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Topology Optimization and Finite Element Analysis of Disc Brake of Two Wheeler

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ABSTRACT: Topology Optimization (TO) be the process of removing the unwanted or excess mass from the components without compromising its strength and working nature. TO is different from shape optimization and sizing optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations. The literature review shows that optimization interns of mass was achieved by changing the materials and Trial and error method by changing the design of component. In this project work, Objective is to optimize the wheel rim of the two wheeler bike using direct topology optimization techniques. Two wheeler Bajaj Pulsar 150 cc basic Model is considered in this study. By the concept of reverse engineering all the design parameters of wheel rim are studied and 3D modeling is done using Solid works software. Finite Element analysis software ANSYS 18.0 is integrated with Direct Topology optimization techniques that can be used as tool for Mass Optimization. The FEA result will show that optimized model which will obtained after optimization method will have less mass with same strength and same load sustainability. These types of advance techniques helps the engineering's to enhance the efficiency of the vehicle by removing the excess mass from the different parts of the automobile which intern reduces the cost of component.

Keywords: Topology optimization, Finite element analysis, Solid works, Reverse engineering

1. INTRODUCTION:

Engineering optimization is the subject which uses optimization techniques to achieve design goals in engineering. It is sometimes referred to as design optimization. Design optimization is the process of finding the best design parameters that satisfy project requirements. Engineers typically use the design of experiments (DOE), statistics, and optimization techniques to evaluate trade-offs and determine the best design [1].

1.1 TOPOLOGY OPTIMIZATION:

Topology optimization is a mathematical method that optimizes material layout within a given design space, for a given set of loads. TO is different from shape optimization and sizing optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations.

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Topology Optimization has a wide range of applications in aerospace, mechanical, biochemical and civil engineering Currently, engineers mostly use TO at the concept level of a design process. Due to the free forms that naturally occur, the result is often difficult to manufacture. For that reason, the result emerging from TO is often fine-tuned for manufacturability [4].

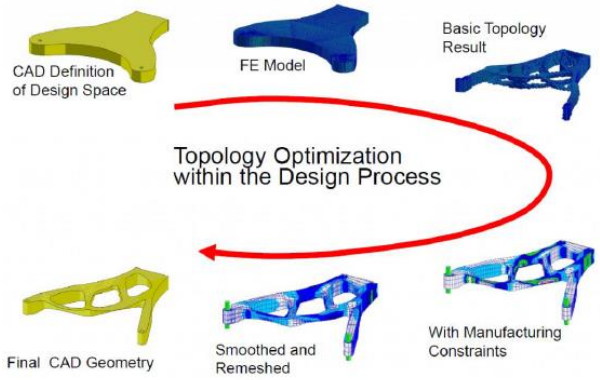

Fig. 1: Stages of topology optimization [5]

2. LITERATURE REVIEW:

Manjunath TV and Dr Suresh PM [1] carried out the transient thermal and structural analysis of the rotor disc of disc brake. Analysis of disc brake model was done by using tool ANSYS Workbench 14.5.The main aim of the study is to analyze thermo mechanical behavior of the dry contact type disc brake during breaking phase. Thermal structural analysis used to determine von-misses and

deformation in solid and ventilated of two different material i.e. stainless steel and cast iron. Comparison between analytic and FEM results is done to get the appropriate solutions by comparing result obtained in the ventilated cast iron disc reduce temperature stress and deformation by 31.47 % and 22.5% 8% respectively than the solid disc.

Andreas Wagner [3] has carried out structural topology optimization of an asymmetric automotive disc brake with cooling channels. The main objective is to split all Eigen frequencies of the brake rotor in a certain frequency range by introducing asymmetry to the cooling channels.

The Braking system is most critical system in the vehicle instead of having air bags or good suspension system. Therefore it is must for air vehicles to have proper braking system. In this ANSYS Software is used for thermal Analysis and modal Analysis which is based on the FEM (Finite Element Method) which is usually used in mechanical engineering the material for Disc Brake usually used is carbon ceramic material [2].

3. METHODOLOGY:

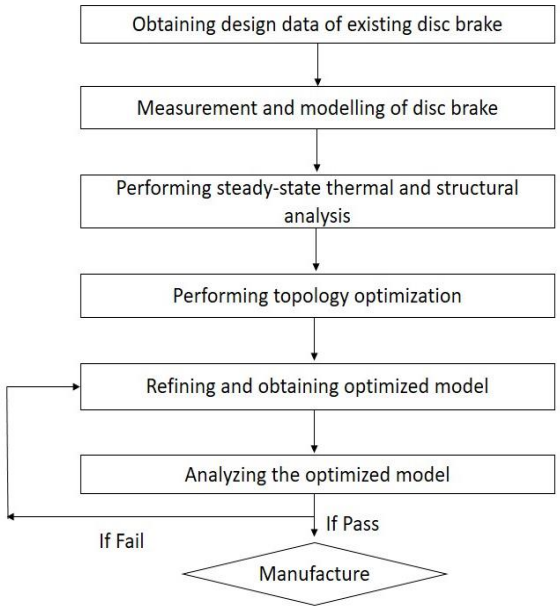

Fig.2: Research methodology flow chart

4. VEHICLE SPECIFICATION:

Table No. 1 Bike Specification

S.N.	Parameters	Specifications
1	Vehicle Type: Bike	Bajaj Pulsar 150 cc
2	Engine Type	Air cooled, 4S, SI Engine
3	Front Brake	Disc
4	Displacement	149.2 cc
5	Maximum Power	12.73 bhp @ 8000 rpm
6	Maximum Torque	12.8 Nm @ 5500 rpm
7	Bore	57.3 mm
8	Stroke	57.8 mm

Fig.3: Disc brake of pulsar 150 cc bike

4. MEASUREMENT & 2D SKETCHING:

Fig.4: Steel disc brake model

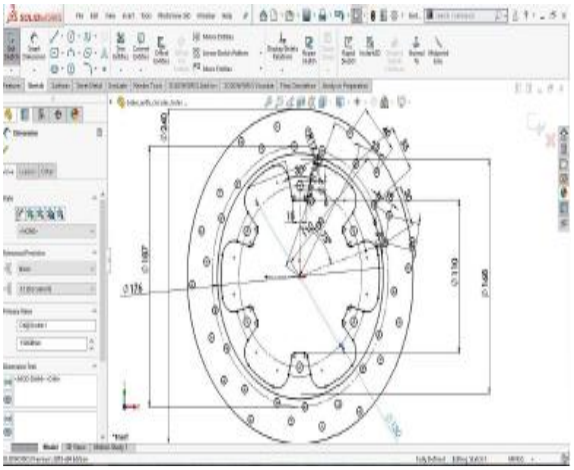

Fig.5: 2D sketch of disc brake model

5. OPTIMIZATION MODEL:

Draw the slot at the location of holes and cut by using extrude cut command as shown in fig.6.

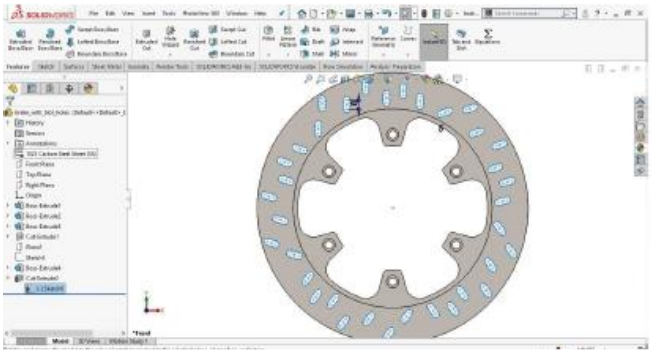

Fig.6: Slot provided on disc brake model for optimization

Fig.7: Rendered part of optimized disc brake model

5. FINITE ELEMENT ANALYSIS:

5.1 MESHING:

Hex type mesh is used and size of element is taken as 1 mm.

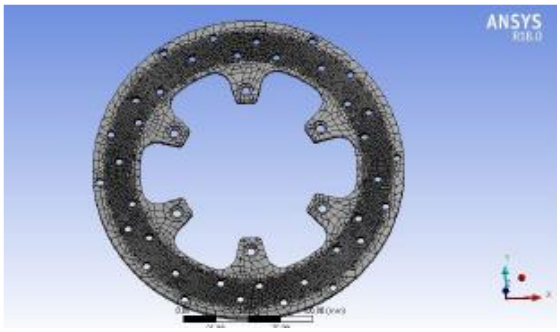

Fig.8: Meshed part of disc brake

5.1 BOUNDARY CONDITIONS:

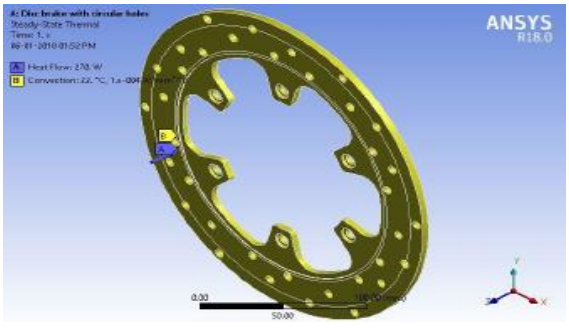

Fig.9: Boundary conditions

6. RESULTS:

6.1 EXISTING DISC BRAKE ANALYSIS:

6.1.1 STATIC THERMAL ANALYSIS:

As shown in fig.10 the maximum value is specified for danger criteria in red that is 72.978 ^{0}C which is indicated near the caliper contact area and minimum for safe criteria is blue that is 42.046 ^{0}C. The physics of simulation of this plot is that temperature rises from fixed bolt and move toward the braking zone.

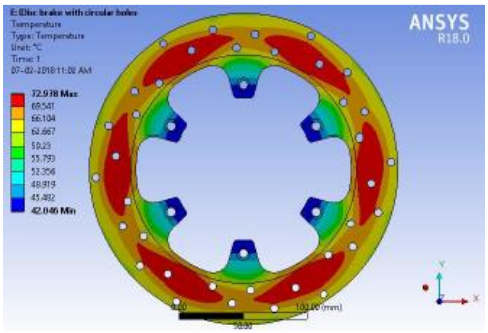

Fig.10: Temperature plot for original disc brake

As shown in fig.11 the plot of variable is total Heat flux. The unit of variable in this plot is W/mm^2. The maximum value is denoted for danger that is red color 0.055648 and minimum value as blue that is 0.00022456.

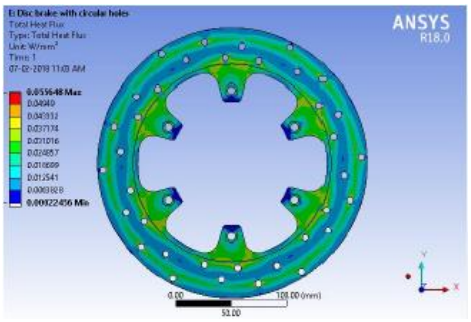

Fig.11: Heat flux plot for original disc brake

6.1.2 STATIC STRUCTURAL ANALYSIS:

Fig. 12 shows the total deformation plot. The unit of this variable in this plot is mm. The maximum value is denoted for danger that is red in color 0.085142 at the outermost radius of disc and minimum value as blue that is 0 mm where are bolt are attached.

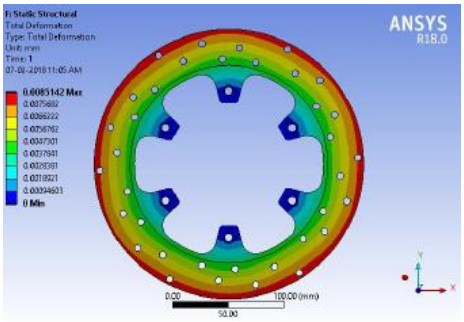

Fig.12: Deformation plot for original disc brake

6.2 OPTIMIZED DISC BRAKE ANALYSIS:

6.2.1 STATIC THERMAL ANALYSIS:

As shown in fig. 13 The maximum value is specified for danger criteria in red that is 75.188 ^{0}C which is indicated near the caliper contact area and Minimum for safe criteria is blue that is 41.896 ^{0}C.

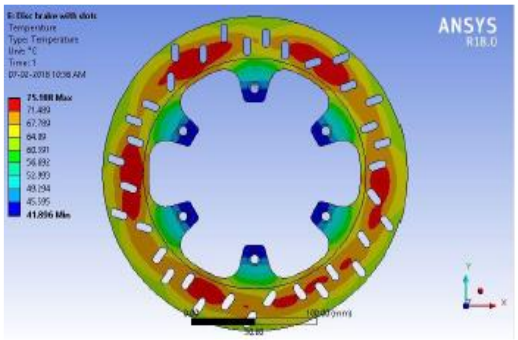

Fig.13: Temperature plot for optimized disc brake

Fig. 14 shows the heat flux plot. The unit of variable in this plot is W/mm^2. The maximum value is denoted for danger that is red color 0.055498 and minimum value as blue that is 7.0115e-5.

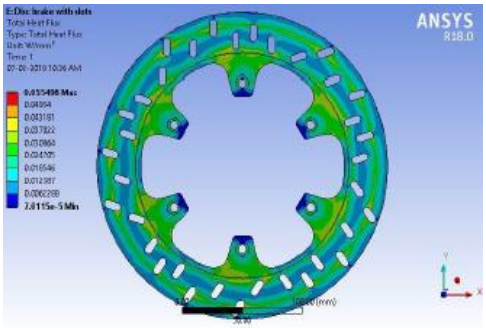

Fig.14: Heat flux plot for optimized disc brake

6.2.2 STATIC STRUCTURAL ANALYSIS:

Fig. 15 shows total deformation plot. The unit of this variable in this plot is mm. The maximum value is denoted for danger that is red in color 0.0073946 at the outermost radius of disc and minimum value as blue that is 0 mm where are bolt are attached. Total deformation which increases from the fixed section to the outermost diameter of the disc brake.

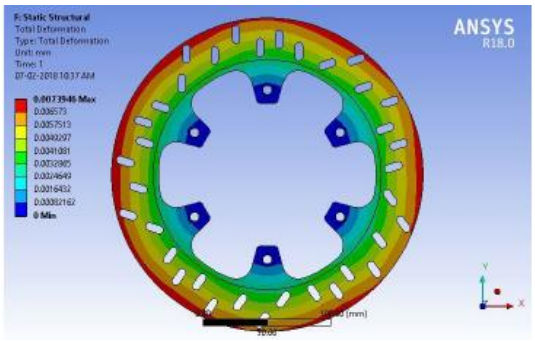

Fig.15: Deformation plot for optimized disc brake

6.3 EXISTING vs. OPTIMIZED DISC BRAKE

Table No. 2 Results Comparisons

Parameters	Existing Disc Brake	Optimized Disc Brake
Temperature (^{0}C)	72.978	75.188
Heat Flux (W/mm^2)	0.055648	0.055498
Deformation (mm)	0.0085142	0.0073496
Weight (kg)	0.99554	0.92941 (6% Weight reduction)

7. CONCLUSIONS:

Weight and deformation of disc brake is reduced by using topology optimization concept. Total 6% weight reduction of disc brake is achieved. As weight of disc brake is reduced therefore performance efficiency of disc brake is improved.

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