

DESIGN AND ANALYSIS OF LEG GUARD OF TWO-WHEELER FOR OPTIMIZATION OF WEIGHT AND STRENGTH

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Abstract - This study presents the design, explicit dynamic analysis, and material optimization of a diamond-shaped two-wheeler leg guard. A three-dimensional leg guard model was developed in CATIA V5 and analyzed in ANSYS 19.0 Explicit Dynamics under an impact condition against a fixed concrete block. Four materials—SS202, SS440C, Mild Steel, and Titanium Alloy—were evaluated under identical geometry, meshing, and loading conditions. A 10 mm tetrahedral mesh was used, with an initial velocity of 8560 mm/s and an analysis end time of 0.005841 s. The numerical response was assessed using maximum equivalent (von Mises) stress and total deformation, while theoretical load-carrying capacity and component weight were calculated from material yield strength, tube cross-sectional area, and density. The calculated load-carrying capacities were 32.39, 53.01, 53.01, and 97.53 kN for SS202, SS440C, Mild Steel, and Titanium Alloy, respectively. The corresponding weights were 1.56, 1.54, 1.62, and 0.89 kg. A Weighted Sum Method, with priorities of 0.8 for strength and 0.2 for weight, identified Titanium Alloy as the optimum material with a score of 1. The study demonstrates a numerical material-selection approach for achieving a lightweight leg guard with improved theoretical strength performance.

Keywords: motorcycle leg guard, diamond-shaped guard, explicit dynamic analysis, material selection, strength, weight optimization.

1. INTRODUCTION

Two-wheelers are widely used because of their affordability, fuel efficiency, and ease of operation. However, riders remain exposed during side impacts, low-speed collisions, and motorcycle overturning. The legs are particularly vulnerable because a motorcycle does not provide an enclosed passenger compartment. A leg guard can provide a physical barrier between the rider and external obstacles and may also reduce damage to the motorcycle during minor impacts.

The design of a leg guard requires a balance between structural performance and mass. Excessive weight adds unnecessary mass to the vehicle, whereas insufficient strength may reduce protective performance. Computer-aided design and finite element methods allow alternative geometries and materials to be evaluated before physical fabrication. In the present work, a diamond-shaped leg guard is modeled and subjected to explicit dynamic analysis, followed by a quantitative comparison of four candidate materials.

The study specifically investigates SS202, SS440C, Mild Steel, and Titanium Alloy under identical impact conditions. Strength

is additionally estimated from yield strength and tubular cross-sectional area, while weight is obtained from tube volume and density. The two criteria are combined using the Weighted Sum Method (WSM) to identify the material offering the best balance of strength and weight.

2. LITERATURE REVIEW

Toma et al. (2010) investigated motorcycle crash-related head injuries using finite element simulations and showed the usefulness of numerical models for evaluating injury mechanisms and protective-system design.

Moradi et al. (2010) studied motorcyclist impact with concrete barriers under different road conditions using numerical crash simulation. The work highlighted the influence of impact speed, collision angle, and road condition on rider kinematics.

Liz de Rome et al. (2011) examined motorcycle protective clothing and its association with injury outcomes. The study reported that certified protective clothing was associated with reduced injury severity.

Capitani and Pellari (2012) analyzed biker protection devices for roadside barriers using numerical crash simulations and investigated the effects of impact conditions on protection performance.

Miralbes (2013) developed a numerical approach for assessing motorcycle rider protection systems and demonstrated the value of finite element simulation for evaluating rider kinematics and protection performance.

Vangi and Cialdai (2014) evaluated energy loss in motorcycle-to-car collisions and used numerical and experimental approaches to investigate collision behavior.

Badgajar and Barjibhe (2014) designed a motorcycle leg guard and compared C440 and C650 stainless steels under different loading conditions. The reported results indicated improved performance for C650 in terms of deformation and load-carrying capability.

Mántaras and Luque (2015) assessed motorcyclist protection systems using finite element simulations and demonstrated the usefulness of validated numerical analysis for dynamic crash conditions.

Balamurugan et al. (2018) designed and analyzed a scooter front guard using CAD and ANSYS Explicit Dynamics. The modified guard showed improved crashworthiness and energy-absorption behavior under the investigated impact condition.

Vignesh et al. (2020) compared motorcycle leg-guard configurations using ANSYS Explicit Dynamics and reported favorable crashworthiness for a diamond-type design.

Srikar et al. (2023) evaluated motorcycle leg-guard configurations using different stainless-steel materials and

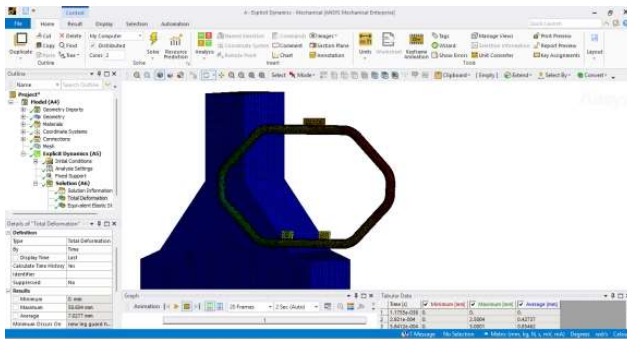


Fig. 3. Analysis result of SS440C

Table 2: Explicit dynamic results

Material	Max. equivalent stress (N/mm ²)	Max. total deformation (mm)
SS202	185.33	58.606
SS440C	186.20	58.604
Mild Steel	201.86	58.569
Titanium Alloy	115.89	58.665

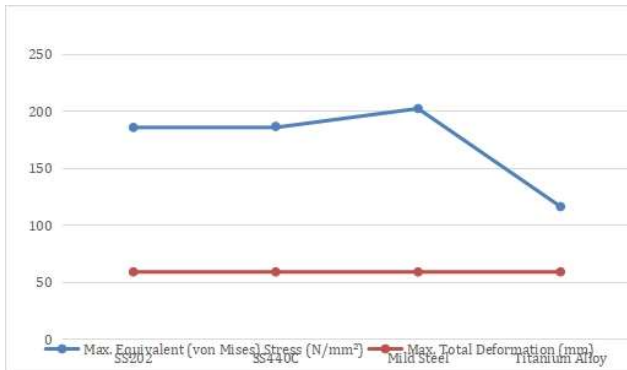


Fig. 3. Comparison of Explicit dynamic results

6. STRENGTH AND WEIGHT CALCULATION

For the tubular section, the cross-sectional area was calculated from the outer and inner diameters as $A = (\pi/4)(D^2 - d^2)$. With $D = 31.25$ mm and $d = 28.75$ mm, the area is 117.80 mm². The theoretical maximum axial load-carrying capacity was then estimated from $F_{max} = \sigma_{yield} A$. The total tube length was 1720 mm, giving a volume of 0.000202616 m³. Weight was calculated from $W = \rho V$.

Table 3: Load-caring capacity and weight of different material

Material	Yield strength (MPa)	Load capacity (kN)	Weight (kg)
SS202	275	32.39	1.56
SS440C	450	53.01	1.54
Mild Steel	450	53.01	1.62
Titanium Alloy	828	97.53	0.89

Titanium Alloy provides the highest theoretical load-carrying capacity (97.53 kN) and the lowest calculated weight (0.89 kg). SS440C and Mild Steel have the same theoretical load capacity because their yield strengths are equal, while Mild Steel has the highest weight among the four materials.

7. MATERIAL OPTIMIZATION USING WEIGHTED SUM METHOD

The Weighted Sum Method was used as a multi-criteria decision method. Strength was treated as a benefit criterion to be maximized and weight as a cost criterion to be minimized. The selected weights were 0.8 for strength and 0.2 for weight. Strength was normalized by dividing each value by the maximum strength, while weight was normalized by dividing the minimum weight by each material's weight. The overall score was calculated by summing the weighted normalized criteria.

Material	Normalized strength	Normalized weight	WSM score
SS202	0.3321	0.5705	0.3798
SS440C	0.5435	0.5779	0.5504
Mild Steel	0.5435	0.5494	0.5447
Titanium Alloy	1.0000	1.0000	1.0000

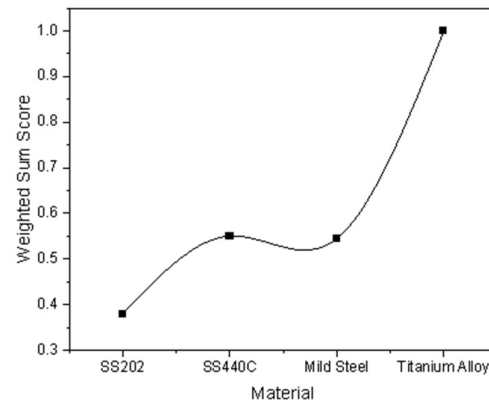


Fig. 4. Weighted Sum Method score for the selected materials

Titanium Alloy obtained the highest WSM score of 1.0000, followed by SS440C (0.5504), Mild Steel (0.5447), and SS202 (0.3798). Under the selected 0.8/0.2 weighting scheme, Titanium Alloy is therefore the optimum material among the evaluated alternatives.

8. RESULTS AND DISCUSSION

The explicit dynamic results show that the deformation response is nearly unchanged across the candidate materials for the specified impact model, whereas the equivalent stress values differ. The independent strength and weight calculations provide a clearer distinction between the materials: Titanium Alloy combines the highest theoretical load capacity with the lowest mass. The WSM result reinforces this combined performance because the strength criterion carries the larger decision weight.

The selected Titanium Alloy therefore offers the most favorable strength-to-weight balance within the assumptions of the present numerical study. The result should be interpreted as

a material-selection outcome for the specified geometry, loading, material data, and WSM weighting rather than as experimental validation of crash safety.

9. CONCLUSION

A diamond-shaped two-wheeler leg guard was designed in CATIA V5 and evaluated using ANSYS 19.0 Explicit Dynamics. Four materials—SS202, SS440C, Mild Steel, and Titanium Alloy—were compared using identical geometry and impact conditions. The calculated theoretical load-carrying capacity was highest for Titanium Alloy at 97.53 kN, while its calculated weight was lowest at 0.89 kg. The explicit dynamic analysis produced maximum equivalent stresses of 185.33, 186.20, 201.86, and 115.89 N/mm² for SS202, SS440C, Mild Steel, and Titanium Alloy, respectively, with total deformation remaining approximately 58.6 mm. The WSM, using strength and weight weights of 0.8 and 0.2, respectively, produced the highest score of 1.0 for Titanium Alloy. Thus, within the defined numerical framework, Titanium Alloy was identified as the optimum material for the diamond-shaped leg guard.

10. FUTURE WORK

Future work may include experimental validation, prototype fabrication, evaluation under different impact velocities and directions, and investigation of advanced lightweight or composite materials. Cost and additional safety criteria may also be incorporated into a multi-objective optimization framework. Topology or design optimization could further reduce mass while maintaining the required structural performance.

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