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A Study of Design and Analysis of Automobile Wheel Rim Using Different Fillet Radius and Different Y Spoke Angle

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Abstract: ***Wheel rims are the most important part of automobile, in an automobile there are fatigue loads and static loads which are actively participated in design. There are several ways of failure of wheel rim like critical stresses and material failure due to design, dimension and shape of wheel also play vital role in its dimensions and shape vehicle rim design. Present paper studied the Y angle optimization in alloy wheel rim. The present design analysed by ANSYS software. For the structural analysis for the remote force the magnitude applied is 1000N and for the pressure which applied on the wheel is 245kPa.***
Therefore, so comparing the wheels with the total deformation occurred alloy wheels are better than the steel wheel and comparing the both the alloy wheels multi-spoke alloy wheel is better than the 6-spoke alloy wheel. The total deformation of 8 spoke alloy wheel with 55° Y spoke angle, figure clearly depicted the total deformation maximum value 0.00155mm maximum at base of wheel or outer periphery of wheel rim.
Keywords: ***Wheel Rim, Y Spoke Angle of rim, fillet radius of rim, total deformation occurring, ANSYS***

I. INTRODUCTION

Origin of human civilization is truly stated with invention of wheel and absolutely it is significant discovery of evolution of human race. The invention of wheel accelerates the transportation idea. Wheel is a part with circular shape which rotates around axle and enable the rolling motion of vehicle. Inception concept of wheel is simply wooden disk with hole manufactured for cart or bullock cart. Wheel with spoke is used for construction of lighter and speedy vehicle. Designing and production of modern motor vehicles follows strict guidelines to ensure safety of travelers. Each component of vehicle may have to follow criticality of each design consideration. Simply the automobile wheels distinguished as per international coding system.

There are three elements in wheel classified as hub, spokes, and rim. Components related to design may be constructed in one or multiple parts. Firstly, the hub is basic centrally located and attached through wheel knuckle. Secondly the spokes act as bridge between hub and rim. At last, the rim which is outermost part of wheel to grasp type. There are few essential characteristics for wheel of vehicle. Wheel should be in proper balancing in statically and dynamically both conditions. Wheel should be light in weight with ease in mounting and removing. Wheel material should have good in strength as well as less corrosive to weather conditions. The wheel has well in steering control and able to absorb shock loads, it should also be able to resist deformation against impact load during bump.

A. Steel and Aluminium Wheels

More popular and standard part of vehicles. They also added the sophistication to vehicle with light weighting Constructions of wheel for modern cars have started with steel wheels which are usually constructed with metal sheet and then welded together. Due to durability, flexibility, and greater strength of material like steel they are still in use, but the disadvantage with steel wheels is their heavy weight. To reduce the weight in car wheels to achieve better stability and dynamics of vehicles, car manufactures introduced the aluminium wheels as add-ons to vehicles. But technologies shifted to more organized sectors and aluminium wheels become measure, as well as stylish feature in cars. Aluminium modelled wheels started its flagship to all luxury vehicles with exclusively personnel touched reason. In 1948 forged aluminium wheel invented in ALCOA and 1962 the Porsche with aluminium alloy increases the popularity of forged aluminium wheels. The penetration of aluminium in wheels was approx. 35 % in the year in European context, which is near about 1.5 times as compare with USA and Japan. Now a days aluminium wheels increase their popularity in commercial market. Nowadays, the growth rate of the aluminium wheel market has slowed down, but the market volume is still increasing.

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B. Manufacturing of Aluminium Wheels

In modern days the aluminium wheels are made by casting and forging processes. Performance of wheels is directly propositional to the manufacturing process. Their performance is a direct result of the employed manufacturing technique. Forged wheels are stronger one as well as lighter. Casting wheels are known as durable ones for moderate conditions. The manufacturing of wheel classified into two types as per manufacturing process

1) Cast aluminum wheels
2) Forged aluminum wheels

C. Aluminium Alloy Wheels

Alloy wheels are basic combination of two materials: aluminium and magnesium. Basically, two types of alloy type used in manufacturing in wheels, first is AlSi1MgMn (6082) and other AA 6061 (AlSiMgCu). Recently manufacturing with Titanium is being measured for better durability and shock absorbing. Different Spoke design is also considered for better durability and design consideration, and it should be able to face all consequences while riding the vehicles in all terrains of roads.

Magnesium alloy wheels are sometimes used on special cars (sports cars, upper class models) for better performance instead of heavier steel or aluminium wheels. These wheels are produced by hot forging or casting from magnesium alloys such as ZK60, AZ31 or AZ91. Their typical mass is about 5–9 kg (depending on size). But apart from the high price, magnesium wheels have also additional disadvantages for normal road use (flammability, corrosion resistance)

II. LITERATURE SURVEY

P. Meghashyam et.al studies the car wheel rim designed by CATIA to reduce the risk involved in manufacturing and design. Further it is analysed by ANSYS software, in this analysis the 3D model exported and simulated with different forces and pressure. ANSYS used static model of analysis, where two different models of aluminium and forged steel were calculated for wheel rim component. Structural behaviour of rim model analysed by input data of software, calculation of different rim model ANSYS workbench is used with different materials like Steel, Aluminium alloy, Titanium alloy, Magnesium alloy. A standard rim size i.e. 17 Inch taken for analysis as per SAE standard with fixed ends for lug holes. Total 0.35 MPa applied on the wheel barrel with different materials. In all four possibilities the best suited material is aluminium, the second-best material is titanium alloy, but high cost makes the titanium alloy non-commercial.

Hence, titanium alloy is better suitable material if cost is no issue; otherwise, Aluminium Alloy among these four materials is good for wheel rim obtained from this research analysis.

Sunil Prashanth Kumar et. al studies the aluminum alloy and steel rim, designed in Auto CAD 2022. The project is analyzed with ANSYS software with two category steel and aluminum alloy. Study occurred in two designs first simply six spoke design and second one is multi spoke alloy, where total force applied is 1000N and pressure 245 kPa. In result comparison alloy wheels have less deformation as compared with steel ones. In design format there is multi spoke alloy have better results than6 spoke alloy wheels.

Manugonda Babu et al researches on shape and dimension constraint of wheel rim basically. The modelling of wheel rim initiated in CATIA by 3D model, further work of analysis is done by ANSYS software, where different constraints like deformation, strains and stress are calculated. Overall analysis is considered on different material wheel rim like carbon fibre, aluminium, and Kevlar. Wheel rim also subjected with fatigue structural analysis. This research also recommended the best material and weight comparison between all materials chosen. Along with these materials Kevlar chosen with best suitable material with all constraints like fatigue and weight reduction.

M.Ravichandra et al studied different auto motive wheels with different materials like carbon epoxy, E glass and S glass. Alloy wheels have better stability control with greater steering quality and less in weight. In this paper composite materials studied with their data of present automobile, results are compared with all other data with existing model. In this project a parametric model is designed for Alloy wheel used in four-wheeler by collecting data from reverse engineering process from existing model. The designed model analysed with ultimate strength of three composite materials with help of Pro- E model and Ansys Model

X Jiang et al emphasis on light in weight automobile technique, where it suggested new automotive model of wheel. This article designs a model for bending test and radial load testing in FEM for three different materials. There materials named as magnesium alloy, aluminium alloy, and steel where different performance test like stress and strain studied. Along with all test material research found magnesium alloy wheel better. Also the deformation for alloy wheel, magnesium alloy found better in all three materials of magnesium alloy wheel. Result showed better quality approx. 30% in weight consideration with respect to aluminium and 70%

lighter with steel structure wheel. Also magnesium alloy wheel found with lower stress value and acceptable deformation with help of ANSYS software.

JaslokPandey et al reviewed different paper information of passenger cars. In design and manufacturing, there is analysis regarding disc performance could be optimized in static and dynamic load condition. Also, it suggested the failure of rim lead to serious injury and financial loss also. This paper deals with the design of aluminium alloy wheel for automobile application which is carried out paying special reference to optimization of the failures of the wheel.

M. Sabriet.al studied the car wheel rim with different load condition in CATIA and Solid Works. The research condition data input taken from Malaysia where basic two models are in used, which are Steel and Alloy. All the results are on the basis of displacement verses speed and stress occurred at different speed. Data clearly show the steel rim have more deformation than alloy wheel as wheel as more stress value also. Analysis also suggested less efficient value of steel rim under load condition and potholes load absorption. Study suggested alloy wheel as safer than steel rim. Researches also suggest the alloy wheel as more reliable in crash conditions.

Sourav Das et al investigated the aluminium alloy by finite element method, emphasis on reduction of mass of wheel rim. There is approx. 50% mass reduction of aluminium alloy for existing alloy model. The finite element method used for optimizing the component by yield stress calculation. The test condition taken as radial fatigue condition, where fatigue life and stress distribution estimated. The yield stress of alloy material estimated up to 90 MPA for safe application.

Ch. VeeraVenkata Krishnaraddy et al In this study Alloy wheel rim with existing dimension by using cad tool solid works &analysed with CAE tool Ansys workbench. Three different material Al2024, Al6061, Zn-Al in 5spoke and 6spokes.

we applied boundary conditions on each model separately, i.e., when car is moving with 5 members, we applied forces acting on the body and rotational velocity, by these boundary conditions calculated deformations, stress, strain, and safety factor values. These results concluding that which material has very less stressed with good amount of safety factor values even though high amount of boundary conditions acting on it. By knowing static and dynamic analysis results, both al-2024 and znal4 materials are having better results than al6061 material, and the both materials can reduce the stress value on the object, finally thesis can conclude here with znal4 material is suggested for this automobile wheel rim to improve the static and dynamic performance.

B. LALUNAYAK et al In this study the Modelling of the different wheel rims(elliptical spokes shape, Hexagon shape)is generated in CATIA and this is imported to ANSYS(14.5) for processing work. Alloy wheel rim has been designed using Catia software, after that static and modal analysis is done with different materials (Carbon Fibre, Mg Alloy, Al 6061) boundary conditions taking in ANSYS14.5 Software. Taking boundary conditions on alloy wheel Radial load 3240N is applied along the circumference of the wheel rims Finally observed results of stress, total deformation, and shear stress on different wheel rims and materials and compared with each other. Thus, the best design and material can be selected for manufacturing of the alloy wheel. AL6061 with Elliptical spoke shape have subjected to more total deformation compared to Remaining materials 2 materials. Carbon fibre have less deformation. AL 6061 with Elliptical spoke shape have subjected more von-misses stress & shear stress compared to Remaining materials 2 materials, carbon fibre have less von-misses stress and shear stress. Carbon fibre has a more life compared to remaining materials. Weight of carbon fibre is 40 to 50% less weight compared to remaining materials. By comparing all result we are suggested that carbon fibre with hexagon shape is better material compared to remaining material it is suitable material and this shape manufacturing of Alloy wheel.

M. Swamy, D Suresh Reddy In this study the modelling of alloy wheel is done is SOLID WORKS design software by using various structural analysis is carried out in ANSYS work branch at two different pressure with four different material such as aluminium alloy, Mg alloy, Peek material, Peek(20% carbon fibre) material.

Stress, deformation, strain, max shear stresses of these four materials at two different pressure (0.8MPa & 1.2MPa) Generally aluminium alloy and magnesium alloy are commonly used materials whereas peek material and peek (20%carbon fibre) materials are rarely used. From the analysis we notified that that stress values of peek material and peek(20% carbon fibre) material are also equivalent to Al alloy and mg alloy. Hence these materials are also preferable.

Mr. CHINTAPALLI SHEKHAR et al. In the present study Modelling of the different wheel rims(elliptical spokes shape, Hexagon shape)is generated in CATIA and this is imported to ANSYS(14.5) for processing work. Alloy wheel rim has been designed using CATIA software, after that static and modal analysis is done with different materials (Carbon Fiber, Mg Alloy, Al 6061) boundary conditions taking in ANSYS14.5 Software. Taking boundary conditions on alloy wheel Radial load 3240N is applied along the circumference of the wheel rims Finally observed results of stress, total deformation, and shear stress on different wheel rims and materials and compared with each other. Thus, the best design and material can be selected for manufacturing of the alloy wheel.

1. AL6061 with Elliptical spoke shape have subjected to more total deformation compared to Remaining materials 2 materials. carbon fibre has less deformation. 2. AL 6061 with Elliptical spoke shape have subjected more von-mises stress & shear stress compared to Remaining materials 2 materials, carbon fibre has less vonmisses stress and shear stress. 3.. Carbon fiber has a more life compared to remaining materials. 4. Weight of carbon fiber is 40 to 50% less weight compared to remaining materials 5. By comparing all result we are suggested that carbon fiber with hexagon shape is better material compared to remaining material it is suitable material and this shape manufacturing of Alloy wheel.

Prasad SatisDivekar, Dr.ThippeswamyEkbotel In this research work the wheel modelling in CAD &analysed with Ansys software . In analysing different properties in6 different materials (Al alloy, Mg alloy, titanium alloy, carbon/epoxy, E glass/epoxy, S glass/epoxy).

Aluminium alloy has better sustainable properties when compared to other alloy materials, which has better deformation factors and stress now a days Aluminium alloy is widely used because it has good Equivalent Elastic Strain and deformation coefficient. But composite material has better advantage than aluminium alloy material because of its low weight, low deformation factor and high stress handling properties T. Siva Prasad et al. This study wheel rim is modelled by using modelling software Catia. Catia model is imported to ansys for analysis work.

Ansys static analysis work is carried out by considered aluminium and forged steel and their relative performances have been observed respectively.

The amount pressure 21.3 KPa is applies along the circumference of the wheel rims and bolt circle of wheel rim is fix.

The result obtained Forged steel is performed as best material for designing of wheel rim. Aluminium alloy wheel rim is subjected to more displacement compared to Forged steel. In both cases von-mises stresses are less than stress intensity. Aluminium alloy wheel rim subjected to more stresses compared to Forged steel. Since in both the cases von-mises stresses less than the ultimate strength i.e. stresses intensity, hence deflections taking into account, Forged steel is preferred as best material for designing of wheel rim.

S. Vikranth Deepak et al. In this study Al alloy are comparing with other alloy. In this project a parametric model is designed by collecting data from is designed for alloy wheel used in four-wheeler by collecting data from reverse engineering process from existing model. Design is evaluated by analysing the model by taking the constraints as ultimate stresses and variables as two different alloy material and different loads and goals as maximum outer diameter of the wheel. For all comparing the three materials of stress, strain displacement, total life, load factor and damage factor we suggest aluminium alloy is the best material for the alloy wheel.

Vaddi Naveen In this study Alloy wheel Rim modelling in Catia and import design in Ansys. Analysing stress and displacement distribution in vehicle wheels subjected to increase pressure and radial load. Static analysis in done with different material ZA21, Al6061 and Carbon fibre load and boundary condition. the total deformation less in carbon fibre compare than Al6061, ZA21. Von-mises stress less in carbon fibre compare that Al6061, ZA21. Weight of carbon fibre is less compared to Al 6061 alloy and ZA21 alloy. Carbon fibre is a good strength, fatigue life (endurance limit), reliability

Kalpesh R. Salunkhe, Prof. Shailesh S Pimpale In this research work Alloy Wheel rim has been designed using Creo software, after that static structure analysis is done with different materials, load & boundary conditions using ANSYS software.

The static structure analysis was done by applying the materials namely Aluminium6061, ZA21 & mg alloy

The maximum total deformation and Equivalent stress obtained are lowest at 0.0536 mm and 20.69 respectively for ZA21. Hence it is the best suitable material for manufacturing Alloy wheel rim. Also selection of an optimum material for alloy wheel rim (material as Zinc) can be done which will increase their strength, fatigue life (endurance limit), reliability and reduce the overall weight and cost.

Sasankshekhar Panda et al. Present work gives analysis the wheel rim is designed by using modelling software Catia vr18., later this Catia model is imported ANSYS for analysis work. ANSYS software is the latest used for simulating the different forces, pressure acting on the component and also for calculating and viewing the results

A solver mode in ANSYS software calculates the stresses ad their relations without manual interventions reduces the time compared with the method of mathematical calculations by a human.

ANSYS static analysis work is carried out by considered two different materials namely aluminium and magnesium alloy and their relative performance have been observed respectively.

The objective was to reduce the weight of the wheel rim has been achieved, we compared the stresses and strains during static and dynamic condition in case of aluminium and magnesium alloy and found that in case aluminium alloy the stresses are acting less and have higher FOS in the model design.

G Ragul et. al. In this work, the design, analysis, and impact behaviour of magnesium alloy automotive wheels by finite element method is presented. The main findings of this analysis include: (i) Stress developed in the steel alloy is 142.056MPa which is below the yield stress of the material; (ii) Stress developed in the magnesium alloy is 32.294MPa which is below the yield stress of the material; and (iii) Comparatively stress developed in the magnesium alloy is lower than the stress developed in steel alloy. It is found that the Zk60A magnesium alloy results in lighter wheel and enjoys associated benefits like reduced stress, better mileage, improved service life, etc. With this encouraging result, the Zk60A magnesium alloy wheel will provide a better alternate to the existing materials. Besides by using magnesium alloy the unsprung mass of the vehicle is reduced which improves the vehicle performance.

III.KEY FINDING

In various literature reviews studied for this research, different aluminum alloy for wheel rim for different design studies. Overall consideration shows that less mass, better design and material selection plays vital role in design of wheel rim. Multi spoke rim is better option to get better stability in vehicle. For mass reduction used of alloy are suggested, in review, paper emphasis on multi spoke but the optimization of spoke with their fillet radius is missing. So in this present research studies with fillet radius variation with Y spoke angle variation.

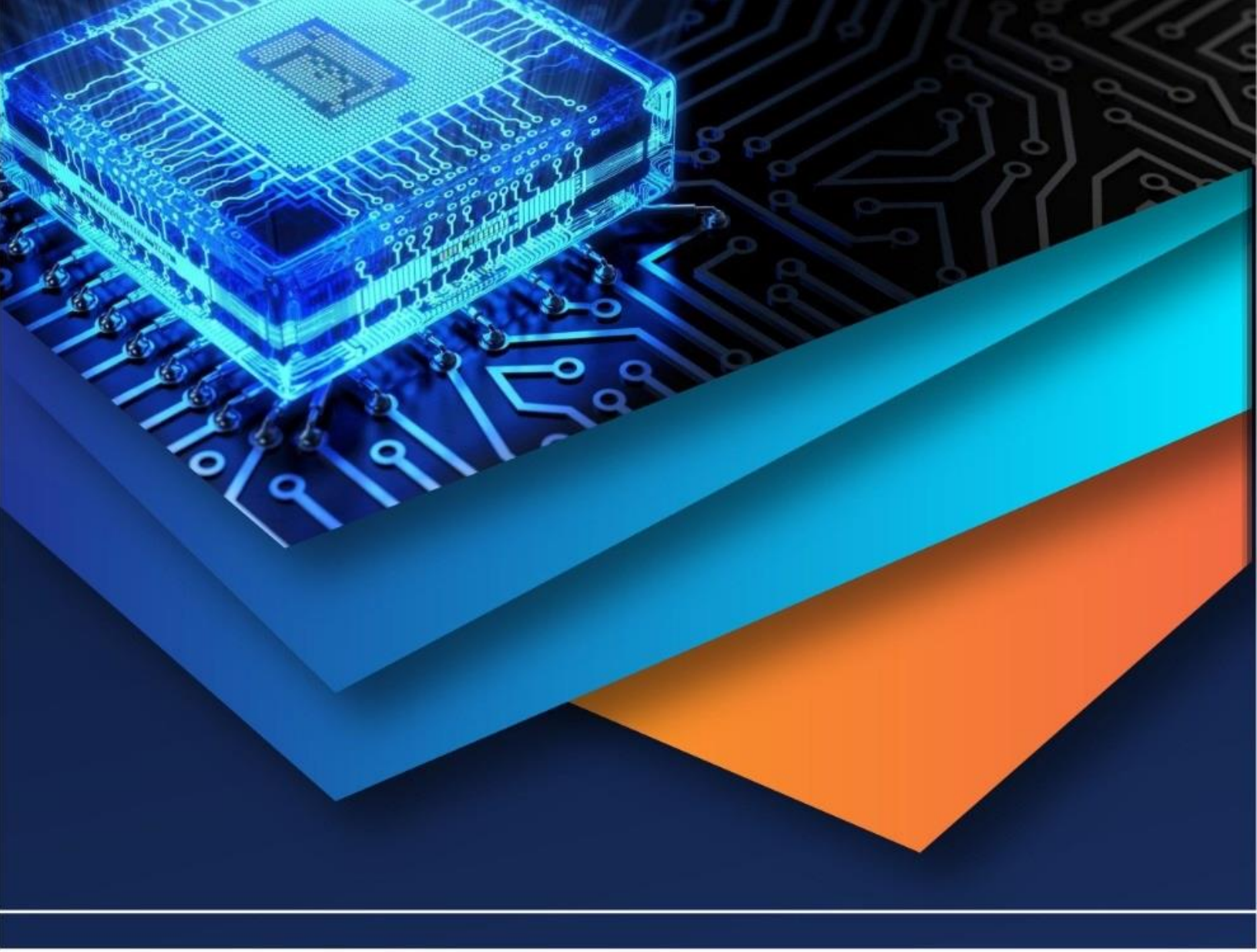
IV.CONCLUSIONS

For the structural analysis for the remote force the magnitude applied is 1000N and for the pressure which applied on the wheel is 245kPa. Therefore, so comparing the wheels with the total deformation occurred alloy wheels are better than the steel wheel, and comparing the both the alloy wheels multi-spoke alloy wheel is better than the 6-spoke alloy wheel. Since the alloy wheel have some dis-advantages then also considering the results alloy wheels have better structural tendency than the steel wheels and if the spokes are Static and dynamic analysis of wheel rim can be done together. For static load car weight can be considered and for dynamic condition acceleration load can be considered. For practical realistic condition harmonic excitation can be considered. All the above factors can be considered on three different materials which after comparing in Ansys software; will suggest which the best material.

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