iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: IV Month of publication: April 2023

DOI: https://doi.org/10.22214/ijraset.2023.51317

Analysis of Front Roof Header of Vehicle for Rollover Protection by using Ansys Software

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***Abstract:** Inadequate roof strength in vehicles is a major concern as it greatly increases the risk of head and neck injuries for passengers involved in even minor rollover accidents. Despite this, many manufacturers continue to produce cars with inadequate roof strength. Rollover accidents are unfortunately quite common and often result in serious injuries, such as spinal and neck trauma. Even when wearing a seatbelt, front seat passengers can still be at risk of injury as they may be thrown from the vehicle or experience significant forces during the rollover. The key to reducing these risks lies in ensuring that the roof of the vehicle is strong enough to withstand the compressive forces of a rollover and provide enough living space for the occupants. While airbags and seat belts are important safety features, a strong roof is equally essential to protecting passengers. For this reason, we have undertaken a project to improve the strength of the front roof header in order to enhance the safety of vehicle occupants.*

***Keywords:** Rollover accident, Occupant injuries, inadequate roof strength, Protecting passengers, improve safety*

I. INTRODUCTION

Rollover accidents pose a significant risk to vehicle occupants, particularly compared to other types of collisions. This is because the roof of a typical passenger car is likely to fold towards the occupant, resulting in serious head injuries. However, rollover accidents are relatively uncommon on American roads, accounting for only 3 percent of the 11 million crashes in 2019, according to the National Highway Traffic Safety Administration (NHTSA). Nonetheless, they remain a major concern for vehicle safety due to their high fatality and injury rates. Of the 41,000 claims that arose from rollover accidents, a third involved serious injuries or fatalities. Out of the 420,000 occupants involved in rollovers, more than half suffered minor to moderate injuries, while around 17,000 people were seriously injured and more than 20,000 people died. A recent trend shows that rollover accidents have become more deadly in the past two decades (i.e., 2017 and after) compared to the 1980s and 1990s. This indicates that improving rollover safety, whether by preventing a vehicle from rolling or reducing the severity of injuries during a rollover, could have a greater impact on reducing fatalities in more recent years.[4]

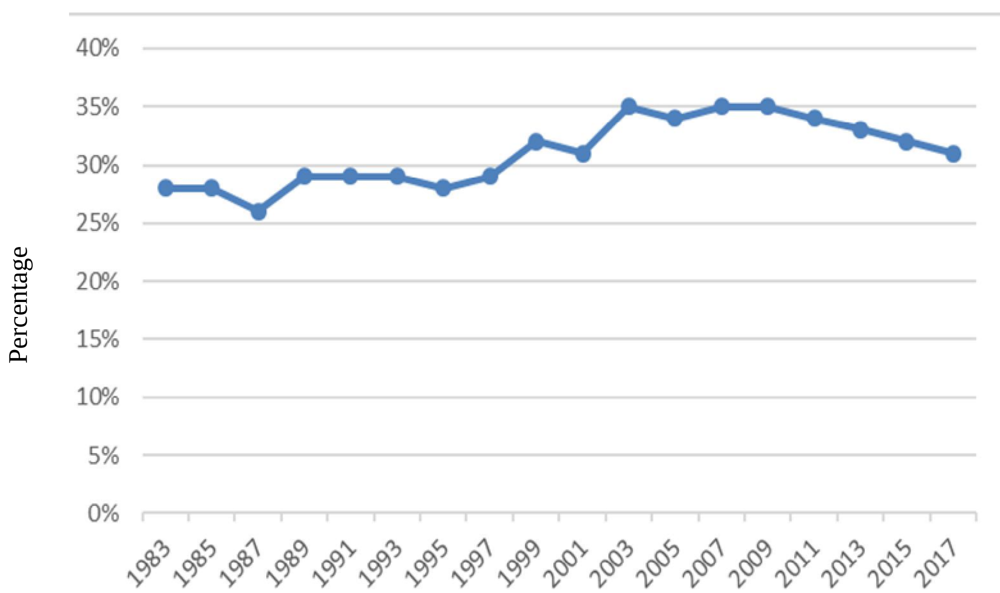


Figure No. 1. Rollover percentage per year

A. Vehicle Roof Strength

Rollover accidents can cause injuries through various incident, including occupant ejection and roof crush. Seat belt use and other ejection mitigation features, such as improved side curtain airbags and advanced window glazing, can help prevent occupant ejection during rollover crashes. On the other hand, a stronger roof structure can help mitigate the risk of crushing into the occupant compartment during a rollover. These measures address two of the primary causes of injury during rollovers and can help improve vehicle safety in the event of such accidents.

B. Federal motor Vehicle Safety Standard. 216

To address the issue of roof structures interfering with the occupant area during rollover accidents, the National Highway Traffic Safety Administration (NHTSA) established Federal Motor Vehicle Safety Standard (FMVSS) No. 216. This standard was created in the early 1970s in response to the need for stronger vehicle roof structures and has since been revised several times, with the most recent upgrade occurring in 2009, resulting in FMVSS No. 216a.

The standard includes various requirements, including one that specifies roof strength measured in the strength-to-weight ratio (SWR). This unit less metric measures a vehicle's roof strength by its own weight and indicates how well the roof structure can withstand the forces of a rollover.

For example, a 3.0 SWR means that a vehicle's roof structure can withstand 3.0 times its unloaded weight under the test conditions specified in FMVSS No. 216a. The inclusion of such requirements helps ensure that vehicle roofs are strong enough to withstand the impact of a rollover and reduce the risk of injury to occupants.[4]

C. NHTSA (National Highway Traffic Safety Administration)

In order to comply with FMVSS No. 216a, car manufacturers conduct roof crush tests on their vehicles and submit compliance reports to the National Highway Traffic Safety Administration. However, these compliance tests may not provide maximum SWR values as they often stop after meeting the minimum requirement. This means that the maximum SWR value obtained from compliance reports may not accurately represent a vehicle's roof strength. In contrast, the National Highway Traffic Safety Administration performed roof crush tests on 76 vehicles to support upgrading the roof crush resistance standard resulting in FMVSS No. 216a in 2009, and in those tests, the crushing metal plates travelled at least 5 inches. Therefore, the peak SWR value obtained from each of these vehicles was used in this study as it represents the maximum SWR value within 5 inches of the platen travel distance.

These vehicles ranged in model years from 1997 to 2008, and over 80% of them were less than 5 years old. The study included SWR data from all 76 vehicles as there is no reason to believe that a vehicle's roof strength would substantially change over a reasonable range of years. Thirty-two of these vehicles were crush-tested on both sides of their roofs, producing two peak SWRs for each vehicle, while the other 44 vehicles were crushed only on one side. In contrast, all IIHS tests were one-sided, meaning that only one peak SWR was found for each vehicle. The sides to be crushed in a one-side test at NHTSA and at IIHS were chosen randomly. The first side to be crushed in a two-side test was also chosen randomly, and then, the crushing test proceeded to the second side. Since all 358 vehicles from both data sources have peak SWRs on their first sides while 32 of them have the second-side peak SWRs as well, the first-side peak SWRs were used in this study.[4]

II. OBJECTIVES

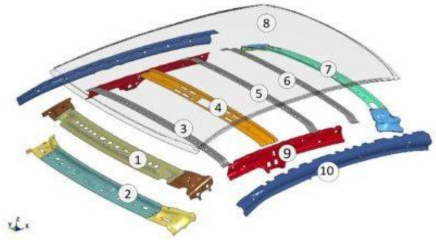
The primary concern addressed in this study is the safety of vehicle occupants in the event of an accident. The goal is to investigate the controlled failure crash mechanism.

The study focuses on the influence of the strength of the connection between the A-pillars (roof headers) on roof impact performance, particularly in relation to high-strength steel (HSS) designs. The approach used in this study is based on finite element analysis and applied load roof design analysis. The findings of this study can be used to improve vehicle design and development, particularly in terms of roof strength and impact performance.

III. MATERIAL USED

The material must have high tensile strength, low weight to reduce the car's centre of gravity, high toughness and space. A common alloy used is 6082 aluminium, which provides the strength, toughness and extra durability that turn multiple steel stampings into efficient one-piece stampings for Ford's flagship product. Ford front roof rails are 2.9kg lighter Extruded roof rails, arches and rails play a key role in protecting the passenger compartment of one of the world's most popular and best-selling vehicles. [5]

Roof along with all the roof bows and roof rail considered for the optimization.



Sl No	Part Name	Thickness (mm)	Material
1	Front header - upper	0.9	IF 300-420 MPa
2	Front header - Lower	0.7	DP 350-600 MPa
3	Roof Bow	1.2	IF 300-420 MPa
4	Roof Bow	1.2	DP 500-800 MPa
5	Roof Bow	1.2	IF 300-420 MPa
6	Roof Bow	1.2	IF 300-420 MPa
7	Rear Header	1.2	IF 300-420 MPa
8	Roof Panel	0.7	IF 140-270 MPa
9	Roof rail inner	1.65	DP 350-600 MPa
10	Roof rail Outer	1.75	DP 350-600 MPa

Note: Both left hand (LH) and right hand (RH) parts are considered for design space.
IF = Interstitial free (IF) Steels
DP = Dual Phase Steels

Baseline:
- Design space Mass = 22.4 Kg
- 100% steel
- Joining – Spot-welds and adhesive bonding between roof and roof bows

Figure No.2. Detail of Material used

Front roof bow header

A roof structure for a vehicle body in which a roof opening is defined by a pair of spaced-apart side panels, each having a flange extending inwardly and vertically offset below the roof surface, a front roof beam, and each rear header having a flange defining a window opening:

1) The outer roof panel that surrounds the roof opening, the outer edge covering the inwardly projecting flange of the si beam and the front and rear edges covering the front and rear collector plates and their flanges;
2) An inverted hat-shaped bracing rail located below the outer edge of the outer roof panel, including inner and outer flanges adjacent to the outer roof panel, and the bracing rail also includes a bottom wall adjacent to the side sill flange;
3) Adhesive acting between the base wall of the reinforcing rails and the inward facing flanges of the side rails.
4) A number of spot welds acting as the leading and trailing edges of the outer roof panel and the front and rear header flanges.

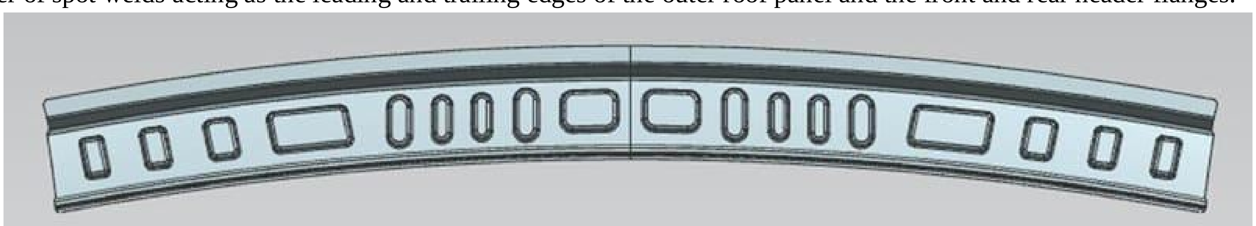


Figure No.3. Front header roof bow

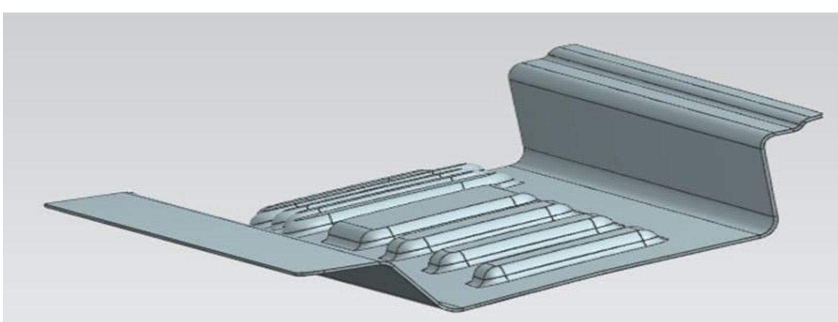


Figure No.4. Cross section of front roof header

5) The roof structure described in the claim includes an edging flange which is positioned between the outer roof panel and the reinforcing rail on both the rearmost and front most sides. This edging flange does not extend to the front and rear edges of the outer roof panels, which are instead spot welded to the front and rear roof rails. Additionally, a compressible seal is used between the slot flange and the side rails to cover any excess adhesive. Finally, a strip of curable sealant is applied between the outer roof panel and the reinforcing rail.[7]

Model details

Ansys software is a powerful tool for performing structural design analysis. The following are the general steps involved in performing static structure design analysis using Ansys software:

Define geometry: The first step is to define the geometry of the structure. This can be done using the Ansys Design Modeler or by importing a CAD file.

1) Define material properties: Next, the material properties of the structure need to be defined, such as the Young' modulus, Poisson's ratio, and density.
2) Mesh generation: The structure needs to be divided into small, discrete elements using mesh generation. This can be done using Ansys Meshing or other external meshing software.
3) Define boundary conditions: Boundary conditions need to be defined to simulate the loads and constraints on the structure. This can include forces, moments, and constraints at specific points.
4) Assign loads: After defining the boundary conditions, loads need to be assigned to the structure, such as point loads, distributed loads, or thermal loads.
5) Solve the model: Once the model is set up with geometry, material properties, mesh, boundary conditions, and loads, the model is solved using Ansys solver.
6) Post-processing: Finally, the results of the analysis are obtained through post-processing. This can include stress and deformation plots, factor of safety calculations, and other results that help to evaluate the design.

We have design a few structure that we can use in the vehicle front roof header are as follow:

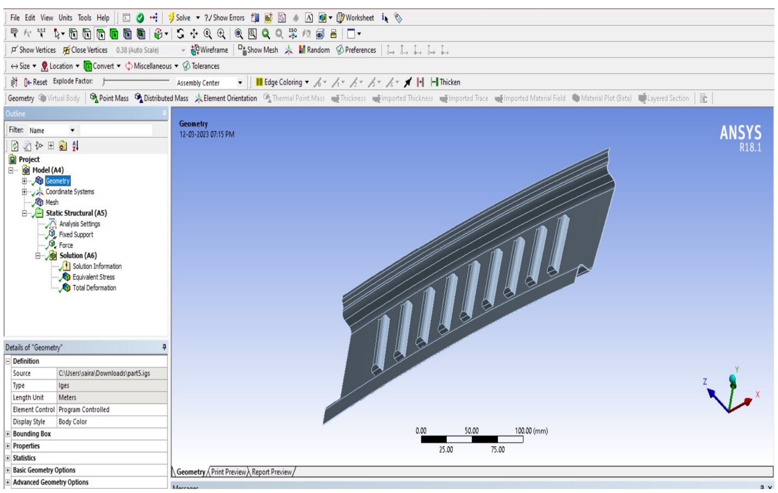


Figure No.5. Structure 1

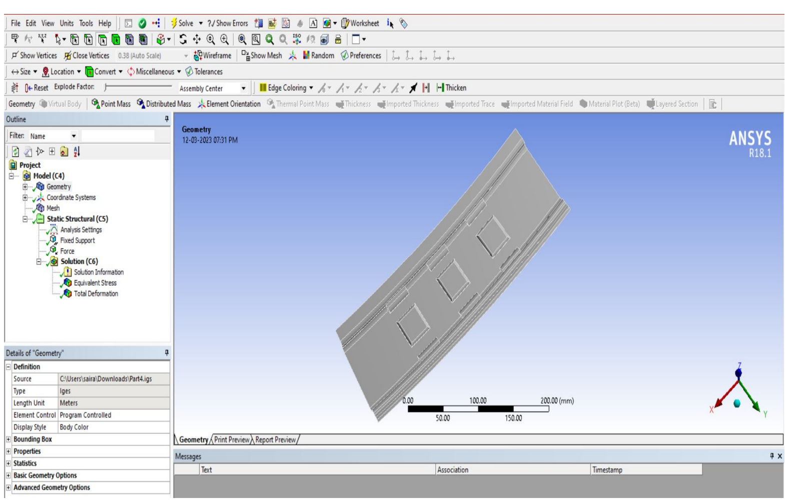


Figure No.6. Structure 2

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

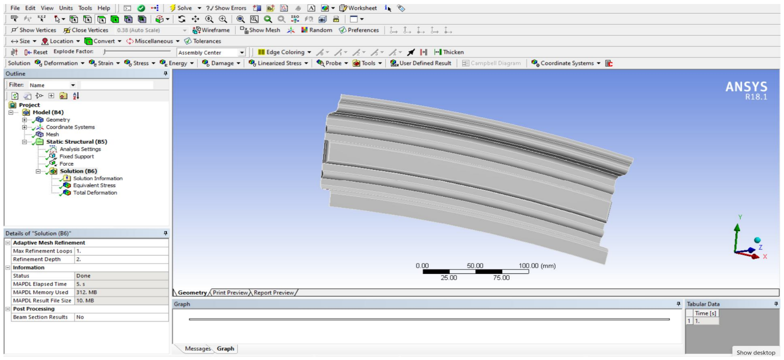


Figure No.7. Structure 3

IV. RESULT

Under extreme conditions. Additionally, the effective structure has shown better stability, stiffness, and durability compared to the other structures. The Section 2 is highly effective to the working condition, the minimum load and maximum load sustain capacity is more as comparatively It is important to note that the effectiveness of the structure may vary depending on the specific application and environmental conditions. However, based on the results obtained from the ANSYS analysis, it can be concluded that the effective structure is a better option for the given application. Further studies can be conducted to optimize the design of the effective structure and enhance its performance even further. Overall, the ANSYS analysis has provided valuable insights into the behaviour of the different structures, helping to identify the most effective one for the given application.

Ansys is a simulation software used for analyzing various aspects of product design and performance, including static structural analysis. The results of a static structural analysis in Ansys typically include the following:

1) *Stress Results:* Ansys provides a color-coded stress contour plot, which shows the magnitude and distribution of stress in the model. The results can be displayed as von Mises stress, principal stress, or any other stress component. The stress plot can also be animated to show how the stress changes as the load is applied.
2) *Deformation Results:* Ansys also provides a color-coded deformation plot, which shows the magnitude and direction of deformation in the model. This plot can help to identify areas of high deformation or displacement, which could lead to failure of the structure.
3) *Reaction Force Results:* Ansys calculates the reaction forces at each support or constraint location. These forces can be used to check the validity of the boundary conditions and to ensure that the model is properly constrained.
4) *Displacement Results:* Ansys also provides a plot of the displacement of each node in the model. This plot can help to identify areas of high deformation or displacement, which could lead to failure of the structure.
5) *Strain Results:* Ansys calculates the strain at each node in the model. The strain results can be displayed as a contour plot, which shows the magnitude and distribution of strain in the model.
6) *Factor of Safety Results:* Ansys can also calculate the factor of safety for the model. The factor of safety is a measure of how close the model is to failure, and is calculated as the ratio of the ultimate strength to the applied load.
7) *Fatigue Life Results:* Ansys can also perform fatigue analysis to estimate the number of cycles that the structure can withstand before failure. The fatigue life results can be displayed as a contour plot, which shows the number of cycles to failure at each node in the model.

Overall, Ansys provides a comprehensive set of results for static structural analysis, which can be used to evaluate the performance and safety of a product design.

Table No. 1. Comparison of structure

Sr. No	Parameter	Structure 1	Structure 2	Structure 3
1	Material used	AHSS	AHSS	AHSS
2	Force Applied	15000 N	15000 N	15000 N
3	Temperature °C	22	22	22
4	Max load Sustain (MPa)	850.35	892.66	815.41
5	Min Load Sustain (MPa)	0.8799	2.059	1.726
6	Deformation(mm)	4.9626	3.9289	4.1288

After analysing above structures using ANSYS, it has been found that one particular structure is more effective than the others. The effective structure has exhibited superior performance in terms of its ability to withstand various types of loads, such as static and dynamic loads. The analysis has also shown that the effective structure has a higher factor of safety, indicating that it is less likely to factor the other structure. Also its deformation is 3.9289 is less than the other section

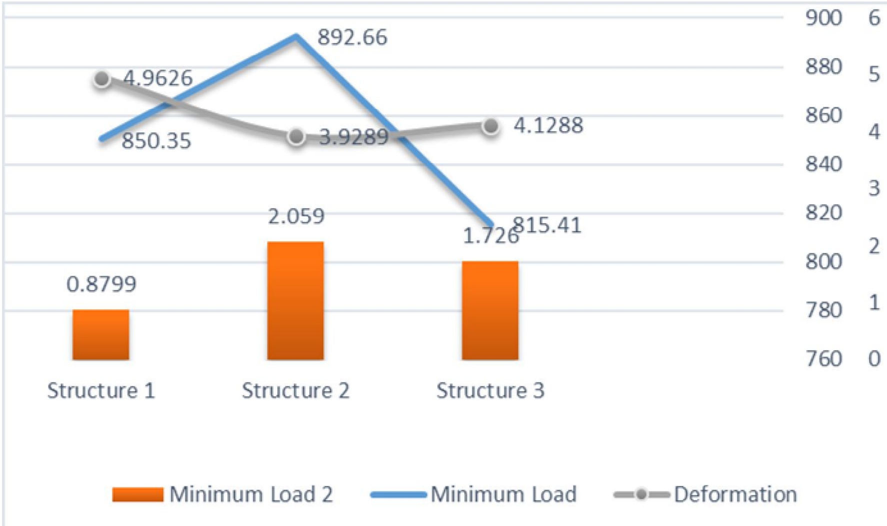


Figure No.8. Comparison of section and deformation

V. CONCLUSION

After conducting an analysis using ANSYS on several structures and comparing their performance, it has been determined that the structure 2 out performs the others. The analysis revealed that the structure 2 has a higher factor of safety, indicating that it is more capable of withstanding different types of loads, such as static and dynamic loads. It also exhibited a higher level of stiffness, stability, and durability compared to the other structures analysed. The comparison also highlighted some areas where the other designs could be improved, such as changing the shape of certain components. However, based on the results of the ANSYS analysis, the structure 2 is the most effective option for the given application. Overall, this analysis provides valuable insights into the behaviour of the different structures and can help guide future design decisions to further enhance the performance of the structure.

REFERENCES

[1] Donald Friedman“ ADVANCED ROOF DESIGN FOR ROLLOVER PROTECTION” MCR/LRI, Inc. Carl E. Nash, Ph.D The George Washington University United States Paper No. 01-S12-W-94.

[2] Joachim Scheub, Fadi Tahan, Kennerly Digges, Cing-Dao Kan. “Influence of Different Platen Angles and Selected Roof Header Reinforcements on the Quasi-Static Roof Strength of a 2003 Ford Explorer FE Model”

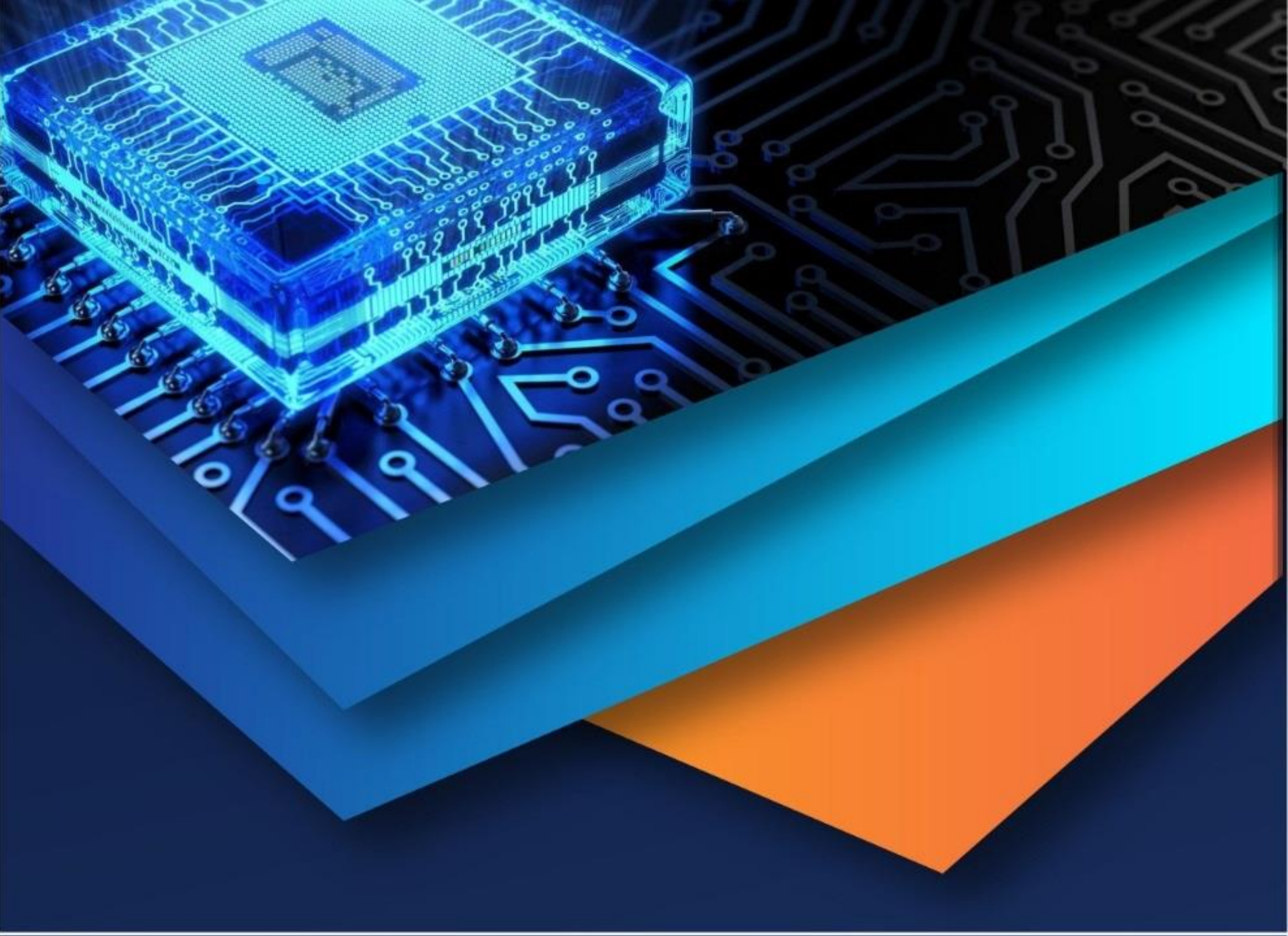
[3] V.Teja 2 J.Goutham raj 3K.Ramesh 1, 2 Final B.Tech, Dept. of ME. 3 Associate Professor, Dept. of Mechanical Engineering, Narayana Engineering College, Nellore “DESIGN AND ANALYSIS OF CAR ROOF CRUSH”

[4] Kweon, Y.-J. (2020, November). Evaluation of FMVSS No. 216a, roof crush resistance, upgraded standard. National Highway Traffic Safety Administration.“Evaluation of FMVSS No. 216a, Roof Crush Resistance, Upgraded Standard”

[5] Pradeep Mohan , Vinay Nagabhushana , Cing-Dao (Steve) Ken 1 Jon Riley “Innovative Approach for Improving Roof Crush Resistance”

[6] Yong-Sang Shin, Hyo-Jun Eun, Yong-Ju Chu and Seung -Yop Lee “Roof-Crush Protection Design of Automotive Bodies Using Clustering and Pattern Recognition”

[7] https://skill-lync.com/student-projects/roof-challenge-139 Roof challenge by Gokul raj



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