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Crash Box Optimization with TPU: A Research Perspective

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Abstract: *This research investigates the crashworthiness of innovative crash box designs utilizing thermoplastic polyurethane (TPU) as a potential alternative to traditional materials. Two unique crash box geometries were developed and simulated using ABAQUS software. The study analyzed the impact performance of three different TPU grades (85A, 95A, and 64D) on energy absorption, peak crush force, and deformation behavior. The objective is to identify optimal material-design combinations for enhanced crashworthiness, contributing to advancements in vehicle safety and light weighting strategies.*

Keywords – *TPU- Thermoplastic polyurethane, FEA- Finite Element Analysis.*

I. INTRODUCTION

Vehicle safety is most important factor in the modern automotive industry. During a frontal collision, the crash box plays a crucial role in absorbing impact energy, protecting occupants, and minimizing damage to the vehicle. Traditional crash boxes, often constructed from metals like aluminum or steel, while effective, may present limitations in terms of energy absorption capacity, deformation behavior, and weight efficiency. This research investigates the potential of thermoplastic polyurethane (TPU) as a promising alternative material for crash box applications. TPU offers a unique combination of high energy absorption, elasticity, and lightweight properties, making it a potential candidate for enhancing crash box performance. To further optimize the design, this study explores different geometric configurations, including two honeycomb structures, to maximize energy absorption and minimize peak crush forces. The findings of this research are expected to contribute to advancements in vehicle safety by providing insights into the design and material selection of high-performance, lightweight crash boxes.

II. PROBLEM DEFINITION

2.1- Problem Statement

Traditional crash boxes, primarily constructed from metals, suffer from limitations in energy absorption capacity and excessive weight. These limitations compromise vehicle safety by potentially increasing the risk of occupant injury during collisions. Moreover, the weight of metal crash boxes contributes to increased fuel consumption and reduced vehicle efficiency. Additionally, current crash box designs often exhibit suboptimal energy distribution during impact, leading to localized damage and potentially inadequate protection. This research aims to address these critical issues by exploring the use of advanced materials and implementing optimized structural designs to develop lighter, more effective crash boxes that enhance vehicle safety.

2.2- Objective

This research aims to develop and evaluate innovative crash box designs. We aim to analyze the load distribution to optimize energy absorption; designing and refining CAD models with various geometries and materials; selecting suitable materials for automotive applications; optimizing crash box designs using ABAQUS for improved performance and weight reduction; and fabricating and testing physical prototypes to validate performance.

III. METHODOLOGY

The proposed Methodology Flowchart for the design and testing process.

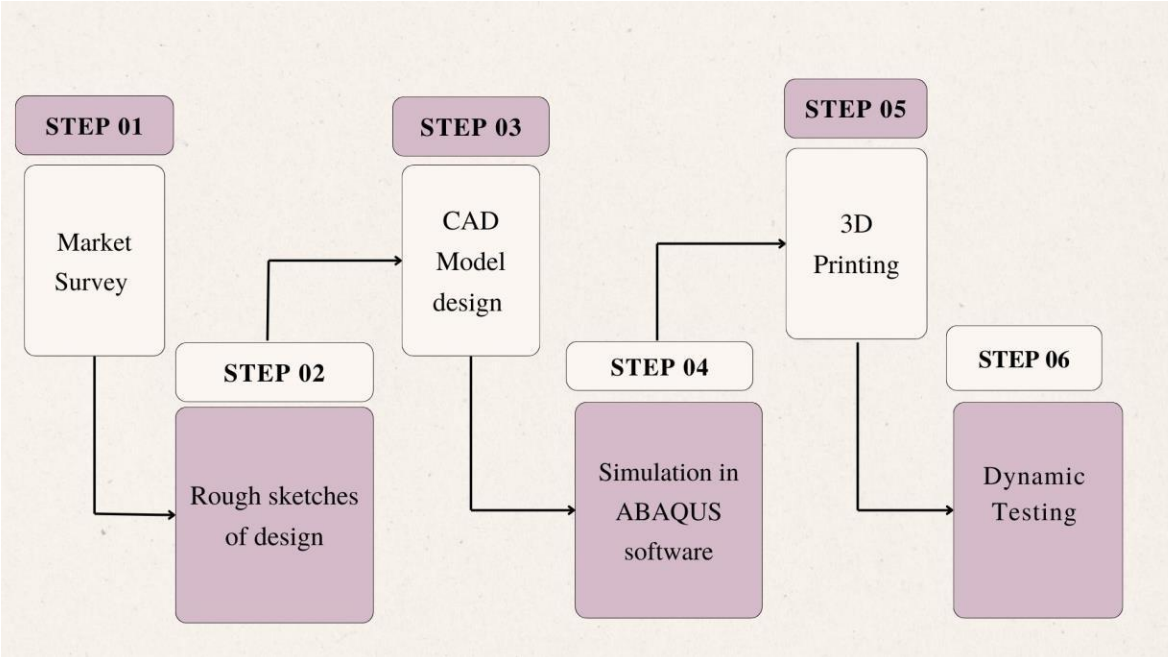

Fig 1. Flowchart for proposed methodology

3.1- Market Survey

A thorough market survey was conducted to assess current trends and identify limitations in existing crash box designs. This analysis focused on materials and structural configurations that optimize energy absorption. The survey findings informed the decision to investigate thermoplastic polyurethane (TPU) as a promising alternative material for improved performance and weight reduction.

Fig 2. Hyundai I10

Fig 3. Hyundai I20

3.2- Rough Sketches of Design

Initial design concepts were visualized and refined through the creation of rough sketches. These sketches served as a foundation for the subsequent development of detailed CAD models.

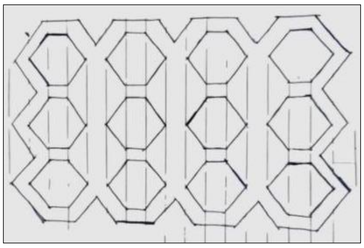

Fig 4. Sketch Design 1

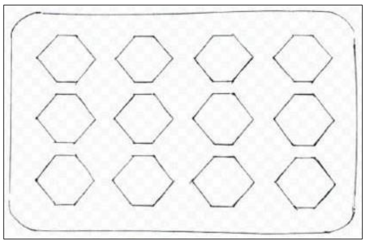

Fig 5. Sketch Design 2

3.3- CAD Model Design

Detailed CAD models were developed based on the rough sketches, incorporating precise dimensions, geometries, and material specifications. These models provided a virtual representation of the crash box design, facilitating visualization and enabling subsequent simulation and analysis.

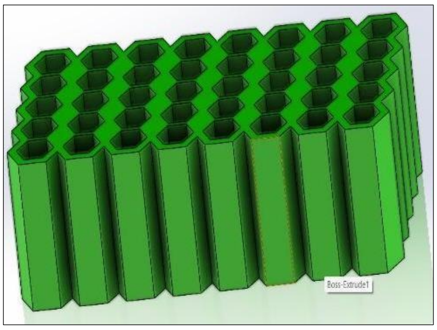

Fig 6. CAD Model 1

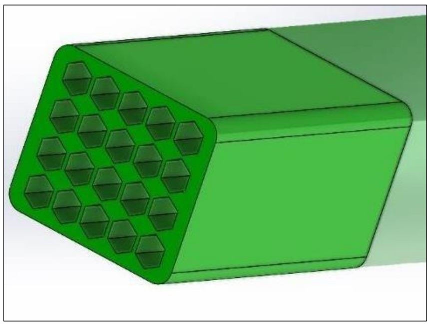

Fig 7. CAD Model 2

3.4 - Simulation in ABAQUS software

FEA was conducted using ABAQUS software to simulate the crash box's performance under various impact scenarios. This allowed for the evaluation of key performance metrics such as energy absorption, peak crush force, and deformation characteristics. The simulations provided valuable insights into the behavior of TPU under dynamic loading conditions.

3.5 - 3D Printing

Physical prototypes of the crash box designs were fabricated using 3D printing technology. TPU filament was utilized for 3D printing to accurately replicate the proposed geometries. This step enabled the transition from virtual models to tangible prototypes for further evaluation.

3.6 - Dynamic Testing

The 3D-printed prototypes underwent rigorous dynamic testing to assess their real-world performance. This involved subjecting the crash boxes to controlled impacts and measuring key performance metrics such as energy absorption, peak crush force, and deformation. The tests aimed to validate the crash box's ability to effectively dissipate impact forces and protect vehicle occupants.

IV. CONCLUSION

In this study, we have identified and selected two alternative designs for the crash box, which have been proposed as replacements for the current design. These new designs are engineered with enhanced materials that offer superior energy absorption capabilities. The goal is to improve the crash box's ability to absorb and dissipate force during an impact, thereby providing better protection in collision scenarios.

V. ACKNOWLEDGEMENT

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