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Value Analysis and Value Engineering of Two Wheeler Light Weight Y-Spoke Alloy Wheel

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Abstract:

This paper presents Value analysis is the process of recognizing and selecting the best value of alternatives for designs, materials, processes and systems. It continues with repeatedly asking "can the cost of product or process be reduced or eliminated without affecting the effectiveness, required quality or customer satisfaction" Value Engineering deals with "Value" of products by examination of function. Here value is the ratio of function to cost. Value can be increased by improved function or reduced cost. Importance of wheel in the automobile is obvious. The vehicle may be towed without the engine but it is not possible without the wheels. The wheels along the tyre have to carry the vehicle load, with the steering control. Generally wheel spokes are the supports consisting of a radial member of a wheel joining the hub to the rim. The most commonly used materials for making wheel spokes are with features of excellent lightness, corrosion resistance, desirable characteristics of casting, high damping property, Mach inability and recycling, etc. The performance of wheel mainly based on the shape and material of the wheel. Hence in our project we have to modify the shape and material of the wheel and they are compared for better results. Presently, for motor-cycles Aluminum alloy wheels are used, Hence currently now we are comparing by new magnesium alloy [ZK60] due its light weight than Al-alloys [201.0 T43 and T7 Insulated Mold Casting (SS)]. This project deals with the static, fatigue and impact analysis of the wheel. The models of alloy wheel for two wheeler vehicle are modeled in Solid Works software.

All the models are validated for strength under different loads in the analysis software COSMOS. A typical alloy wheel configuration of BAJAJ DISCOVER 100T commercial vehicle is chosen.

Keywords:

Alloy wheel, Value Analysis& Value Engineering, Static, Fatigue Impact Analysis

INTRODUCTION:

Aluminum wheels should not fail during service. Their strength and fatigue life are critical. In order to reduce costs, design for light-weight and limited-life is increasingly being used for all vehicle components. In the actual product development, the rotary fatigue test is used to detect the strength and fatigue life of the wheel. Therefore, a reliable design and test procedure is required to guarantee the service strength under operational conditions and full functioning of the wheel. Design is an important industrial activity which influences the quality of the product. The wheel rim is designed by using modeling software SolidWorksv2014. In modeling the time spent in producing the complex 3-D models and the risk involved in design and manufacturing process can be easily minimized. So the modeling of the wheel is made by using Solid Works. COSMOS Works is a design analysis system fully integrated with Solid Works. COSMOS is the software used for simulating the different loads (forces, pressure, etc.) acting on the component and also for calculating and viewing the results.

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A solver mode in COSMOS software calculates the stresses, deflections, bending moments and their relations without manual interventions, reduces the time compared with the method of mathematical calculations by a human. To create simulations of alloy wheel design that focuses on reducing the mass of the current design, selecting better material and to improve the strength of Y spoke. The main changes in the model are changing the angles between the hub and the center of Y spoke, thereby the load applied and stress induced on this particular area will be very less. There after due to gradual increase in thickness of spoke, strength of the spoke increases.

EXPERIMENTAL METHODOLOGY:

Designers and engineers primarily use structural simulation to determine the strength and stiffness of a product by reporting component stress and deformations. The type of structural analysis performs depends on the product being tested, the nature of the loads, and the expected failure mode: A short/stocky structure will most likely fail due to material failure (that is, the yield stress is exceeded). For the given below specification of the allow wheel, the static analysis is performed using solid works to find the maximum safe stress and the corresponding pay load. After geometric modeling of the alloy wheel with given specifications it is subjected to analysis. The Analysis involves the following discretization called meshing, boundary conditions and loading.

The methodology followed in my project is as follows:

- Appling Revers engineering process to taken the Original Wheel dimension and Developed 3D model by using SOLID WORKS software.
- Design changing the angle between Y-Spokes and change the Material of Wheel.
- Perform Modal analysis to find Stresses on the original and modified of the Wheel. Perform spectrum analysis to find maximum and minimum stresses of wheel using COSMOS is the software.

3D MODELLING OF MODIFIED ALLOY WHEEL

Modified Alloy Wheel

Material Properties:

- Presently used for Wheel is Aluminum Alloy 201.0T43
- Changing material of Aluminum 201.0T7 Instead of Aluminum Alloy 201.0T43

Chemical Composition of the A02010 Aluminum Alloy (Wt.%)

	AL	Cu	Ag	Mg	Mn	Ti	Fe	Si	Other
Min	bal	4	0.4	0.15	0.2	0.15			
Max	bal	5.2	1	0.55	0.5	0.35	0.2	0.1	0.1

Material Properties of the A02010 Aluminum Alloy

Property	Values		Units
	T43	T7	
Elastic Modulus	71000	71000	N/mm^2
Poisson's Ratio	0.33	0.33	N/A
Shear Modulus	23000	23000	N/mm^2
Mass Density	2800	2800	kg/m^3
Tensile Strength	273	345	N/mm^2
Yield Strength	225	344	N/mm^2
Thermal Expansion Coefficient	1.9e-005	1.9e-005	/K
Thermal Conductivity	121	121	W/(m·K)
Specific Heat	963	963	J/(kg·K)
Charpy Impact	3.30 - 21.7	3.30 - 21.7	J
Charpy Impact, Unnotched	16.3 - 77.0	16.3 - 77.0	J

STRUCTURAL ANALYSIS OF ALLOY WHEEL [12]

Static Analysis

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (non-zero) displacements

Fatigue Analysis:

During design validation, a structure is exposed to both static strength tests and fatigue tests. However, once a structure is deployed, it spends the vast majority of its lifetime being subjected to smaller repeated forces that can cause cumulative damage over time. For this reason, testing the durability of a structure makes up a larger proportion of the tests that are run. Durability is one of the most important attributes that structures can possess. Fatigue testing measures durability and is defined as the repeated mechanical loading of a structure to determine failure points. It requires complex analysis using the field of fracture mechanics, which is the analysis of material flaws to discover those that are safe and those that are liable to propagate as cracks and cause failure. The number of cycles required for fatigue failure to occur at a location depends on the material and the stress fluctuations. This information, for a certain material, is provided by a curve called the S-N curve. The curve depicts the number of cycles that cause failure for different stress levels. Fatigue studies evaluate the consumed life of an object based on fatigue events and S-N curves. As noted earlier, the applied stress stays within the elastic range of the material. Total Life is determined by running multiple specimen tests at a number of different stresses.

The objective is to identify the highest stress that produces a fatigue life beyond 1 million cycles. This stress is also known as the material's endurance limit.

Impact Analysis:

Drop test studies evaluate the effect of dropping the design on a rigid floor. You can specify the dropping distance or the velocity at the time of impact in addition to gravity. The program solves a dynamic problem as a function of time using explicit integration methods. Explicit methods are fast but require the use of small time increments. Due to the large amount of information the analysis can generate, the program saves results at certain instants and locations as instructed before running the analysis.

Setup Information of Impact Analysis

Type	Velocity at impact
Velocity Magnitude	27.77 m/sec
Impact Velocity Reference	Right Plane
Gravity	9.81 m/s^2
Gravity Reference	Top Plane
Parallel to reference plane	Plane8
Target Stiffness	Rigid target

Structural Analysis Procedure Steps in Solid Work simulation:

- Select the type of analysis require
- Applying the material
- Fixing the geometry and Apply the loads
- Create the mesh for model
- Run the analysis

Volumetric Properties Origenal Wheel

	AL 201.0 t43 and t7	Mg Zk60
Mass (kg)	4.3139	2.61915
Volume (m^3)	0.00154068	0.00154068
Density (kg/m^3)	2800	1700
Weight (N)	42.2762	25.6677

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Volumetric Properties Modified Wheel

	AL 201.0 t43 and t7	Mg Zk60
Mass (kg)	4.24884	2.57965
Volume (m^3)	0.00151744	0.00151744
Density (kg/m^3)	2800	1700
Weight (N)	41.6386	25.2806

Boundary Conditions:

To ensure the accuracy and reliability of the analysis result, the structural and mechanical model of the rear wheel is established. Net weight of the motorcycle is 150kg and the maximum allowable Load 3. The tyre used is a common version with inner tube filled to gas pressure 0.28Mpa, uniformly distributed on the exterior ring surface of wheel. To ensure reliability of the analysis, the sum of motorcycle net weight and maximum allowable load was applied to the rear wheel alone. The sum was considered to be the maximum load, which was distributed on the rim surface. By considering, the maximum load is equal to motorcycle weight including rider and all loads.

Meshing:

Meshing involves division of the entire of model into small pieces called elements. This is done by meshing. It is convenient to select the Standard mesh because of wheel structures, so that shape of the object will not alter. Mesh images of original modified wheels are shown in figures (fig.6.1 and fig.6.8). Mesh Information and details for original and modified wheels are shown in table.

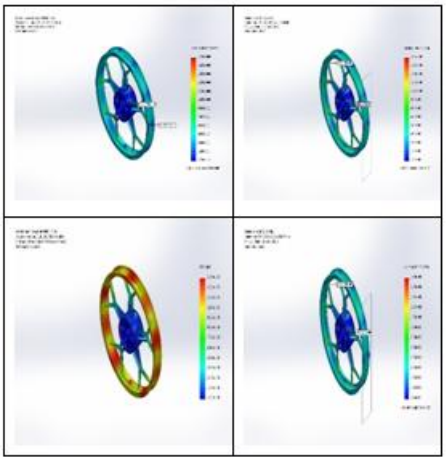
Mesh Information and details of Static, Fatigue, Drop Test

Analysis type	Static, Fatigue, Drop Test	
Mesh type	Solid Mesh	
Mesher Used	Standard mesh	
Solver type	FFEPlus	
Use Adaptive Method	p-Adaptive	
Jacobian points	4 Points	
TYPE OF WHEEL MODEL	**Origenal Wheel**	**Modified Wheel**
Element Size	6mm	6mm
Tolerance	0.3mm	0.3mm
Mesh Quality	High	High
Total Nodes	100371	101890
Total Elements	57194	57403
Maximum Aspect Ratio	18.493	25.413
% of elements with Aspect Ratio < 3	95.1	92.7
% of elements with Aspect Ratio > 10	0.0577	0.0906
% of distorted elements (Jacobian)	0	0
Time to complete mesh*(hh;mm;ss):	00:03:42	00:02:12

ANALYSIS SCREENS

1. STATIC ANALYSIS

Static Analysis– At Load 3



Original Wheel with Al 201.0 T43Modified Wheel with Al 201.0 T43

Min value and is about 0mm at Node: 5433

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Max value and is about 0.00144679 mm at Node: 27264

2. FATIGUE ANALYSI

Fatigue Analysis– At Load 3

Min is about Load factor 40.2913 at Node: 11911
Max is about Load factor 376309 at Node: 44720

3. IMPACT ANALYSIS

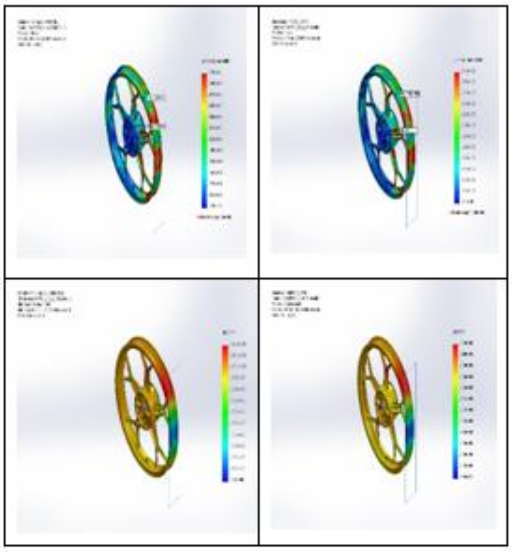
Impact Analysis– AT 100 km/h

Min value and is about 0.460368 mm at Node: 73303
Max value and is about 12.3936 mm at Node: 32128

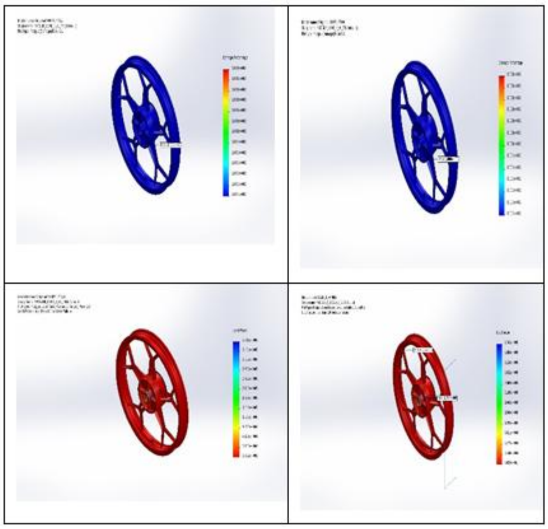
RESULT SUMMARY

STATIC ANALYSIS RESULTS

Stress values for Modified Al and Mg-alloy wheels



S. No	Load (N)	Type of Study Results	AL201 T43	AL201 T7	Mg Zk60
1	1030	Von miss stress (N/mm^2)	0.6702	0.6702	0.6722
2	1991	Von miss stress (N/mm^2)	1.296	1.296	1.3
3	2472	Von miss stress (N/mm^2)	1.609	1.609	1.613
4	Permissible stress		225	344	382



Displacement values for Modified Al and Mg-alloy wheels

S. No	Load (N)	Type of Study Results	AL201 T43	AL201 T7	Mg Zk60
1	1030	Displacement (mm)	$6.028e^{-4}$	$6.028e^{-4}$	$9.505e^{-4}$
2	1991	Displacement (mm)	$1.165e^{-3}$	$1.165e^{-3}$	$1.838e^{-3}$
3	2472	Displacement (mm)	$1.447e^{-3}$	$1.447e^{-3}$	$2.281e^{-3}$

FATIGUE ANALYSIS RESULTS

Fatigue Analysis Result Tables of Modified Wheel

Fatigue Analysis values for Modified Al and Mg-Alloy wheels

S. No	Load (N)	Type of Study Results	AL201 T43	AL201 T7	Mg Zk60
1	2472	Damage	100	100	100
		Life	$1.001e^{6}$	$1.001e^{6}$	$1.001e^{6}$
		Load factor	$3.463e^{5}$	$3.7636e^{5}$	$2.110e^{5}$
			$4.029\ e^{1}$	$4.029e^{1}$	$2.345e^{1}$

IMPACT ANALYSIS RESULTS

Impact Analysis Result Tables of Modified Wheel

Impact Analysis values for Modified Al and Mg-Alloy wheels

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S. No	Velocity m/s	Type of Study Result	AL201 T43	AL201 T7	Mg Zk60
1	16.6666	Von miss stress (N/mm²)	224.998	343.999	4054.28
2	22.2222	Von miss stress (N/mm²)	224.999	343.998	5445.67
3	27.7778	Von miss stress (N/mm²)	224.999	343.987	6849.49
4	Permissible stress		225	344	382

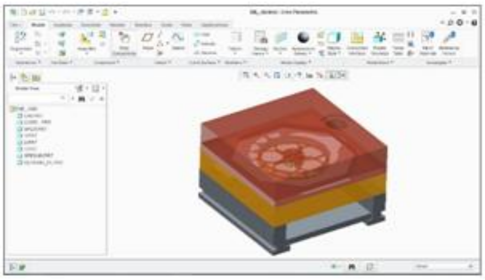
WEIGHT (N) REDUCTION IN THE MODEL

Weight (N) Reduction in the Model

S. No	Material	Original	Modified	% of weight saving
1	AL201.0 T43 and T7	42.2762	41.6386	1.5
3	MG ZK60	25.6677	25.2806	1.79
% of weight saving Al Vs Mg		60.71		

PRODUCTION PROCESS(Value Analysis):

In this process metal is forced into the mold at a high pressure that ensures production of identical parts, a better surface finish, and an increased dimensional accuracy. Some parts produced by die casting even do not require machining after casting, or may require only a light machining to achieve the desired dimensions. Defects of porosity are found more often in large castings because of entrapped air and the solidification of melt before it reaches the boundaries of the cavity. Parts with a uniform wall thickness can be more accurately produced by die casting. Die casting molds are expensive since these are made from hardened steel and because a longer time duration is required for their production.



Die Assembly

RESULT:

One component existing cost with various materials

Cost of Single component with various material

Material	parts	Required Material per Kg	Material cost per Kg	Production cost	Cost in Rupees
Al 201.0 T43	Old wheel	2.54	780	89.648	2070.848
Al 201.0 T7	Modified Wheel	2.159	936.56	89.648	2111.681

CONCLUSION:

The objective to reduce the weight and improve the functionality of the alloy wheel has been achieved. The current design is 1.5**%** lighter than the original design. In this work the overall dimensions are controlled by changing the angle of Y-spoke and gradually increasing the thickness of spoke from rim to hub of alloy wheel with better functioning stability and less weight with the same material when compared with original model. AL201 T7 provides high factor of safety when compared to AL201 T43 (original material) and MG ZK60.

The stress and displacements in current alloy wheel are lesser than original alloy wheels and also having higher FOS in the current model. From the results of the fatigue analysis, the load factor is better for current model with new material (AL201 T7) than current model (with AL201 T43 and MG ZK60) and original model (with AL201 T43, AL201 T7 and MG ZK60). From the results of impact analysis, that Mg ZK60 exceeds the permissible stress. By comparing three materials for original and current models, the factor of safety is better for AL201 T7. We also did value analysis for the existing model with AL 201 T7 and the modified model with AL201 T43. In that we observed the cost of the modified wheel with new material is little more but giving better performance. Finally we conclude that current model with AL201 T7 is better than the existing model.

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