Design and Analysis of Two-Wheeler Wheel Rim with Different Alloy Materials and Loading Conditions

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Abstract - *A Wheel is a circular device that is capable of rotating on its axis, which enables efficient movement of automobiles. It is one of the highly stressed components in an automobile that is subjected to loads. At present, alloy wheels are mostly used because of their lighter weight, high strength, and better heat dissipation. The Alloy wheel is designed by using the CATIA V5 software and then it is imported to Ansys Workbench 2021 R2 to perform static and dynamic analysis on designed wheel rim with three different materials namely, Magnesium, Aluminium, and Titanium alloy. The static and dynamic behavior of the wheel rim is determined after performing the static and dynamic analysis. The analysis results of the wheel rim with different materials were compared in terms Total deflection, Equivalent (Von-mises) stress, Equivalent elastic strain under different load conditions and frequencies of modal analysis, to find out the best possible material for the designed wheel rim.*

Key Words: Alloy wheel, Catia v5, Ansys, Static Analysis, Dynamic Analysis

1.INTRODUCTION

A wheel is mechanical part of the vehicle which allows for the easy movement of the load and bearings present in it take care of the friction it comes across during rotation. The outer edge of a wheel which holds on the tire is called the wheel rim. Wheel design is one of the challenging task in automotive industry where lot of care must be taken in distributing the loads acting on the wheel rim by considering loads on the wheel. Automotive wheels have complicated geometry and must satisfy manifold design criteria, such as style, weight, manufacturability, and performance. In addition to being aesthetic, the wheel design must meet a number of engineering standards, with good performance and durability standards and in order to get maximum driving comfort and road handling capabilities, the wheel must be as light as possible. Nowadays, one of the most difficult tasks in the wheel industry is minimizing the wheel weight. The wheel is designed in such a way that the loads acting on it should be distributed equally so that the shocks are avoided and smooth driving is achieved at the same time the wheel rim should be physically strong enough to bear the impact loads with less deformation.

2. METHODOLOGY

2.1 Materials:

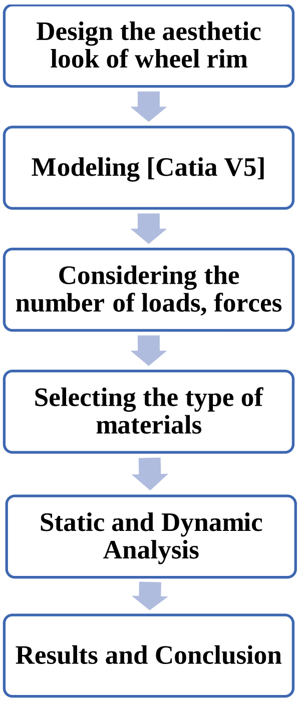
Alloys possess better corrosion resistance, inexpensive, higher strength, and better workability than pure metals. Properties such as machinability, ductility, and brittleness are governed by the alloy's manufacturing process and composition. In this study, Aluminium, Magnesium, and Titanium alloy are considered for the wheel rim material.

Aluminium alloys are alloys with aluminium as the prime metal. The alloying elements can be copper, tin, zinc, magnesium etc, based on the application of the material and its function. The physical and chemical advantages of aluminium and its alloy are light weight, strong, high strength to weight ratio, resilient, non-magnetic etc. The advantages of a product made of it are attractive aesthetics, easy fabricate, uniform quality, cost effective, complex shapes, and recyclable. Aluminium is one third the weight of steel and the manufacturing process has a great influence on its properties.

Magnesium alloys are alloys with magnesium as prime material and the alloying elements can be aluminium, silicon, copper, zinc etc based on the application of the material to a product. Exceptional machinability, low cost, high strength to weight ratio, low specific gravity etc. the advantages of magnesium alloy. The magnesium alloy is used in automotive, industrial, biomedical, aerospace and commercial applications. Impurities in the alloy must be treated properly or can lead to toxic effects during degradation.

Titanium alloy have very high tensile strength and are light in weight, corrosion resistance, toughness at higher temperatures and temperature tolerance. It is heavier compared to others alloy materials but is stronger which makes less material usage compared to others.

2.2 Steps Involved:



Flow Chart-1

3. MODELLING

3.1 Catia V5:

CATIA V5 is modelling software. The wheel rim is drawn in Part design workbench in Catia. The inner and outer diameter, width of wheel rim is collected and a rough diagram of Wheel rim is drawn with designed wheel pattern, then in Catia V5, a cross section is drawn first in sketcher workbench using basis tools like line, circle, spine, mirror, trim and then by using tools like pad, revolve, chamfer and hole a 3D model is generated. The files are saved as STEP files and used to import into Ansys Workbench

3.2 Catia Modelling Steps:

1.First in Skecher module, inner and outer diameter is drawn using Circle command and by using Arc command arc is drawn connecting 2 circles, then by Using Mirror Command Other Arc is draw and unnecessary lines are removed by Trim command as shown in figure 1.

2. The 2D sketch is extruded and made spoke hollow using Pocket command and single spoke is revolved using circular pattern as shown in figure 2.

3.Then Wheel cross-section is drawn on spoke and revolved as shown in figure 3 to generate wheel rim.

4.All the sharp edges are made in smooth curves using edge fillet.

5. Catia part design file is save as Step file

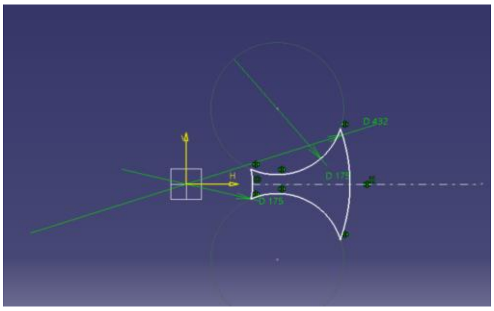


Fig 1: 2D Sketch

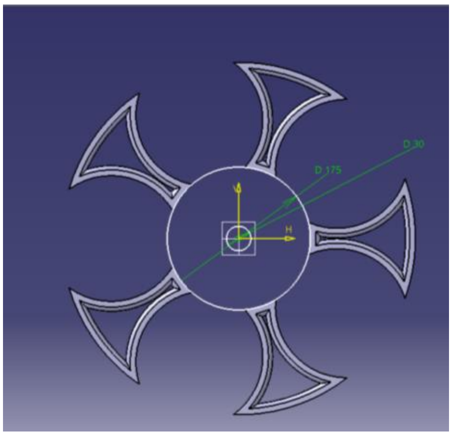


Fig 2: Spokes design

Fig 3: Side View of Wheel rim

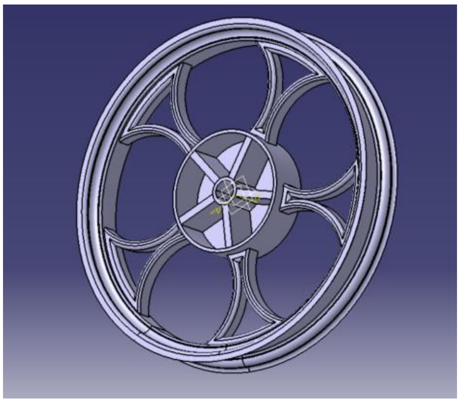


Fig 4: 3D model of Wheel Rim

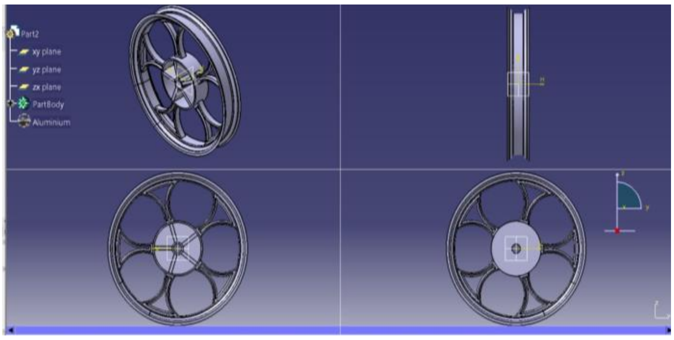


Fig 5: Different views of Wheel rim

4. ANSYS WORKBENCH:

Ansys is mechanical finite element analysis software Used to perform different analysis like static structural, dynamic, fluid, thermal analysis

4.1 Static Structural Analysis:

➢ Steps involved:

I. Engineering data
II. Geometry
III. Model
IV. Meshing
V. Analysis
VI. Results

I. Engineering data:

The Alloy wheel material are selected from the workbench Library

II. Geometry:

Catia step file is imported into Ansys in geometry and units are set properly,

III. Meshing:

The finer the mesh, the more accurately the 3d model is defined

Fig 6: Meshing

IV. Model:

a) Boundary Conditions:

1.The structural model of the rear wheel is taken into consideration for the accurate analysis result.

2. The motorcycle's net weight is 148 kg.

3.The tyre inner tube filled to a gas filled with pressure of 0.193 MPa and it is uniformly distributed over the wheel surface.

4.To ensure the analysis accuracy, the whole weight of the motorbike and the maximum permitted load was applied to the rear wheel alone.

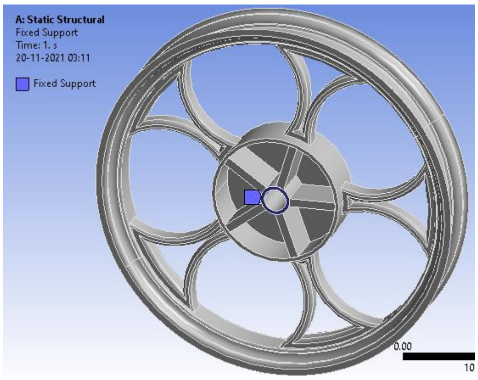


Fig 7: Fixed Support

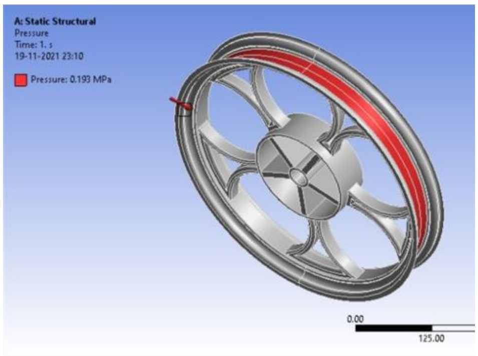


Fig 8: Pressure

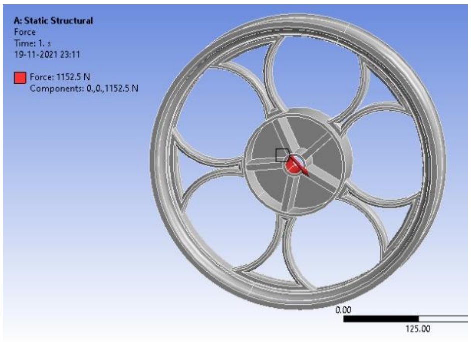


Fig 9: Force

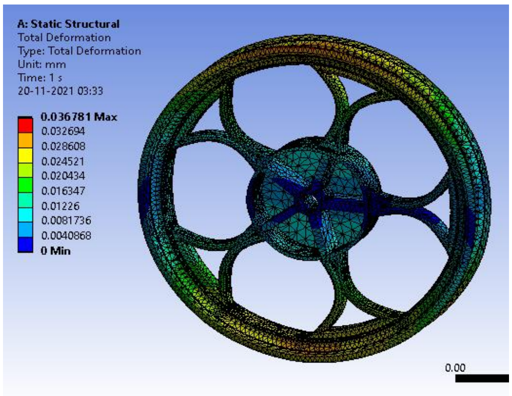
b) Load Calculations for Static Analysis:

- Dead weight of bike = 148 kg,
- Other loads = 20 kg,
- Average weight of the one Person = 65 kg.
- Load 0 = weight of bike (148 vehicle +20 extra kg) = 168 kg,
- Load 1 = Bike weight+ one-person average weight= (148+65) kg =213 kg,
- Load 2 = Bike weight+ one-person average weight= (148+65x2) kg =278 kg.
- Number of Wheels = 2
- Considering the total load acts on Sigle wheel and 30% of load reduces due to tires and suspension system. So, resulted net load in newton is given as:

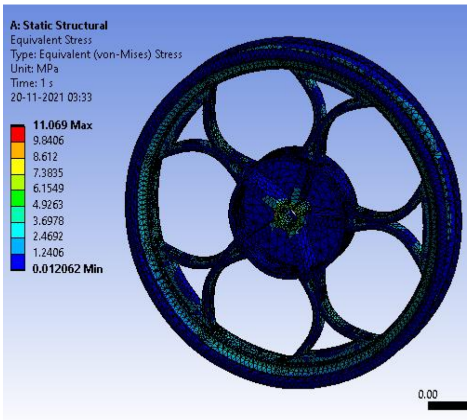
Load 0 = 168 X 9.81 X 0.7 N = 1153.656N
Load 1 = (148+65) X 9.81 X 0.7 N = 1462.671N
Load 2 = (148+65*2) X 9.81 X 0.7 N = 1909.026N

V. Analysis

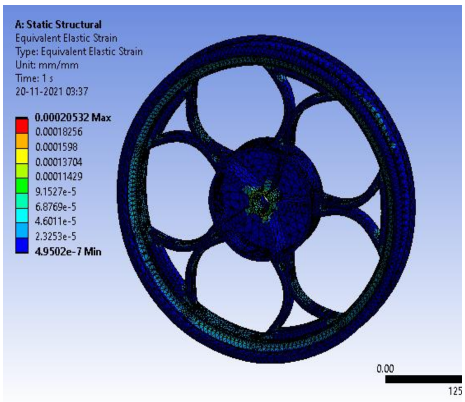
i) Aluminium Alloy:



a) Total Deformation

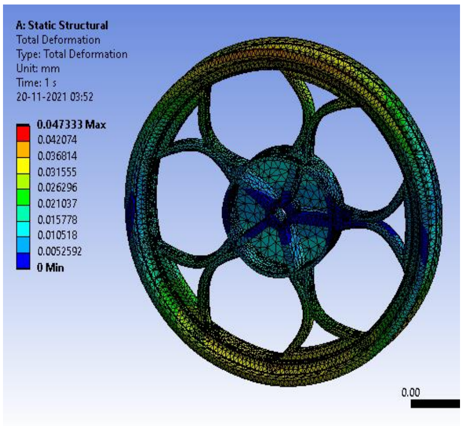


b) Equivalent Stress

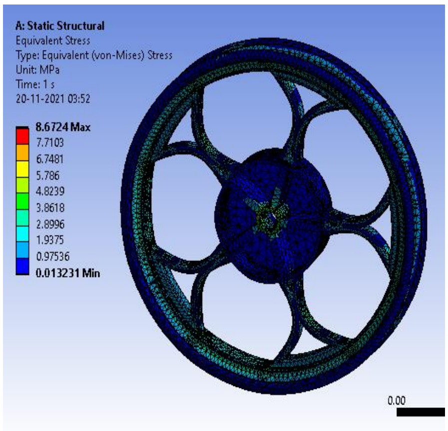


c) Equivalent Strain

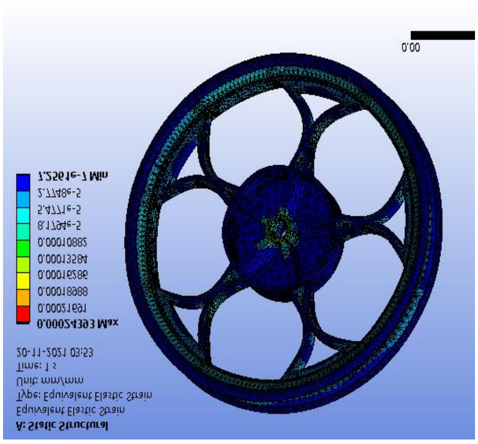
ii) Magnesium Alloy:



a) Total Deformation

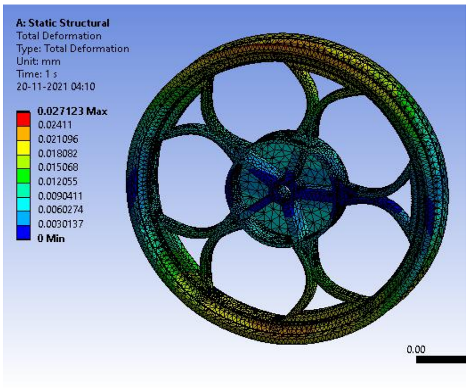


b) Equivalent Stress

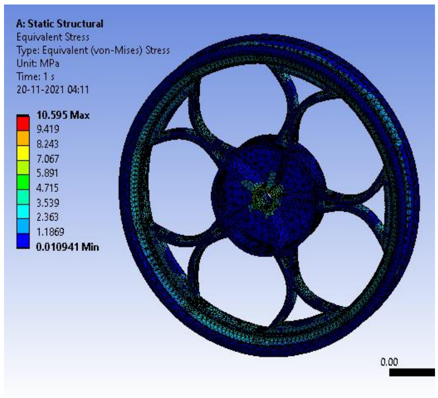


c) Equivalent Strain

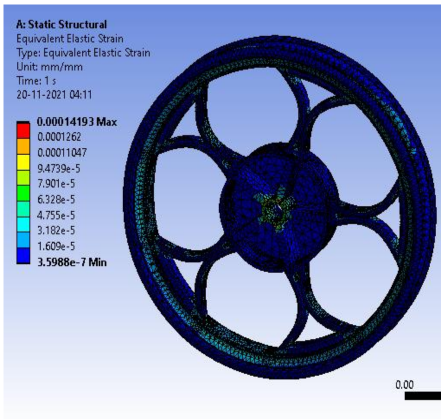
iii) Titanium Alloy:



a) Total Deformation



b) Equivalent Stress



c) Equivalent Strain

VI. Results:

Table 1: Static Results at Load 0

	Aluminium Alloy	Magnesium Alloy	Titanium Alloy
Displacement (mm)	0.030067	0.047333	0.022154
Equivalent stress (MPa)	8.9175	8.6724	8.5417
Equivalent strain	0.00016147	0.00024393	0.00011317

Table 2: Static Results at Load 1

	Aluminium Alloy	Magnesium Alloy	Titanium Alloy
Displacement (mm)	0.036781	0.057935	0.027123
Equivalent stress (MPa)	11.069	10.76	10.595
Equivalent strain	0.00020532	0.00031015	0.00014193

Table 3: Static Results at Load 2

	Aluminium Alloy	Magnesium Alloy	Titanium Alloy
Displacement (mm)	0.046505	0.073284	0.034318
Equivalent stress (MPa)	14.191	13.788	13.573
Equivalent strain	0.00026885	0.00040607	0.0001858

4.2 Modal Analysis:

- A modal analysis, also known as a free vibration analysis, is used to determine a structure's natural frequencies and mode shapes.
- It considers the natural frequencies rather than the structure's response under dynamic loads.
- Before tackling more complex dynamic issues, a modal analysis is generally the initial step.
- The wheel rim structure resonates at natural frequencies and these frequencies are obtained by performing modal analysis on the wheel rim. The number of modes given is as 6 and fixed support is provided at the center of hub. Materials applied to rim are aluminium alloy, magnesium alloy and titanium alloy for finding the natural frequency.
- The meshing for modal analysis is same as static structural analysis.
- Different mode shapes and frequencies are obtained in the modal analysis

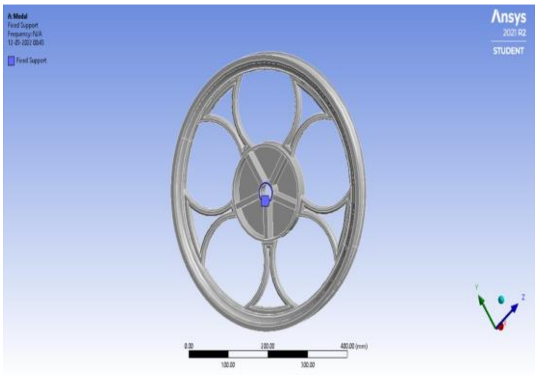
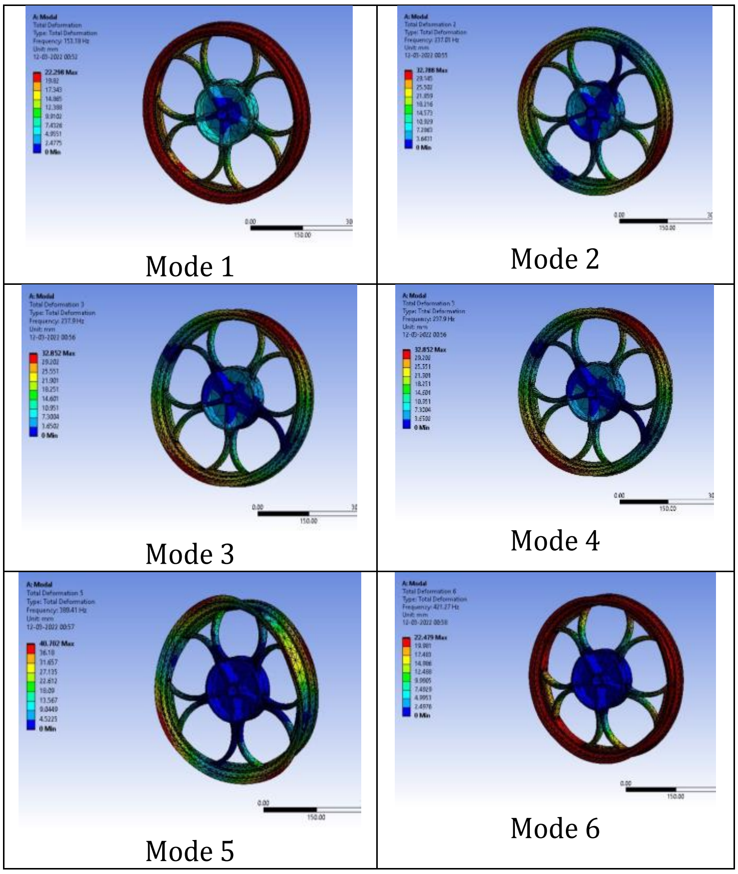


Fig 10: Fixed Support in Modal Analysis

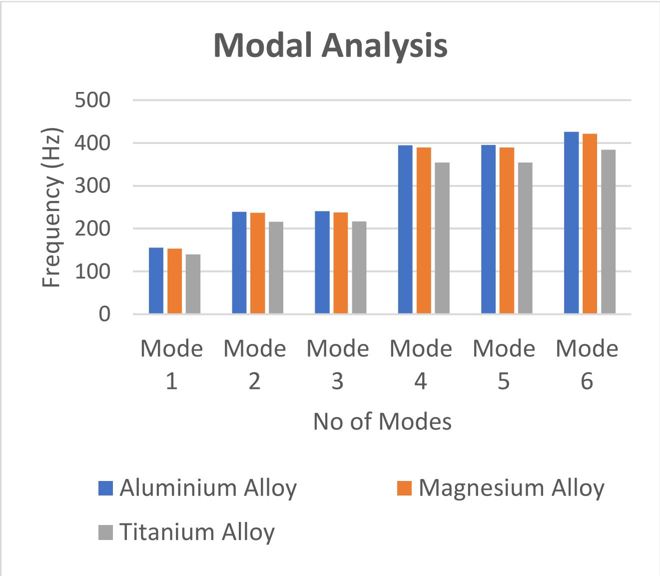
Different Mode shapes of Magnesium Alloy



5.RESULTS:

Table 4: Modal Analysis Results

	Aluminium Alloy	Magnesium Alloy	Titanium Alloy
Mode 1 (hz)	155.19	153.18	139.65
Mode 2 (hz)	239.57	237.03	216.34
Mode 3 (hz)	240.39	237.9	217.16
Mode 4 (hz)	395	389.23	354.48
Mode 5 (hz)	395.19	389.41	354.64
Mode 6 (hz)	425.85	421.27	384.43



Bar Graph

6.CONCLUSION

The Wheel rim is designed using Catia V5 software.
The finite element analysis of wheel rim is done by using Ansys workbench 2021 R2. After performing static structural analysis, various parameters are obtained namely, Total Deformation, Equivalent Stress, Equivalent Strain at different loading conditions and different materials. Modal analysis is carried out with 6 different modes and 6 mode shapes are obtained for each material. A comparison is made between different materials in terms of various parameters. The following are the findings after static structural and Modal analysis:

a) The designed wheel is safe under different loading conditions within permissible limits.

b) By comparing static results, Titanium alloy is considered to be a best material.

c) But in modal analysis, the Titanium alloy dynamic stability is less compared to both aluminium and magnesium alloy.

d) Magnesium Alloy is light weight compare to Aluminium Alloy and Titanium alloy.

e) Equivalent stress of magnesium alloy is lower than Aluminium Alloy and slightly greater than Titanium Alloy.

f) By comparing all the results of static structural and modal analysis results, Magnesium alloy is best material with less equivalent stress and it is considered more feasible material for light weight design with good dynamic stability.

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