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DESIGN AND ANALYSIS OF S-CAMSHAFT AND TORQUE PLATE

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Abstract: **Brakes are being big-league of automobiles. This paper entirely deals with increasing the endurance of the brakes. The major brake failures were to be exposed as breakage due to heat developed through friction. Thereby, braking components namely S-Camshaft and Torque Plate are taken into an account. By proposing the usage of variable material rather than existence to reduce the friction effects and stress factors on the Torque plate and S-Camshaft respectively. The existing material of the S-camshaft is mild steel (MS) and the Torque plate is spheroidized Cast Iron (CI). Evaluate and select the higher strengthen material than cast iron and mild steel. Formerly changing those materials has to achieve greater performance of braking system. Decisively the design structure by design Software and then analysing of stress components/ on analysis software.**

***Keywords*: Mild steel (MS), Spheroidized Cast Iron, S-Camshaft, Torque plate.**

1.INTRODUCTION

The brake system is usually considered to be a safety part of the automobile system and plays important role of operation. Thereby, many nations have recently introduced modulation and operational needs for brake systems. Modulation defines a controllable, stable, predictable, and repeatable brake system performance for every road, load, weather condition, or partial failure. All these expectations can be met if the brake performance remains stable in its operation.

The components of a brake subsystem, such as valves and actuators, are well-controlled, and they do not significantly contribute to the variations in performance. They are mostly respond to driver inputs as recommended in their specified outputs. However, the performance variation of foundation brake generally depends on previous unreliable physical conditions, such as load, road, and weather conditions. In a brake system, these conditions can arise as heat and wet affect the entire brake system through deflection in friction. Electronic subsystems may partially reduce such performance variations of brakes by preventing wheel locks or accommodating vertical load related force distribution by controlling line air pressure. However, such systems do not guarantee a fully stable brake operation. Therefore, in this study, the performance variation issue by changing the materials of brake parts of automobile system.

Structural steel has less deformation and von-Mises stress compared with the chilled cast iron. Hence the structural steel has used as an alternative material in camshaft [1]. Usage of carbon ceramic matrix rather than grey cast iron improves the thermal and structural properties in the disc brake [2]. After conducting static structural analysis on Magnesium alloy, Aluminum alloy, Magnesium alloy and 42CrMo4 it is determined that 42CrMo4 material has less deformation compared with other materials [3]. By analyzing stress, frequency and factor of safety of cast iron and Nickel Chromium Molybdenum steel, it is observed that Nickel Chromium Molybdenum steel has most desirable properties comparing with cast iron [4]. From the comparison of numerical model and experimental measurement of brake friction lining material environment like riveting, thermal forces, and stress factors gives an idea about choosing effective friction lining material [5]. By increasing the frictional surface area and decreasing the inertial force the load on brakes can be reduced [6]. The noise produced in the braking system is decreased by applying higher force instead of higher torque. Hence the torque applied is directly proportional to the noise produced [7]. When the strength consistently increases with respect to the strain rate, most of the materials yields continuously [8]. FEM analysis helps to determine various modes of noise and vibration and its influencing factors [9]. An S-cam foundation brake designed with reduction of Brake Factor (BF) for 22.93% which gives better performance than Disc foundation brake [10].

2. METHOD OF EXCISTENCE

Currently, there are various types of brakes namely band brakes commonly called drum brakes and disc brakes. The band brakes consist of various parts such as S-camshaft and Torque plate etc.

S-cam is a major part of a heavy automobile braking system like trucks and wheeled machinery. It consists of a shaft of length varies from 4 inches to 25 inches. One end of the shaft is turned by means of air powered brake booster and the other end consists of S-cam which operates the brake shoe. The braking effect is produced by the S cam movement when the input torque is given to the one end of the S-cam by means of lever by the driver of the vehicle; the S-cam end causes brake shoes to open. This produces the frictional effect between the brake shoe and the brake drum. This friction reduces the speed of the vehicle. There are some variation between front brake s cam shaft and rear brake s cam shaft by means of length. The rear S-camshaft is lengthier than the front one. S-camshaft is made up of ***mild steel*** material. The properties of the mild steel are discussed in following Table 1. The chemical composition of mild steel is given by

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Carbon - 0.05 %-0.25 %
Magnesium - 0.6 %-0.9 %
Phosphorous - 0.040 %
Sulphur - 0.050 %
Iron balance

Table 1: Properties of mild steel.

PROPERTIES	VALUES
Yield strength	370 MPa
Ultimate strength	440 MPa
Young's modulus	205 GPa
Elongation at break	15%
Density	7.87 g/cm^3
Poisson's ratio	0.29
Shear modulus	80 GPa

Torque plate plays a major role in braking system of heavy automobiles. It performs the mounting role of s-camshaft, axle and brake shoes. The center opening of the torque plate receives the axle shaft. The torque plate is made up with the ***spheroidized cast iron***. It is mounted in the brake drum. While braking a large amount of forces acts in the torque plate. The torque plate consists of the following parts, 1.AxleMounting holes, 2. Dust cover hole, 3.ABS hole, 4. Cam hole, 5.Fulcrum mounting hole.

Each mounting hole is defined by a center axis that is non-parallel to the lateral axis. A torque plate in the form of a sheet metal disc having a central opening for positioning of the torque plate around a shaft and a peripheral flange on the outer edge of the disc with distance-apart supporting surfaces for mounting a slider support on which the caliper and friction lining carriers are marginally mounted. The torque plate may have a mounting surface around the opening and a second surface offset from the mounting surface at transitional positions between the opening and flange. The properties of the spheroidizedcast iron has discussed in following Table 2. The chemical composition of spheroidized cast iron is given by

Carbon - 3.2 to 3.60%
Silicon - 2.2 to 2.8%
Manganese - 0.1 to 0.2%
Magnesium - 0.03 to 0.04%
Phosphorus - 0.005 to 0.04%
Sulphur - 0.005 to 0.02%
Copper - 0.40%
Iron balance

Table 2: Properties of spheroidized cast iron.

PROPERTIES	VALUES
Yield strength	310 to 670 MPa
Ultimate strength	460 to 920 MPa
Young's modulus	180 GPa
Elongation at break	2.1 % to 20%
Poisson's ratio	0.29
Shear modulus	70GPa
Thermal conductivity	31 to 36 W/mK
Thermal expansion	11 × 10^{-6}/K
Density	7.5 g/cm^3

3. BRAKE FACTOR

The Brake Factor can be expressed as the ratio of drum-lining friction drag force and the shoe actuation force.

$$C = \frac{\sum F\text{ (drum drag)}}{\sum F\text{(shoe actuation)}}$$

Where, Σ*F(drum drag)* is the summation of drum drag force and Σ*F(shoe actuation)* is the summation of total shoe actuation force.In order to compute the total Brake Factor, first, each shoe's Brake Factor can be computed separately. While calculating the braking factors there are shown in Fig 1.

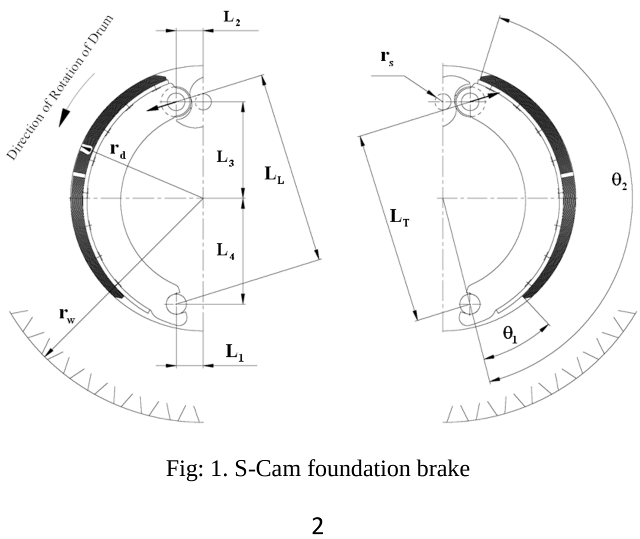

Fig: 1. S-Cam foundation brake

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$$C_L = \frac{4\square L_L(\cos\theta_1 - \cos\theta_2)}{(-a\sin 2\theta_2 + 2a\theta_2 + a\sin 2\theta_1 - 2a\theta_1 + 4\square r_d\cos\theta_2 - \square a\cos 2\theta_2 - 4\square r_d\cos\theta_1 + \square a\cos 2\theta_1)}$$

$$C_T = \frac{4\square L_T(\cos\theta_2 - \cos\theta_1)}{(a\sin 2\theta_2 - 2a\theta_2 - a\sin 2\theta_1 + 2a\theta_1 - 4\square r_d\cos\theta_2 - \square a\cos 2\theta_2 - 4\square r_d\cos\theta_1 + \square a\cos 2\theta_1)}$$

Here a = $(L_1^2 + L_4^2)^{1/2}$ and μ is the friction coefficient. $L_L$and $L_T$are the brake shoe's actuation lever arm lengths for leading and trailing shoes respectively and they can be

$$\begin{bmatrix} L_L \\ L_T \end{bmatrix} = \begin{bmatrix} \cos\varphi & -\sin\varphi \\ \sin\varphi & \cos\varphi \end{bmatrix} \begin{bmatrix} L_2 + L_3 \\ L_1 \end{bmatrix} + \begin{bmatrix} r_s \\ r_s \end{bmatrix}$$

Where φ = $\arcsin(b_1/L_4)$+ $\arcsin(r_s/b_2)$.In this equation, $b_1 = R - (R^2 - (L_4 - L_i)^2)^{1/2}$ and$b_2 = (b_1^2 + L_4^2)^{1/2}$ with $R = ((L_i + L_1)^2 + (L_2 +$ *L3)2)1/2. rs*is the S-Cam evolving (i.e. S-Cam base) radius. In analysis, L_2 is varied between L_i (i.e. before lining wear - full lining thickness) and L_f (i.e. after lining wear - lowest lining thickness) depending the rotation position of cam given by
$(L_i \leq L_2 \leq L_f$). Sub-index L and T represent leading and trailing shoes respectively. Each shoe's Brake Factor versus friction coefficient is plotted in Fig 2.

Fig 2.Shows that the Brake Factor grows exponentially for the leading shoe (C_L) causes the friction coefficient increases. This occurrence is called "self-energized", and it can only be seen in type foundation brakes. Brake lining wear can be categorized into two types, as follows:

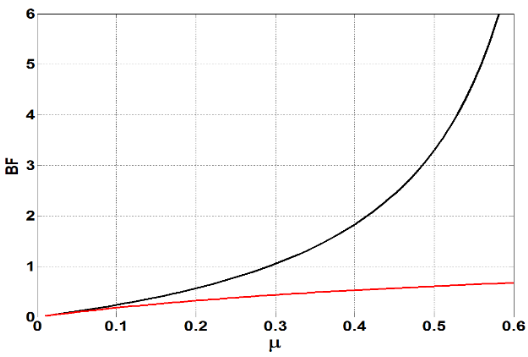


Fig: 2. Brake Factor for Leading and Trailing shoes.

Type A: Linear wear (LW): in this case, the leading and trailing shoes have no floating mechanism of actuation (i.e. actuation load transfer is prevented between both shoes). This case implies an unequal shoes actuation force or an equal lining wear. S-Cam foundation brake is a typical example.

Type B: Differential wears (DW): In this case, leading and trailing shoes have a floating mechanism of actuation (i.e. actuation load transfer is permitted between both shoes). This case implies an equal actuation force or an unequal lining wear. A simplex wedge foundation brake is a typical example.

4. MATERIAL MODIFICATION

The one of the preferable way to increase the life expectancy of the Torque plate and S-camshaft is to strengthen the material properties, which already exists. It can be achieved by replacing a material having superior properties. For this several materials has been evaluated with the existing material properties. The material which gives the best results in all considerations has been selected as an alternative material.

Thereby it is ensured to choose***C55 Steel***(Medium carbon Steel) as an alternative material for S-camshaft instead of mild steel. Table 3 shows the comparison between mild steel and C55 steel properties.

For Torque plate it is confirmed to select ***50CrV4*** (Chromium Vanadium Alloy) as a substitute for Spheroidized cast iron. Table 4 compares the properties of Spheroidized Cast iron and 50CrV4.

Table 3: Mild Steel vs. C55 Steel

Properties	**Mild Steel**	**C55 Steel**
Yield strength	370 MPa	450 MPa
Ultimate Strength	440 MPa	850 MPa
Young's Modulus	205 GPa	210 GPa
Elongation at break	15%	15%

Density	7.87 g/cm^3	7.85 g/cm^3
Poisson's ratio	0.29	0.29

Table 4: Spheroidized Cast iron vs. 50CrV4

Properties	Spheroidized Cast iron	50CrV4
Yield strength	490 MPa	900 MPa
Ultimate Strength	650 MPa	1200 MPa
Young's Modulus	180 GPa	210GPa
Elongation at break	2.1 – 20 %	12%
Density	7.5 g/cm^3	7.8 $g\backslash cm^3$
Poisson's ratio	0.29	0.3

5. DESIGN AND ANALYSIS

5.1. Design:

The design process were done through CREO Parametric 3.0 which is quite reliable to make a 3D-modeling compared to other design software like CATIA, Solidworks etc.,

5.1.1. Design of S-Camshaft:

The dimensions of S-camshaft are taken in a metric unit in ASME Standard as shown in Fig (3).

5.2.2. Design of Torque Plate:

The dimensions of torque plate design also taken as metric unit as shown in Fig (4).

5.2. Analysis:

The analysis of the designed model was accomplished by ANSYS Workbench software. The type of analysis in this process is structural analysis.

5.2.1. Analysis of S-Camshaft:

For analyzing the S-camshaft, the input force is given in Newton at both ends of S-cam, which have a direct contact with brake shoes of brake drum. The total deformation, equivalent strain and equivalent (von-mises) stress are analysed for both existing and proposed material are compared together to get the positive results as shown in Fig (5), (6) and (7).

5.2.2. Analysis of torque plate:

For analyzing the torque plate the inputs are given in the terms of pressure force (N/mm2). The input is given in the inner walls of cam hole, fulcrum mounting hole, dust cover hole and axle mounting hole respectively.
The total deformation, equivalent strain and equivalent (von-mises) stress are analyzed for both existing and proposed material are compared together to get the positive results as shown in Fig (8), (9) and (10).

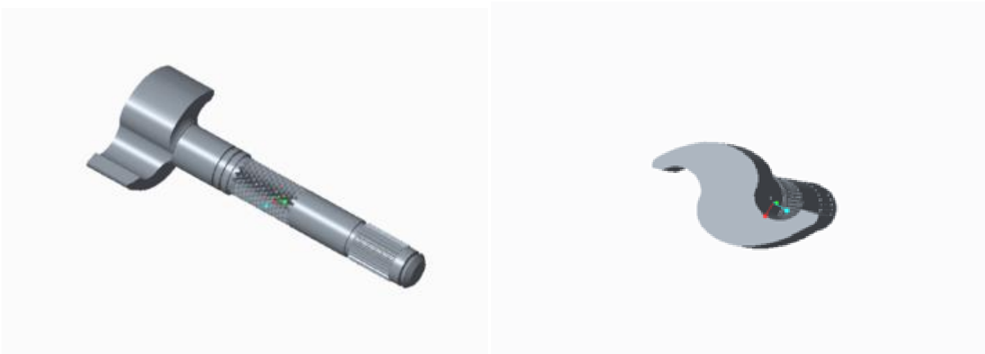
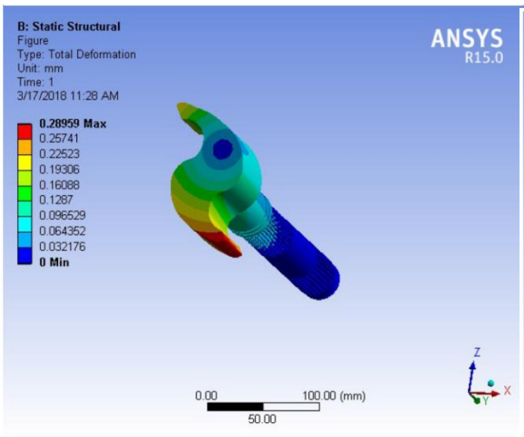


Fig (3)

Fig (4)

Fig (3) shows about the designed S-camshaft with different views

Fig (4) shows about the designed Torque plate with different views



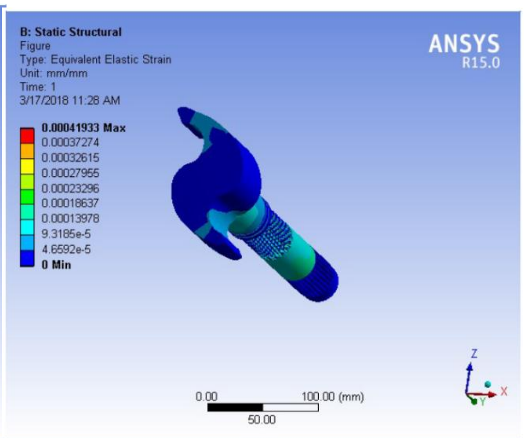


Fig (5) Fig (6)

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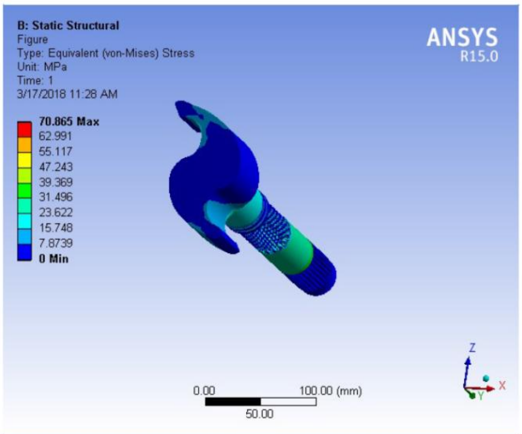

Fig (7)

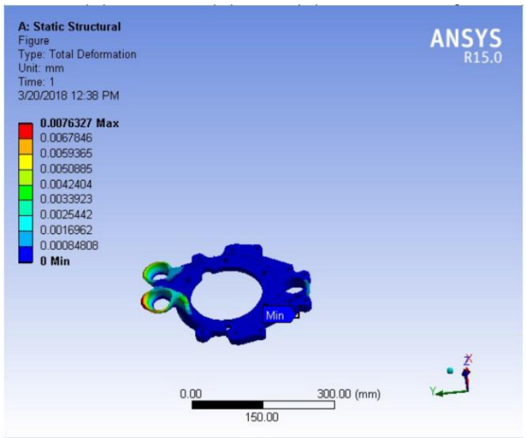

Fig (8)

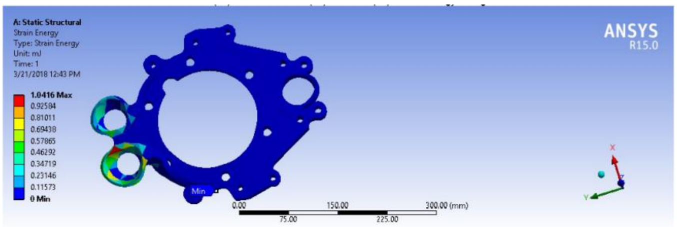

Fig (9)

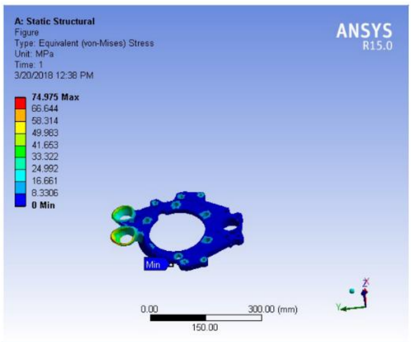

Fig (10)

Fig (5) shows the total deformation of S-camshaft. Fig (6) shows the Equivalent Strain of S-camshaft. Fig (7) shows the Equivalent (von-mises) Stress of S-camshaft. Fig (8) shows the total deformation of Torque plate. Fig (9) shows the Strain energy of Torque plate. Fig (10) shows the Equivalent (von-mises) Stress of Torque plate

Table 5: Result from the analysis

Categories	S-Camshaft		Torque plate	
	Mild Steel	C55 Steel	Spheroidized cast iron	50CrV4
Total Deformation (mm)	0.28959	0.28269	0.0088182	0.0076327
Equivalent Strain (or) Strain Energy	0.00041933	0.00040935	1.2078	1.0416
Equivalent (von-mises) stress (N/mm^2)	70.865	70.865	74.981	74.975

The Table 5 contains the values are which is obtained from the static structural analysis report of the different materials of S-camshaft and Torque plate.

The existing material of these components values has been compared with the alternative material values in the categories like total deformation, equivalent (von-Mises) stress and equivalent elastic strain.

6. CONCLUSION

From the comparison of materials with the values of total deformation, equivalent (von-Mises) stress and equivalent elastic strain acquired from the static structural analysis of S-camshaft C55 steel has the less values of total deformations and equivalent elastic strain compared with the Mild steel. Hence C55 steel can be choose as an alternative material for S-camshaft. In the case of static structural analysis of Torque plate it is observed that the total deformation, equivalent (von-Mises) stress and equivalent elastic strain values are lesser for 50CrV4 alloy steel compared with spheroidized cast iron. Hence it is recommended to choose 50CrV4 alloy steel as an alternative material for Torque plate existing material spheroidized cast iron.

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