Parametric design optimization of a skate cycle

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ABSTRACT

In recent years, fatigue is a prominent failure mechanism for any vehicle's frame Structure, and it can lead to serious accidents, costly recalls, and poor product image for the vehicle's frame manufacturers. This paper deals with investigation of the fatigue behaviour of the vehicle's chassis and has carried out a design and optimization in Solid Works. In the first part of the study, the static loads acting on the connecting rod, after that the work is carried out for safe design. Based on the observations of the static Finite Element Analysis (FEA) and the load analysis results, the load for the optimization study was selected. The results were also used to determine degree of stress, and the fatigue model to be used for analysing the fatigue strength. Outputs include fatigue life, damage, factor of safety, fatigue sensitivity. A method has been proposed to optimize the wheels and frame's material and design for an improved fatigue resistance.

KEY WORDS: skate cycle, Design optimization, fatigue analysis.

1. INTRODUCTION

The ability to optimize and improvement in design has created substantial amount of growing engineering requirements. This paper analyses the design of a Skate cycle – A hub less personal vehicle used for recreational activities. The analyses is done utilizing finite element analysis using number of calculated forces and contact forces representing what a Skate cycle would undergo under normal use, on both sets of wheels. The analysis for this piece was done by using SolidWorks for modelling and design analysis. Proper stress levels, a very complex problem in highly redundant structures, are calculated using versatile computer matrix methods to solve for detailed internal loads. Modern FEM models of personal vehicle components include many degrees-of-freedom and are used to determine the required thicknesses to avoid any excessive stress levels, deflections or strain. The main goal of detailed design is to reduce or eliminate the stress concentrations, any hidden undetectable cracks or a single failure leading to overall component failure. Every vehicle should be able to provide comfort in the terms of the ride and smooth handling. But along with this, the components should have a good fatigue life. Fatigue is a phenomenon with respect to variable loading or cyclic loading resulting in straining of the material. Fatigue is one of the major issues in automobile components. It must be able to withstand numerous cycles before failing or not fail during the service period of the automobile. Fatigue cracks are most commonly found in areas where there is a change in geometry eg., holes, notches or sudden changes in section, cause stress concentration. This paper presents modal analysis, stress and strain analysis and fatigue analysis to the Skate-cycle modelled using Solidworks software.

2. METHODOLOGY

The proposed methodology is explained by the following procedure.
Step 1: Analyse skate cycle information.
Step 3: Skate cycle unit design
All components are created based on ANSI standard (ANSI B 94.33).
Step 4: Interference checking.
Step 5: Creation of three dimensional skate cycle.
Step 6: Design verification is done by solid works interference checker. This assures that the skate assembly is not having any interference with other components.
Step 7: Optimization of Skate cycle design. This is shown in figure 1.

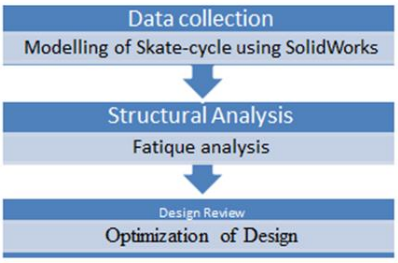

Figure.1. Methodology

Application of Constraints: Constraints are the only real correlation between simulation and the actual real-life application. If not given correctly, the software's results wouldn't match with theoretical answers. Since we have considered a Static analysis, it was sufficient to fix both hinges as well as the central frame of the Skate-cycle. The hinges remained fixed as the planar rotational motion would only be about the hinges. The fixture of the central frame ensured no relative motion among the static parts.

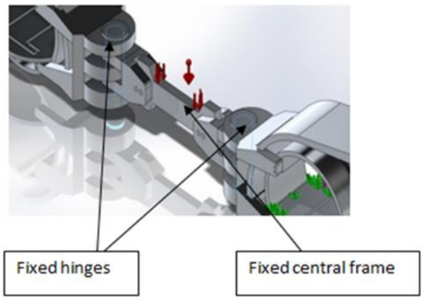

Figure.2. Assembly Constraints

Structural Analysis of skate assembly: The aim of a stress- strain analysis is to determine the behavior of the material for different loads. It gives us an insight into the various stages the material undergoes and gives us information regarding the distribution of the stress along with an understanding of the areas that are subjected to maximum and minimum stresses. By evaluating these results one can determine the areas for optimization in the design.

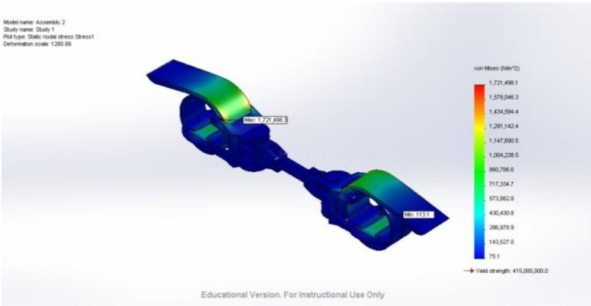

Figure.3. Stress analysis

Strain: Max Value: 1.77e-5; Min Value: 8.97e-10. Since the stress and strain diagrams, have the same gradient at the same areas, one could conclude that the loading conditions are well within the proportional limit of the stress-strain curve. Hence the design is safe, as per the loading conditions recommended.

As per the results, the maximum value of stress obtained is 1.72 MPa. The yield strength of the aluminum alloy in consideration is given to be 4.15MPa. Since the maximum design stress is less than 42% of the yield stress, the design is safe.

Stress: Maximum Value: 1.7215e6 N/m^2; Minimum Value: 75.07 N/m^2

Strain is defined as the ratio of the deformation caused to the initial dimension. Strain is important factor in the design analysis as it gives us a range of values through which the model will deform.

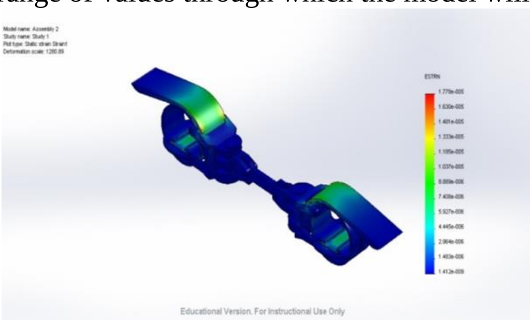

Figure.4. Strain analysis

Design Optimization: Optimization of the model was done considering three parameters namely: Wheel width, Hole diameter and Mid Length. Table no.1 depicts the original dimension of the aforementioned parameters. The parameter of wheel width was considered as optimization criteria in order to maximize the function that would result in a fractional decrease in stress concentration along the wheel rim; thereby increasing its life cycle.

Table.1. Design Variables

Name	Type	Values	Units
wheel width	Discrete Values	120	mm
Hole Diameter	Discrete Values	5	mm
mid length	Discrete Values	120	mm

During the optimization the main goals were to minimize both mass of the body as well as overall stress values. In order to do the same, eight scenarios were considered featuring different dimensions of wheel width respectively. The current and initial dimension of the wheel width were taken as 120mm. The following table depicts the result of the various scenarios from 1 through 8.

Table.2. Objective Functions

Name	Goal	Properties	Weight	Study name
Mass1	Minimize	Mass	5 kg	-
Stress1	Minimize	Stress	160000 N/m2	op1

Table.3. Design optimization 1

Component name	Units	Current	Initial	Optimal	Scenario1	Scenario2
wheel width	mm	120	120	135	122	123
hole dia	mm	5	5	5	4.5	4.7
mid length	mm	120	120	120	110	113
Mass1	g	5000	5000	3344.81	-	-
Stress1					-	-

Table.4. Design optimization 2

Component name	Units	Scenario3	Scenario4	Scenario5	Scenario6	Scenario7
wheel width	mm	125	130	135	140	143
hole dia	mm	4.8	4.9	5	5.1	5.2
mid length	mm	115	117	120	123	125
Mass1	g	-	-	3344.81	-	-
Stress1		-	-		-	-

Table.5. Design optimization 3

Component name	Units	Scenario8	Scenario9	Scenario10
wheel width	mm	145	147	150
hole dia	mm	5.3	5.4	5.5
mid length	mm	127	130	135
Mass1	g	-	-	-
Stress1		-	-	-

3. RESULTS AND DISCUSSIONS

In order to determine the best possible combination for the 3 parameters we have considered a range values to test for various possible optimal solutions. The optimum solution is obtained at a wheel width of 135mm, hole diameter 5mm and Mid length 120mm.Since the dimension of the width of the wheel has increased by 15mm, on further stress analysis it can be observed that there is a reduction in stress value considering the optimized design.

4. CONCLUSION

Fatigue strength was the most significant factor (design driving factor) in the optimization of this skate cycle. The parameter consideration for optimization are its 20 % reduction in weight of wheel, while reducing the weight, the static strength, fatigue strength, and the buckling load factor were taken into account. The optimized geometry is 20% lighter than the current skate cycle.

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