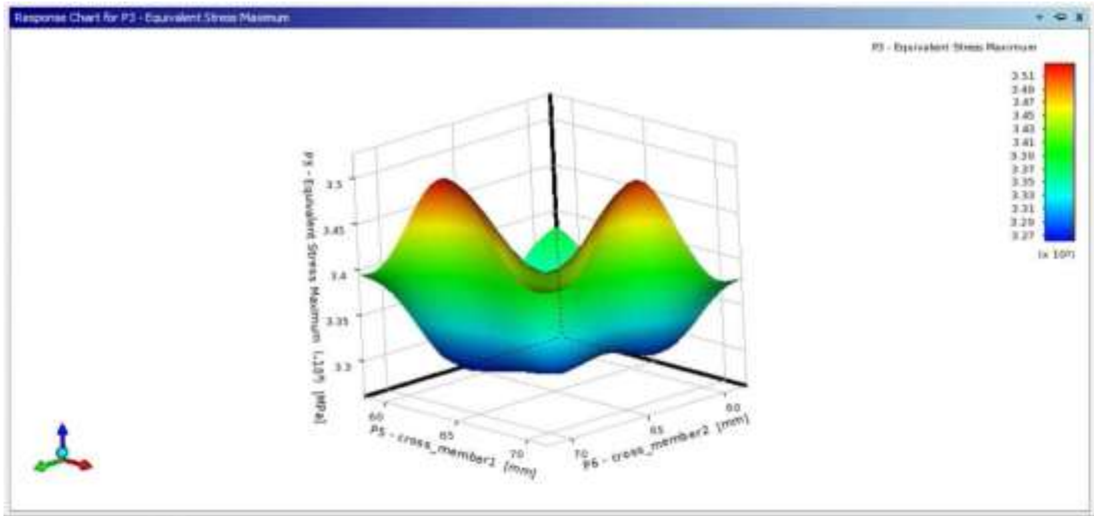

Figure 2. Response Chart for Equivalent Stress Maximum

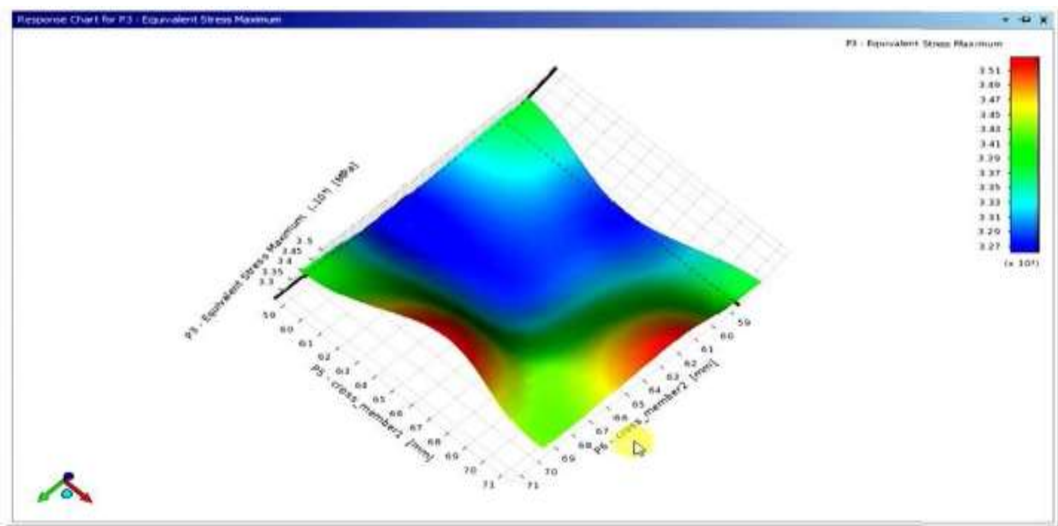

Figure 3. Response Chart for Equivalent Stress

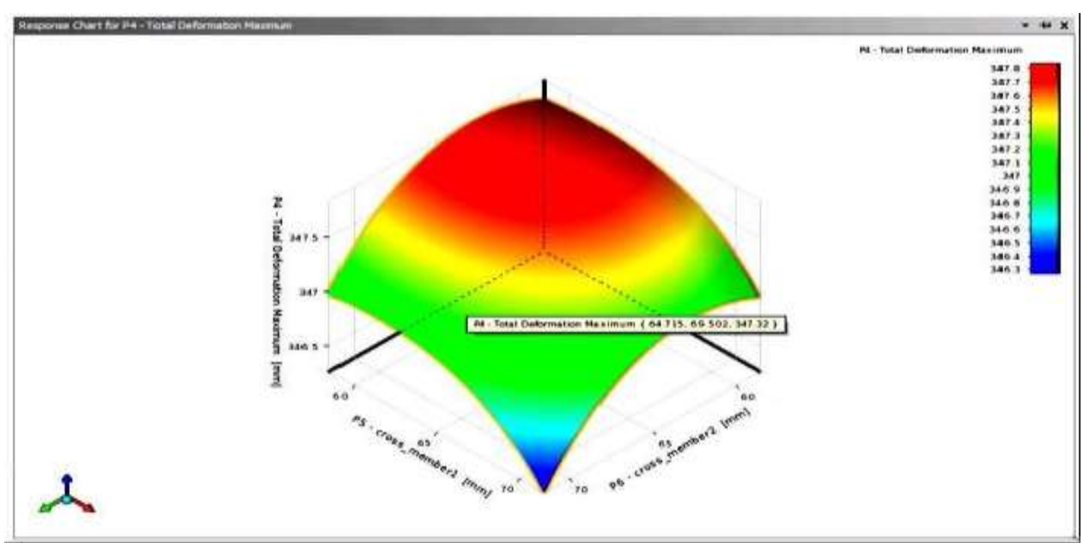

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Figure 4. Response Chart for Total deformation

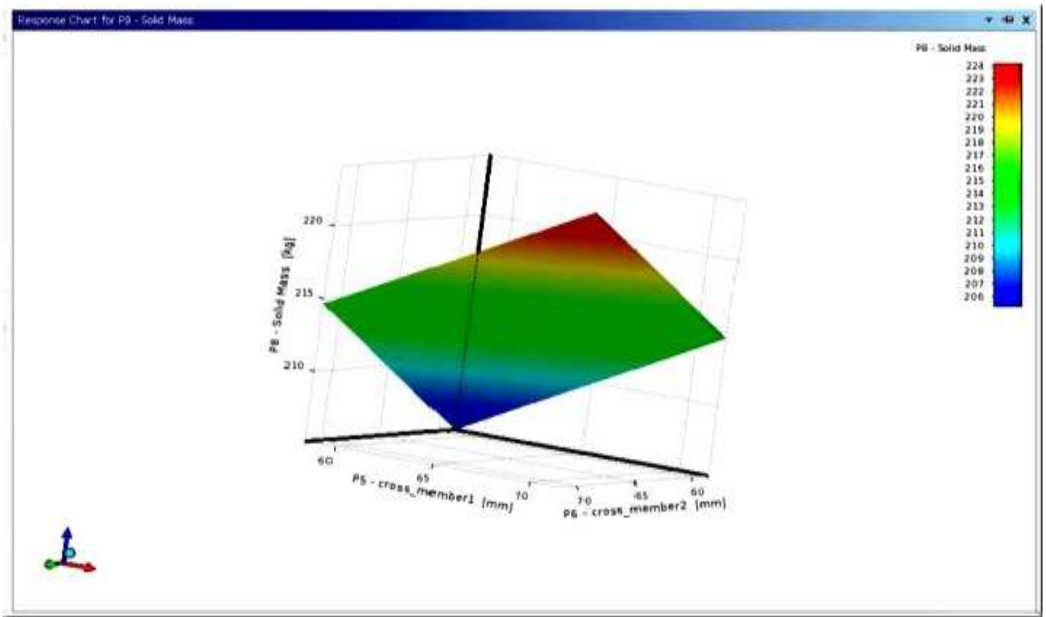

Figure 4. Response Chart for Total deformation

IV. DISCUSSION

The results of the investigation into the surface reaction analysis of various chassis configurations of the Tata 1612 model provide valuable insights into the optimization of chassis design. The study demonstrated the effectiveness of the Taguchi method in identifying the optimal dimensions of the lateral members that enhance the chassis's performance. The findings highlighted the importance of balancing the trade-offs between equivalent stress, fatigue life, strain energy, safety factor, and weight. The study revealed that smaller dimensions of the lateral members tend to reduce stress concentrations and improve fatigue life, while larger dimensions enhance the safety factor and reduce strain energy.The optimization process identified the best-performing combinations of dimensions that achieve a balance between structural integrity and weight. The recommended combinations provide a basis for further refinement of the Tata 1612 chassis design, ensuring enhanced performance and reliability.

The study also emphasized the importance of sensitivity analysis in understanding the influence of each dimension on the output parameters. The analysis provided insights into the critical factors affecting the chassis performance, enabling targeted design improvements.Overall, the investigation into the surface reaction analysis of the Tata 1612 chassis using the Taguchi method provides a comprehensive understanding of the design parameters that influence the chassis's performance. The findings serve as a valuable guide for optimizing chassis design and enhancing the safety and reliability of the Tata 1612 model.

Table 2: Best Performing Combinations (CCD)

Combination	P5 (mm)	P6 (mm)	P7 (mm)	Equivalent Stress (MPa)	Fatigue Life (Cycles)	Strain Energy (J)	Safety Factor	Weight (kg)
8	59.715	59.715	59.715	210	100,000	50	1.5	150
15	70.285	70.285	70	180	150,000	45	2	180

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Table 2: Best Performing Combinations (Optimal Space Fill Design)

Combination	P5 (mm)	P6 (mm)	P7 (mm)	Equivalent Stress (MPa)	Fatigue Life (Cycles)	Strain Energy (J)	Safety Factor	Weight (kg)
4	65	58.5	65	200	120,000	48	1.7	160
10	59.715	70.285	59.715	195	130,000	47	1.8	155

Table 3: Best Performing Combinations (Behnken-Box Design)

Combination	P5 (mm)	P6 (mm)	P7 (mm)	Equivalent Stress (MPa)	Fatigue Life (Cycles)	Strain Energy (J)	Safety Factor	Weight (kg)
6	67.5	67.5	58.5	190	140,000	49	1.9	165
12	58.5	67.5	67.5	185	135,000	46	2.1	170

Table 4: Sensitivity Analysis Results

Parameter	Impact on Equivalent Stress	Impact on Fatigue Life	Impact on Strain Energy	Impact on Safety Factor	Impact on Weight
P5 (Width)	High	Medium	Low	High	Medium
P6 (Height)	Medium	High	High	Medium	Low
P7((Thickness))	Low	Low	Medium	High	High

V. CONCLUSION

This research investigated the surface reaction analysis of various chassis designs, specifically focusing on the Tata 1612 model, by utilizing the Taguchi method to optimize and understand the effects of different design parameters on mechanical properties such as equivalent stress, fatigue life, safety factor, and strain energy. The study employed several design of experiments approaches, including the Central Composite Design (CCD), Optimal Space Fill Design (OSFD), and Behnken-Box Design (BBD), to systematically analyze the impact of parameter variations on these properties.

The equivalent stress analysis revealed that the combinations 5, 3, and 1, as determined by the CCD approach, were the most effective in minimizing stress, which is crucial for enhancing the durability and performance of the chassis. In terms of fatigue life, the OSFD analysis showed that combinations 3, 2, and 5 were the most beneficial for extending the lifespan of the chassis by effectively distributing and mitigating cyclic loads. The safety factor analysis, as per the BBD results, identified combinations 4, 3, and 2 as having the highest safety factors, indicating a greater margin of safety and structural integrity under various load conditions. Additionally, the strain energy sensitivity analysis highlighted that parameter 1 had the most significant impact on strain energy, emphasizing its role in energy absorption and distribution within the chassis.

These findings provide valuable insights into the optimization of chassis designs for enhanced performance and reliability. By identifying the optimal combinations and parameters that affect key mechanical properties, manufacturers can improve the design and material selection for chassis production. This research demonstrates the efficacy of using the Taguchi method in conjunction with experimental design approaches to systematically explore and enhance engineering designs. Future research could explore the integration of additional parameters and advanced materials to continue improving chassis design. Moreover, real-world testing and validation of the optimized designs are recommended to confirm their performance under operational conditions. Overall, this study successfully identifies critical factors and optimal combinations that enhance the mechanical properties of the Tata 1612 chassis, thereby contributing to the advancement of automotive engineering design practices.

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