International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 1 | 2019

Determination of Fatigue Life of Drum Brake Using Experimental and Finite Element Analysis

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Abstract:-*In the automobile vehicle the braking system is most important safety system. It is essential to evaluate behaviour of the braking systems for fatigue loading. Mechanical fatigue failures occur due to cyclic loading during the operation. In this paper, the fatigue analysis is done by considering a braking force, braking time for drum brake of two wheelers. The experiment was performed on fatigue test rig to determine fatigue life of the drum brake. The experiment value was validated by finite element analysis. The percentage of error of fatigue life for two methods is acceptable.*

Keywords: *Braking system, Fatigue test rig, Finite life, Cyclic loading, Finite Element Analysis (FEA).*

1. INTRODUCTION

The brake system is the vital integral part of an automobile which is used to control the speed of an automobile. Failure of the brake system can lead to accidents. In recent years, brake systems have undergone tremendous changes in terms of fatigue life, material, and safety [1].

Universally the drum brakes are widely used in the rear wheel. A drum brake uses brake shoes or friction pads to create braking force. A brake drum must be highly heat conductive, sufficiently rigid, lightweight and resistant against wear. The drum brake is generally made of a special type of aluminium and cast iron. The drum provides a friction surface, usually cast iron, on which the brake shoes are applied. When the shoes and drum come together due to friction, the motion gets retired.

Fatigue failure of the component is caused due to the action of fluctuating loads in a shorter time period and that causes localized structural damage in which initiation of a fatigue crack starts. The drum brake is subjected to such type of loading while braking. Therefore, the fatigue failure analysis of the drum brake is significant in order to improve life [2]. The factors such as braking pressure, material, and the speed of a vehicle are considered as the fatigue loading conditions. To obtain accurate fatigue analysis results of the design, the Finite Element Analysis (FEA) is done that gives the simulation of the braking phenomenon. [3][4]

Hence, it is present investigation includes the reverse engineering, experimentation fatigue test and finite elemental analysis.

2. LITERATURE REVIEW

Shenshen Shi [1] discussed that the basic principle and composition, structure of automobile brake system. The automobile brake system is the most important system in vehicles that if fails, there may be a crash. In addition, automobile brake system is an essential element to measure the performance of an automobile.

Venkataramanaet. al. [2] studied the factors in FEM for more accuracy is very essential. Designing the brake drum under different load and speed conditions. The obtained stresses in the brake drum are lower the allowable stresses of the brake drum material so the design will be acceptable.

Klaus-Jurgen Bathe [3] described the finite element procedures for design of products. FEA is now an important part of engineering analysis and design. Engineers use it to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products in short period.

Prof. K. Gopinath et al. [4] discussed the design aspects related to fatigue failure, such as how component leads to fatigue failure, what factors influence them, how to account them and finally how to design parts or components to resist failure by fatigue.

Dan Yang et. al [5] studied that the dynamic characteristics of the brake drum by theoretical calculations and by the finite element method. Through the analysis and calculation of the model, the natural frequencies and vibration shapes are computed, which provides a reference for analysis and design of the brake drum.

Meenakshiet. al. [6] optimized the design of Hero Honda Passion brake drum through approach of Reverse Engineering by using ANSYS Software. Optimization is done by changing the material of the brake drum, under different braking time and operational conditions with different stresses, deformation values. The results conclude that the CE alloys can be a better material for brake drum applications of light commercial vehicles and it also increases the braking performance.

UdayPratap Singh et. al [7] studied the efficient material for the manufacturing of brake drum was found by analyzing different selected materials under given boundary conditions. Aluminum metal matrix 2 shows less value of deformation as well as maximum von-mises stress under static structural analysis. Cast iron can be replaced by aluminum metal matrix 2.

Subramanyamet. al. [8] studied the drum brake and brake pad under goes several rough conditions on road different types of loads and temperatures for study of stress, strain deformation, temperature and heat flux. From result it concludes that, aluminum metal matrix which is economically less cost and less weight ratio.

3. METHODOLOGY

3.1 Reverse Engineering applied for Drum Brake

- Reverse Engineering is the process of duplicating an existing component, without the help of drawings and documentation. This process can be applied to the design of similar products and the shortcomings of existing designs.[6]
- In this paper, the reverse engineering method was used to get exact geometrical information and the material properties of the drum brake. [9] [10]
- To obtain accurate geometrical features and dimensions of the drum brake, the LASER scanning was done. From this scanning data the drum brake model and dimensions were obtained and is shown in 3.2 section. This model was imported in ANSYS for analysis.
- To identify the material grade of the drum brake, the Spectral Analysis was carried out. By pair comparison of the spectral report and the material standard handbook,[11]The mechanical properties are obtained.
  - ➢ Aluminum casted body : LM2 ($AlSi_{10}$ Cu_2Fe)
  - ➢ Insert lining : ASTM Class 30 Gray Iron (FG 200)
- The fatigue loading parameter braking force was calculated by considering the vehicle speed, braking time and total weight of the vehicle. These boundary conditions and the drum material's properties were feed to ANSYS software for the fatigue results. The braking force and braking time as an input value were used for the experimental fatigue test.
- The comparative study was carried out between experimental and FEA results to decide the feasibility of the design.

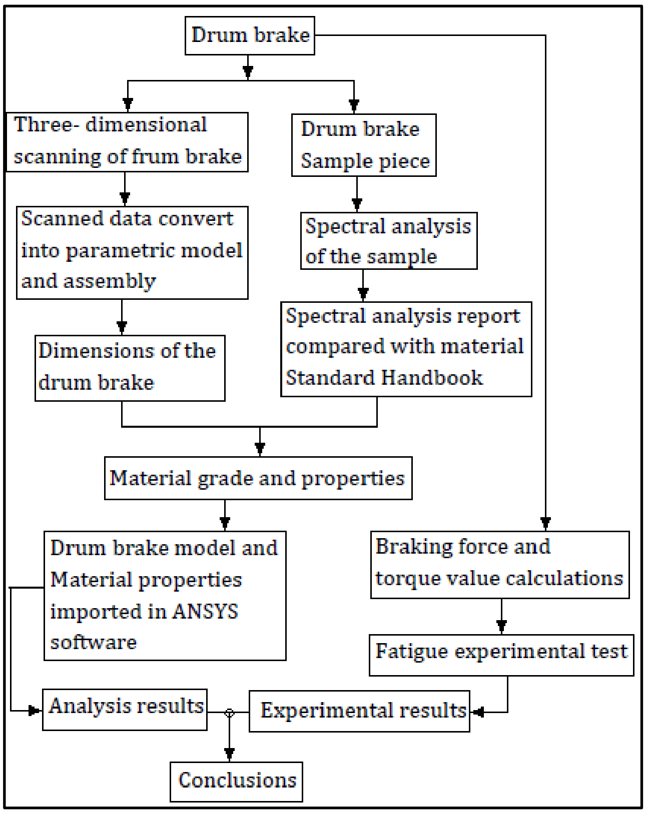

Fig -3.1: Flow chart of the Reverse Engineering

3.2 Drum Brake

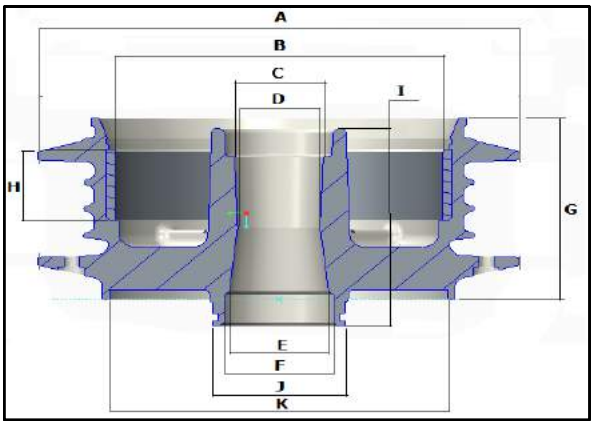

Fig -3.2: Cross Section of Drum Brake

ISSN 2455-4863 (Online) www.ijisset.org Volume: 5 Issue: 1 | 2019

A- Over all outer diameter = 164 mm
B- Brake lining inner diameter = 110 mm
C, D, E and F- Hub diameter = 30, 28, 34 and 37 mm
G- Total width = 75 mm
H- Brake shoes rubbing surface length = 28 mm
I- Total hub length = 81 mm
J- Hub outer diameter (rubber grip pad side) = 45 mm
K- Rubber grip pad side diameter = 115 mm

4. EXPERIMENTAL FATIGUE TESTING

The drum brake's fatigue test is conducted in CIRT (Central Institute of Road Transport), Pune. The test is performed on rotary actuator fatigue test rig. [12]

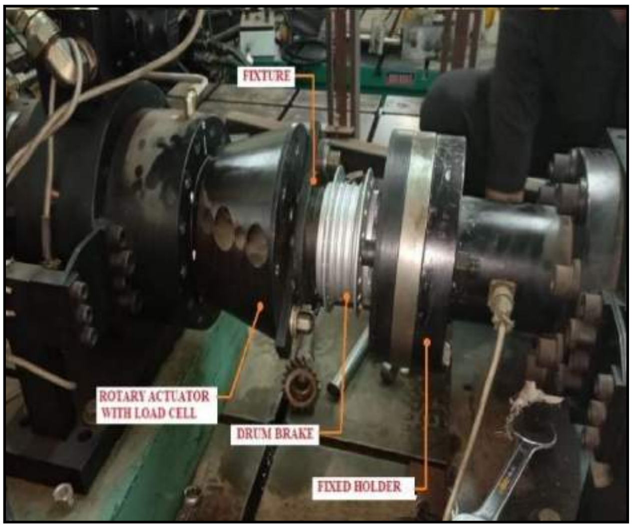

Fig -4.1: Drum Brake loading on Fatigue Test Rig.

4.1 Testing Procedure:

- Drum brake was mounted on the fixture.
- The fixturewas mounted concentrically on rotary actuator with fasteners.
- The fatigue test was started with unloaded condition and as per calculated torque; the loadwas increased gradually in the interval of torque value increment. So it simulates the actual braking action with cyclic loading.
- As cyclic torque goes on gradually increasing and reached on the maximum value; the drum brake fatigue failure occurs and related torque data was stored in the computer.

4.2 Results:

- At the cyclic twist angle 0.25 degree and the cyclic torsional load is 345.6 Nm.
  The fatigue life of the drum brake = 8.54×10^5 cycles to be measured.

5. FINITE ELEMENT ANALYSIS

- It is not always possible to obtain the exact analytical solution at any location in the body, especially for those elements having complex shapes or geometries. The finite element procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements. Mathematically, the structure to be analyzed is subdivided into a mesh of finite sized elements of simple shape. After applying the appropriate boundary conditions, the nodal displacements are found.
- Once the nodal displacements are known, element stresses and strains can be calculated. Generally the steps in a Finite Element Analysis are categorized into Preprocessing, Processing and Post-processing. [3] [7]

5.1 The analysis was carried out using following steps:

a) Model of drum brake was prepared in modeling software. This model was imported in ANSYS software.
b) The proper elements for meshing were decided and meshed model was prepared.
c) Required inputs such as component material properties were added in the ANSYS software.
d) Boundary conditions and constraints were applied to the meshed model.[13]
e) Post process in ANSYS software was carried out to obtain total deformation, equivalent stress, factor of safety and fatigue life of the drum brake.

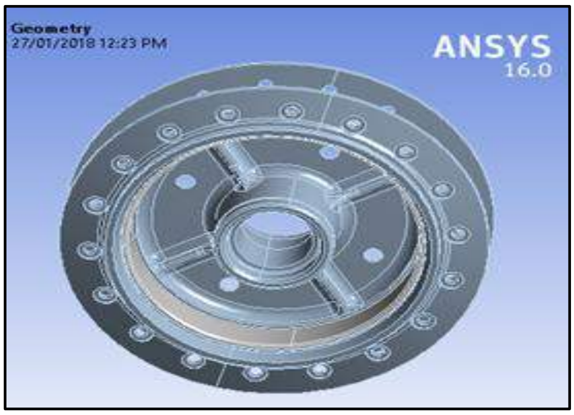

Fig -5.1: Model import in ANSYS software

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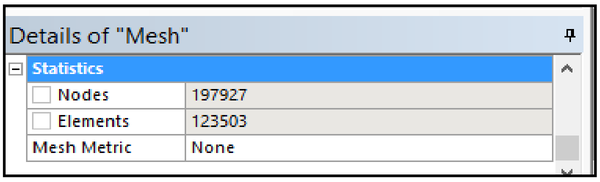

Details of "Mesh"	
Statistics	
Nodes	197927
Elements	123503
Mesh Metric	None

Fig -5.2: Nodes and Elements for Mesh

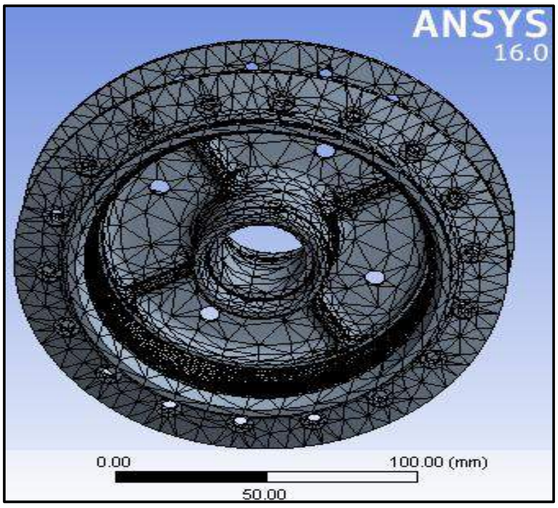

Fig -5.3: Meshed model

- Boundary Conditions value defined for Drum Brake as below:

The boundary condition is the application of a force and/or constraint.

- The braking pressure at the point A and B= 1.0MPa
- Braking time period: 1 second
- Fixed constraints are defined at that region where wheel forks fitted point C

Fig -5.4: Boundary Conditions

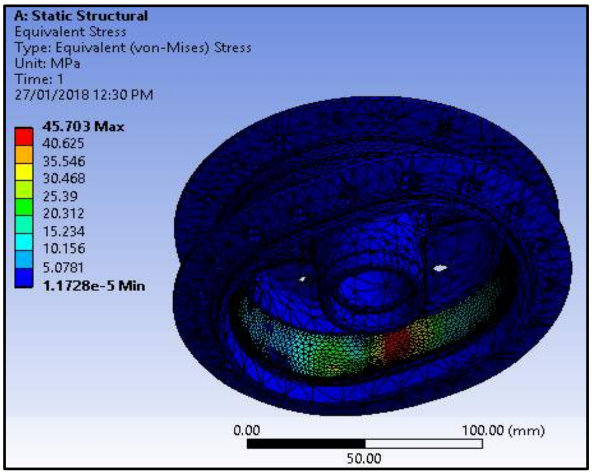

Fig -5.5: Equivalent Stress (Von-Mises)

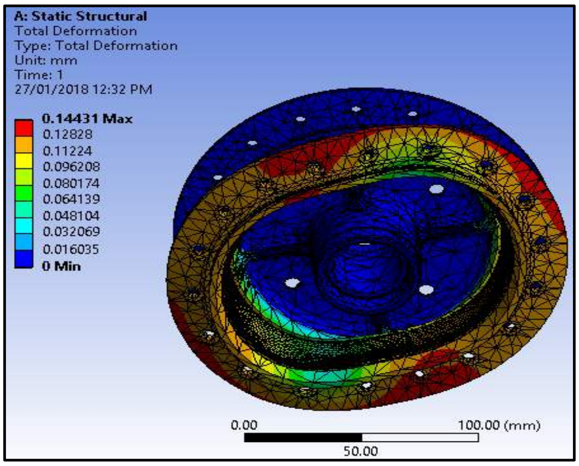

Fig -5.6:Total Deformation

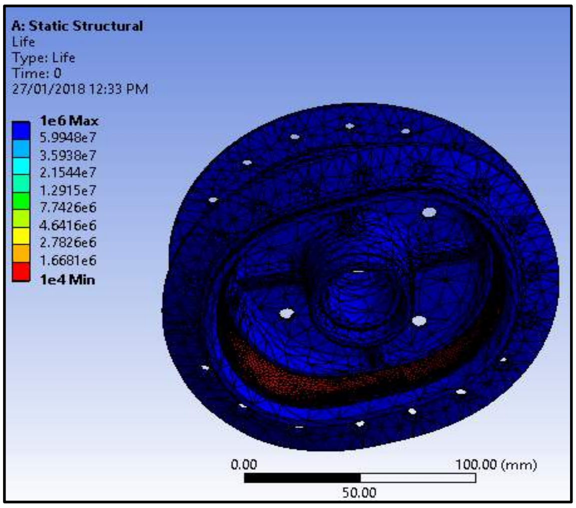

Fig -5.7: Life

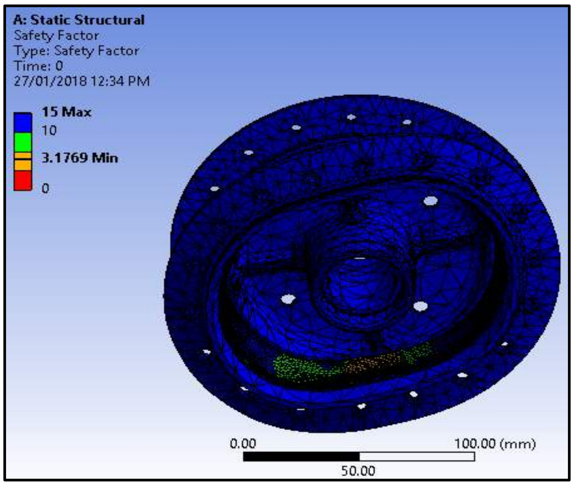

Fig -5.7: Safety Factor

5.2 Results:

- Equivalent stress (Von-Mises) = 45.703 MPa (Max.) and 1.1728e-5 MPa (Min.) at the brake lining inside area.
- Total deformation = 0.14431 mm (Max.) at the brake lining side area.
- Fatigue life = 1x 10^6 (Max.) and 1x 10^4 (Min.) number of cycles.
- Safety factor = 15 (Max.) and 3.1769 (Min.)

6. COMPARISON OF RESULTS

The fatigue life of drum brake using fatigue test rig = 8.45 x 10^5 cycles and the fatigue life of drum brake using finite element analysis =1x 10^4 (Min.) to 1x 10^6 (Max.)

Hence, % error between fatigue life

$$= [(8.54\text{x } 10^5 - 1\text{x } 10^6)/1\text{x } 10^6] \text{ x } 100$$

$$= 14.5\ \%$$

7. CONCLUSIONS

- The reverse engineering was used to obtain the geometry and the material properties of the drum brake.
- The fatigue life of the drum brake prediction was performed based on FEA and experimental method.
- Fatigue life of the drum brake using ANSYS is obtained as 1e^6(Max.) and 1e^4(Min.) and from fatigue test experiment is measured 8.54 x 10^5 cycles. The difference of 14.5% in between these results was acceptable.
- The % error may be due to possible sources of random error in experiment such as improper loading, environmental conditions (humidity), friction during the test, and variation in drum material properties.

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