DESIGN, ANALYSIS AND FABRICATION OF DISC BRAKE USING DIFFERENT PATTERN OF HOLES

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Abstract
Automobile braking machine is one of the most important mechanical device (known as Disc Brake) is used for slowing or stopping the rotation of a wheel. Disc Brakes are more effective in transferring heat to atmosphere, self-adjusting, and are easier to maintain in always service condition. Every Automobile is equipped with Disc Brakes for smooth running of the vehicle. The main aim of this study is to increase the life period of Disc brake by considering different types of materials, designs and by varying the thickness of it. Using the ANSYS software, the coupled discipline Analysis (Static + Thermal) under different boundary conditions are Performed on the Disc brake. The Taguchi method of Optimization Technique and Anova Analysis gives us the best material, design and thickness parameters of the Disc brake. Total Deformation under Static Analysis is considered for Taguchi method of Optimization Technique. From Taguchi method the obtained results were Structural steel, Star Shaped hub with Rectangular and Circular Pattern of holes and 6 mm as thickness of disc brake and these combination provided less deformation under static analysis.

Keywords: Disc Brake, Taguchi method, Optimisation technique, Anova Analysis

INTRODUCTION:

Disc brakes came into usage and existence from England in 1890. The first Caliper based disc brake was licensed by the Frederick William Lanchester. In the year 1902, Lanchester Motor Company invented and made available the similar disc with thin and cable activated brake pad. Many designs were not come into existence until next 60 years. Its use started in airplanes before World War 2, and in German Tigertank in 1942. After that mass Production was started in the year 1955.

The disc brake has a metal disc in place of a drum when it is compared with drum brake. Disc brake has a Flat shoe or pad situated on the either side of the disc. This brake pad mounted on a tool called Brake Caliper. To slow or stop the bike, these two flat shoes help in bringing the rotating disc brake to stop position by the application of applying brakes of Brake Caliper either by hydraulically, pneumatically, automatically or electro-magnetically. Fluid in the Master Cylinder forces the pistons to move with pressure from one side to another side. This makes the Friction shoes or pads to control the Disc brake rigidly and hence the friction between the brake shoes or pads help in slowing down the disc brake to stop position completely.

Disc brakes get excess heat upon its working conditions. The hotness makes the brakes uncomfortable and leads to failure and is known as Brake Fade. In Disc brakes more thermal stress created when the force is applied on disc with the help of caliper. Ventilation of Disc brake helps to decrease the hotness of disc brake and also improves the performance of it to greater level. Ventilation makes the Disc brake surface area to be exposed to atmosphere [1]. This makes the heat loss very easy and quick. Disc brakes generates less heat when compared to Drum Brakes. It has uniform wear. It requires less effort to stop the vehicle. Its maintenance is easy. It does not skid easily in wet area. Hence they are more efficient and has higher safety reserves.

The principle segments of a Disk brakes are:

1. Brake cushions
2. Calipers, containing piston(s)
3. Disc brake rotor

There are three types of Disc Brakes that are commonly used.

1. Floating Caliper Disc brake
2. Fixed Caliper Disc brake
3. Sliding Caliper Disc brake

PRESENT WORK:

Design Parameters for the Standard Disc brake of a Bajaj Pulsar 150cc

Parameters	Dimensions(mm)
Outer Diameter of Disc	240 mm
Inner Diameter of Disc	110 mm
Rotor Disc Material	Stainless Steel
Thickness of Disc	5 mm
Hole diameter	7 mm
Permissible Temperature	250 C
Maximum Pressure	1 Mpa

Table – 1 Design Parameters of a Standard Disc Brake

MODELLING OF DISC BRAKE:

Modelling of Disc Brake is carried out using CATIA V5 software. CATIA is a robust application that enables you to create rich and complex designs. Using CATIA V5 Software, three models were developed with three different patterns of holes with change in hub design and also by changing the thickness of the Disc Brake [2].

The first model is designed to Star shaped Hub with Circular and Triangular Holes with 4, 5 and 6mm as thickness of Disc Brake with 240 mm of Outer Diameter, Inner Diameter of 110 mm, Holes on the Outer Periphery of the disc are of 12 mm and 6 mm diameters respectively and Holes on the Inner Hub are of 13.8 mm diameter, the thickness of Disc brake is varied to conduct Taguchi Optimisation technique. Catia software provides very good features to design even complex design also. This model is named as D1 in this paper.

The second model is designed to Big Circular Hub with Circular and Polygon Shaped Holes with the same 4, 5 and 6 mm as thickness of Disc Brake with 240 mm of Outer Diameter, Inner Diameter of 110 mm .Hole Diameters on the Outer Periphery are of 9, 7, 5 and 3 mm respectively and Holes on the Inner Hub are of 9 mm diameter. This model is named as D2 in this paper.

The Third model is designed to Small Circular Hub with Rectangular and Right triangular shaped holes with the same 4, 5, and 6 mm as thickness of Disc Brake with 240 mm of Outer Diameter, Inner Diameter is of 110 mm. Rectangular Slots on the Outer Periphery of the disc are of 10 mm diameter and Holes on the Inner Hub are of 13.8 mm diameter. In this paper model is named as D3.

ANALYSIS OF DISC BRAKE:

For the analysis of model, software ANSYS 16.0 Version is used. Above 3 models named D1, D2, D3 are imported into Ansys software. And for the analysis of 3 models selection of material is also very important factor. In this paper for static analysis of D1, D2, D3 the selected material are Structural steel (S312), Aluminium alloy (A356), and Stainless Steel (SS304). In this paper above 3 materials named as M1, M2, M3 are taken under static condition and applied force of 20N with fixed support in the hub region. Boundary conditions also concerned depends on material[3], For the static analysis under different boundary conditions we obtained von-mises stress[4] , Elastic equivalent strain and total deformation , results are tabulated as per requirement of Taguchi Design of Experiment.

Procedure for Static Analysis in Ansys:

After Building the FE Model, material properties are defined. Further boundary conditions like fixed support and force on it are applied and after applying run the solution to

evaluate the von-mises stress, Equivalent elastic strain and total deformation are obtained[4].

Taguchi Optimisation Technique:

Dr.Taguchi of Nippon Telephones and Telegraph Company , Japan has developed a method based on OA experiments which gives much reduced variance for the experiment with optimum settings of control parameters. Taguchi technique is applied to plan the experiments, in a tree step approach namely system design, parameter design, and tolerance design. In system design the most influenced process parameters were identified taking with minimum trails into consideration [5].

The quality control selected is according to the design need i.e., minimize total deformation under static analysis; lesser the deformation of material under required conditions increases the life of the component. The three most influenced identified parameters are (A) Material, (B) Design of Hub, (C) Thickness of Disc Brake.

Design of Experiments:

Design of Experiment (DOE) is a powerful statistical technique for improving product/process designs and solving production problems.

Parameters that are considered are:

M - Material

M1 = Structural Steel (S312)

M2 = Aluminium Alloy (A356)

M3 = Stainless Steel (SS304)

D - Design of Hub

D1 = Star Shaped Hub with Circular and Triangular holes

D2 = Big Circular Hub with Circular and Polygon shaped holes

D3 = Small Circular Hub with Rectangular and Right triangular shaped holes

T – Thickness of material

T1 = 4 mm

T2 = 5 mm

T3 = 6 mm

Table 2. Design of Experiment for Taguchi Optimisation Technique

S.NO	Material	Design	Thickness
1	M1	D1	T1
2	M1	D2	T2
3	M1	D3	T3
4	M2	D1	T2
5	M2	D2	T3
6	M2	D3	T1
7	M3	D1	T3
8	M3	D2	T1
9	M3	D3	T2

RESULTS AND DISCUSSIONS:

1. Results of static Analysis:

Static Analysis is implemented using ANSYS 16.0 Software, with the patterns explained in DOE and results obtained for total deformation under static analysis with different boundary conditions are tabulated below.

Table 3. Results of static analysis for different patterns

S.NO	Material	Design	Thickness	Deformation under Static Analysis (mm)
1	M1	D1	T1	0.0023826
2	M1	D2	T2	0.008611
3	M1	D3	T3	0.0055498
4	M2	D1	T2	0.0035028
5	M2	D2	T3	0.014364
6	M2	D3	T1	0.051373
7	M3	D1	T3	0.00081636
8	M3	D2	T1	0.01707
9	M3	D3	T2	0.0098148

1. Quality Control :

As per Design rules the model with less deformation either in Static Analysis or Thermal Analysis gives more life period for the component , so that total deformation is considered for Taguchi Optimization technique[6].

2. Main effects of the factor :

Qualitek software is used for Optimisation process which is best software for Taguchi Optimisation technique to optimise the results and to grab out the best pattern for more life period of component .The results obtained by taking DOE 9 patterns into consideration, the result pattern with values are tabulated below.

Table 4. Table of Main effects of the factor

Level	Material	Design of Hub	Thickness
1	0.005	0.001	0.023
2	0.022	0.013	0.006
3	0.008	0.021	0.00599

From above table we can conclude that 0.005 (M1), 0.001 (D1), 0.00599 (T3) are less compared to previous values, so the pattern obtained after Taguchi Optimisation technique is M1, D1,T3.The results also shown in Fig.1.

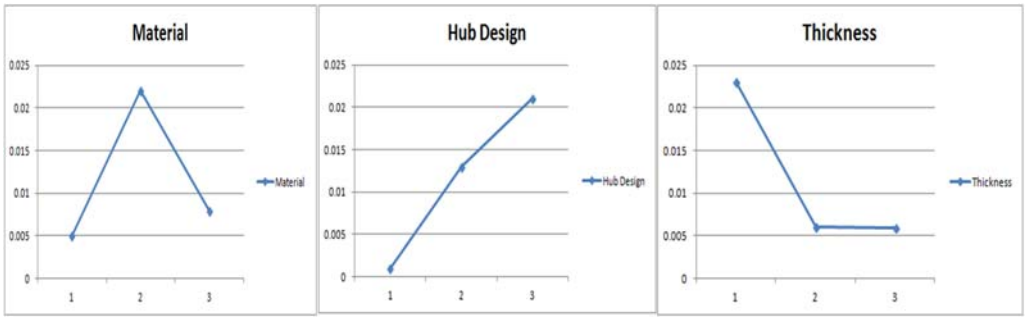

Figure .1 Main effects of the parameters

2. ANOVA Method :

ANOVA is a statistically based, and an objective decision making tool. It is used for detecting any differences in the average performance of groups of items that are tested. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels. Using ANOVA method percentage contribution of each parameter can be calculated in the process of Optimization technique[7]. In this paper the parameters of Material, Design and Thickness of Disc Brake are done and the percentage contribution is also calculated and shown in the following pi-chart diagram.

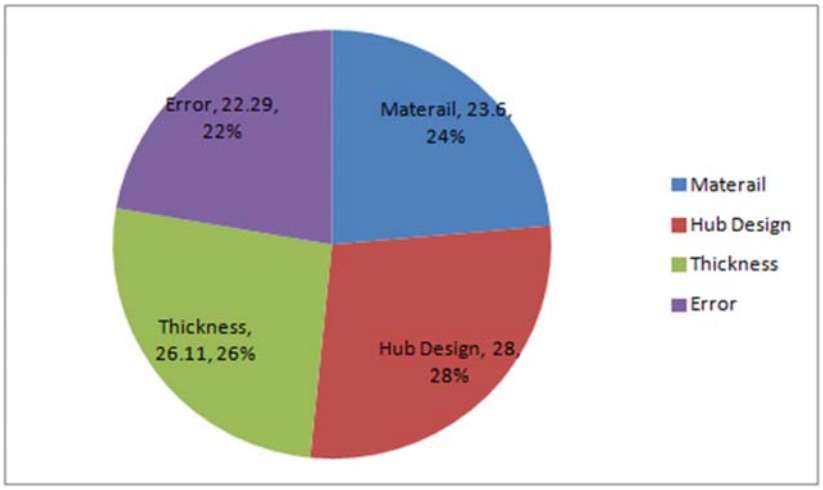

Figure .2 The Percentage contribution of the Parameters Material, Hub design and Thickness under ANOVA Method

3. Confirmation of deformation for optimized parameters:

Static Analysis is conducted for the optimized result Fig. 3 of patternM1, D1 and T3. The result of total deformation under static analysis is obtained and compared with previous 9 patterns which are mentioned in DOE table. It is observed that total deformation value is less for the pattern M1, D1, T3 i.e., **0.00078727** when it is comparedwith 9 patterns**.** Hence, the results obtained from Optimization technique, give more life for a component.

For the optimized parameters M1, D1, T3, thermal analysis is also conducted [8], the results are also tabulated in the table 5.

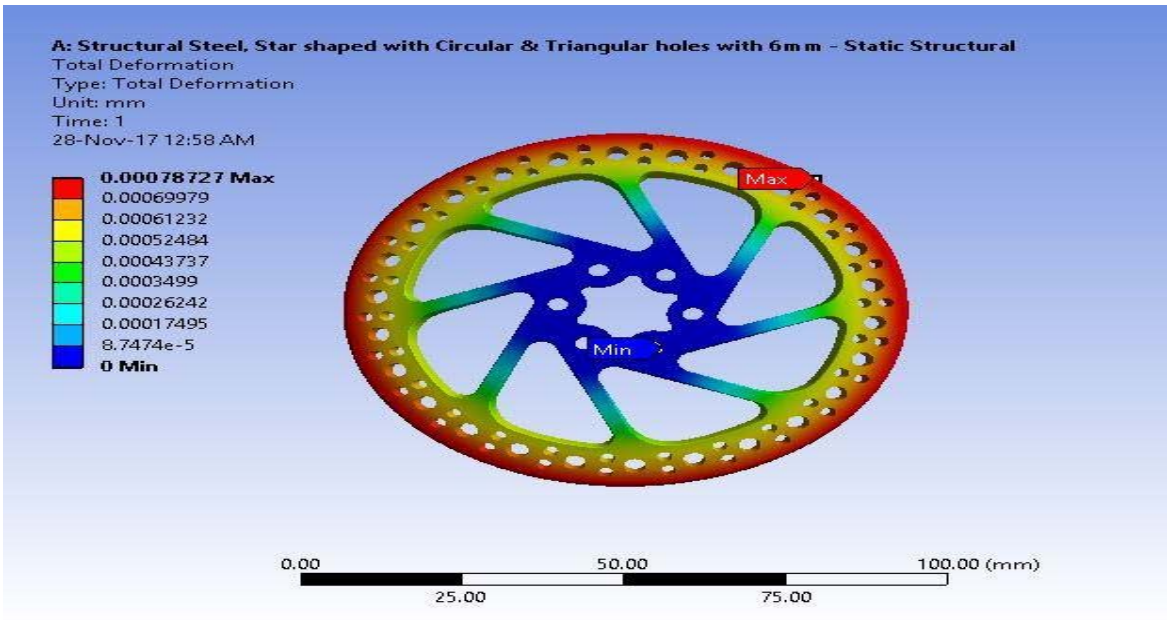

Figure 3 Total Deformation of Structural Steel, Star Shaped Hub with 6 mm Thickness

RESULTS OBTAINED FROM OPTIMIZATION TECHNIQUE (TAGUCHI MEHTOD)

Table – 5 Result Table of Optimized Technique – Taguchi Method

S.No	Material	Hub Design	Thickness of Disc	Von-Mises Stress (MPa)	Equivalent strain	Total Deformation (mm)	Temp (C)	Total Heat Flux (W/mm2)
1	M1	D1	T3	1.9566 Max.	9.7859 e-6 Max.	0.00078727 Max.	179.83 Max.	33.241 Max.

CONCLUSION:

In this paper Design and Analysis of Disc Brake with different Pattern of holes carried out for different materials like Structural Steel, Aluminium Alloy and Stainless Steel with different Models of discs by varying the thickness. The Pattern M1, D1, T3 (Structural Steel, Star Shaped hub with Circular and Triangular holes, with 6 mm thickness) is obtained as the best optimized pattern as compared to all other 9 patterns which are shown in DOE table. The Parameters like Stress (Von – mises), Deformation, Strain, Temperature and Heat Flux are evaluated / generated from Static and Thermal Analysis in Ansys 16.0 and tabulated .The Total deformation for the pattern M1,D1,T3 (Structural steel, Star shaped hub with Circular and Triangular holes of 6 mm thickness which is obtained by Taguchi Optimisation techniques results very less deformation **0.00078727 mm** as compared to other 9 patterns which are shown in DOE table.

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