International Journal of Trendy Research in Engineering and Technology (IJTRET)
Volume 2 Issue 3 June 2018

KINETICS OF DISC BRAKE CALLIPER

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ABSTRACT
The presne work aims to optimize the working parameters and to increase the performance of the brake system. The first step to examine the calliper opening: to find construction points that determine the allowable opening of the calliper; in this case the calliper stiffness. In this research calliper has more parts where some bolts contact different parts and the effect of preload of bolts was examined how it would change the calliper's opening.The next step was to investigate the geometry of the piston to find values suitable to make the optimal design: Optimal wall thickness and optimal position of the top face. As the last step, we examined the consistent pressure distribution on the friction surface of the brake pad to determine optimal diameter ratio in four pistons calliper. The main objective is to increase the efficiency of brake system and increase the lifetime of brake pad.

INTRODUCTION

It isknown that vehicle companies manufactured more and more vehicles in the last few years. There are no cars without a brake system. The brake system can be of two types: disc brake and drum brake.

The working of brake system is of interesr for many researchers to realizeunderstand the optimal function of the given brake system construction, in order to increase the lifetime or the performance. Most brake-researches examine the thermal and tri biological behaviour, where the behaviour of the different friction materials was checked at high temperature.

For examination of brke system both a real system, and a model are being used to examine the properties of the parts. Presently we use computer software for research in brake system since these programs are suitable to model the environment and can compare lots of different constructions.

MATERIAL AND METHOD:

In the present work the material and finite element models are discussed. Three finite element models were used in this research (allowable deformation of calliper, optimal design of piston, optimal diameter ratio in four pistons calliper).

Properties of different parts of disc brake:

Materials of different parts (calliper, disc, brake pad, and piston) were defined about the working parameter. The unspring mass effects on the manoeuvrability, so there were very often low density materials used in the brake system. In this research the calliper material is aluminium alloy (7075T6) and bolts are M10 10.9 steel. The calliper' and bolts material properties are shown in Table 1.

Table 1. Properties of parts of calliper

Mechanical properties	Aluminium, 7075T6	M10 10.9 steel bolt
Yield strength	503 MPa	940 MPa
Modulus of Elasticity	71,7 GPa	220 GPa
Poisson ratio	0,33	0,3

In the disc brake system the other important part are pistons that press the brake pad to the brake disc. Literature shows the three most popular kinds of material of pistons, so these materials (aluminium alloy, steel, titanium alloy) have been investigated. Table 2 shows properties of pistons material.

Table 2. Properties of pistons

Physical and mechanical properties	Aluminium alloy (AlZn4.5Mg1)	Steel (S235JRH)	Titanium alloy (Ti6Al4V)
Density	2770 kg/m^3	7850 kg/m^3	4620 kg/m^3
Yield strength	280 MPa	251 MPa	930 MPa
Modulus of Elasticity	71 GPa	210 GPa	96 GPa
Poisson ratio	0,33	0,3	0,36

The friction elements (disk, brake pad) are the two most important parts of disc brake. Brake pad has two different parts: friction material and steel plate. The properties of material of brake pad and disc are summerised in Table 3.

Table 3. Properties of brake pad and disc

Mechanical properties	Friction material	Steel plate of brake pad	Disc
Modulus of Elasticity	1GPa	210GPa	110GPa
Poisson ratio	0,25	0,3	0,28

Model of pistons of calliper:

The investigation of piston geometry have been carried out using finite element software. In this investigation there was a 2D model used where hydraulic pressure works in different surface depending on the sealing ring position (sealing ring in calliper (SIC), sealing ring in piston (SIP)). Fig. 1 shows the surface where hydraulic pressure works.

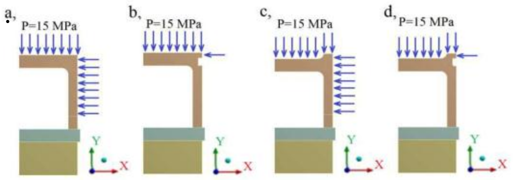

Fig. 1 Piston's surface where hydraulic pressure works in different cases

First, deformation of the piston's wall was checked . In this investigation a simple model was used where the wall thickness had been changed. Wall thickness was between 0.5 mm to solid piston in this examination.

Second, optimal top face position was examined where top face position had been changed to find out, which case gives the smallest deformation of the wall. In this case the wall thickness is constant (3.5 mm), the top face thickness is 5 mm. Fig. 5 shows how the top face position is changing from top to bottom.

2.4. Model to define optimal diameters ratio

In order to find optimal diameter of pistons in four pistons calliper there was a simple model used. The model used to define the optimal diameter ratio is shown in fig. 6.

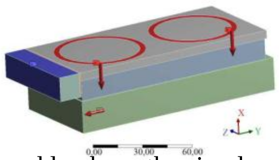

Fig. 2.Constrain and loads on the simple model

In this investigation the first piston's (P1) diameter was observed between 32 mm and 44 mm, the second piston's (P2) diameter was changed between 32 mm & 64 mm.

The pressure distribution was examined on friction surface. Pressure distribution was defined along 7 lines (13 points per line) and different constructions were compared to find optimal diameter of pistons (fig. 3). In this case friction coefficient between the brake pad and the calliper was changed to investigate how the diameter of pistons changes in different cases.

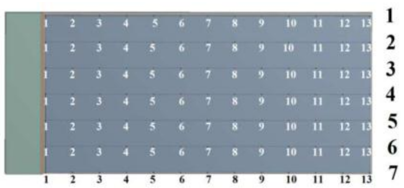

Fig. 3. Check pressure distribution on friction surface along 7 lines (13 points per line)

Defining the allowable deformation of calliper

The investigation of deformation of calliper under different pressures was used to check the degree of deformation. Fig 4.shows the calliper opening when pressure was changed between 0 and 15.1 MPa.

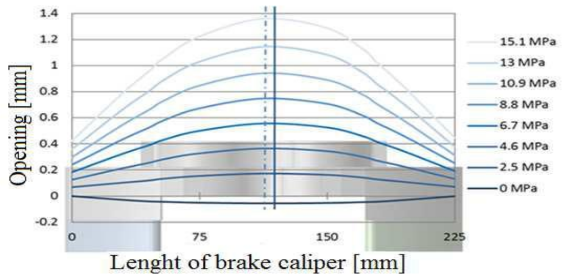

Fig. 4. Total cross-section deformation of calliper at different pressures

The two types of openings namely positive and negative opening has an effect on the working of brake system and on thebrake pad's lifetime. The deformation of the calliper changes the cylinder bore of pistons in calliper and in critical case it changes the pistons optimal position. Cylinder bore position was check in *x* and *z* direction.

Pistons position and working parameters show what calliper opening is allowable or not. The finite element simulation shows how the cylinder of pistons changes in the calliper. Fig. 5a &5b show the cylinder bore degree in *x* direction in *z* directions respectively when different pressure was applied..

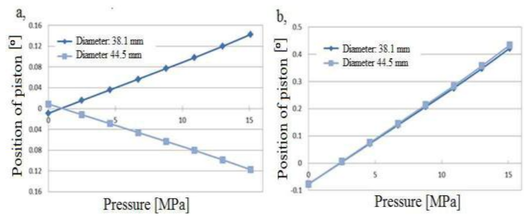

Fig. 5. Cylinder bore of piston bending angle in a) X direction, b) and in Z direction

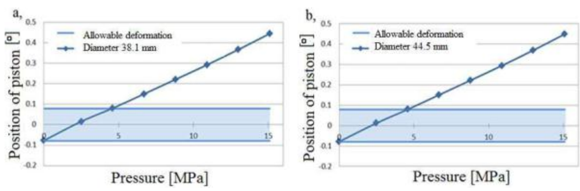

Fig. 6. Cylinder bore of pistons bending angle, a) diameter 38.1 mm, b) diameter 44.5 mm

Bolts preload effects calliper deformation, so calliper deformation was checked when bolts preload was changed. Preload of bolts is between 20 kN and 52 kN which is in agreement with the standard- M10 10.9 bolts preload. The preload depends on the bolt's design and friction is coefficient. Fig. 7a shows the smaller piston's (diameter 38.1) angle when different preloads of bolt were used. Fig. 7b shows the bigger piston's (diameter 38.1) angle when different preloads of bolt were used.

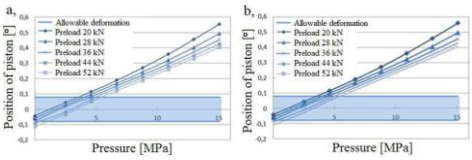

Fig. 7. Cylinder bore of pistons bending angle when different preloads of bolts were used, a) diameter 38.1 mm, b) diameter 44.5 mm

Our results show that bigger preload of bolts uses bigger hydraulic pressure. The bolt preload has a limit, because if cylinder bore of pistons bending angle is bigger than allowable, the pistons position is not optimal, that means the efficiency of brake system is low. The other board of limit is stress, the stress in bolt is not bigger than the yield strength.

NEW SCIENTIFIC RESULTS:

In this study the brake system of high performance cars was investigated where various parameters were defined. These new scientific results help engineers to de-sign or/and optimize the brake system. Finite element models used in this research were identified and validated by measurements. My new scientific result is:

1. Defining the allowable deformation of calliper

I defined the load limit of fix calliper where the opening of calliper changes the pistons position (not optimal position), that means pistons do not press the brake pad's total surface and the performance of brake system decreases. The effect of pre-load of bolts in calliper was determined, if the pre-load of bolts is increased, load limit of calliper will increase. The deadline of bolt's pre-load is if the calliper is unloaded, the piston does not change optimal position and total face presses the brake pad to the brake disc.

2. Defining the optimal wall thickness of piston

I demonstrated limit of wall thickness of piston (not solid piston) where piston's wall is rigid and top face of piston has no effect on deformation of piston's wall. Limit of wall thickness depends on the sealing ring's position (sealing ring is in calliper, sealing ring is in piston).

3. Defining optimal top face position

In case of 0.16 wall thickness-radius ratio certificates that top face optimal position depends on the sealing ring's position (sealing ring is in the calliper, sealing ring is in piston). I proved when sealing ring is in the calliper the optimal position of top face is 20 % of piston's length. In the other case, when sealing ring is in the piston the optimal position of top face is 30 % of piston's length.

4. Method to define optimal diameters ratio of pistons

The pressure distribution made by the two pistons was independent from friction coefficient (friction of coefficient range is 0.1 to 0.2). I defined the optimal diameters ratio of pistons, this optimal diameter ratio is independent from friction coefficient. In this case the pistons pressure centres are on the centre line of brake pad and distance of the pistons is 25% and 75 % of the length of brake pad.

5. Defining optimal diameters ratio of pistons

I certified with my experiments that in the case of diameter of piston being be-tween 32 mm and 64 mm, optimal diameter ratio is 0,805. In this case the pistons pressure centres are on the centre line of brake pad and distance of the pistons is 25% and 75 % of the length of the brake pad.

CONCLUSION AND SUGGESTION:

In this study the results give various parameters, which can help to make an optimal brake system. These parameters are good to optimize the working parameter or to increase the performance of brake system. The disc brake is a complex system. In my work small parts were examined. Finite element models used in this investigation are suitable for the deduction of general inferences.

In this investigation three parts were checked: opening of calliper, deformation of piston and pressure distribution on friction surface of brake pad. The opening results of calliper show that opening has an extent that determined the permissible opening. In mounting calliper this permissible opening changes if preload of bolts was change.

The other part of my research dealt with geometry of pistons of calliper. In this case the aim is to design a piston with suitable working parameter when higher hydraulic pressure is applied to brake system. The investigation results show that positions of sealing ring change the optimal geometry of piston.

The third part of my research optimized the pressure distribution on friction surface of brake pad. The goal is to define optimal diameter ratio of pistons making consistent pressure distribution on friction surface that increases the performance of brake system and increases the lifetime of the brake pad.

Models used in the research are upgradeable and more parameters use to simulate the real environment. The heat load effect was not checked in my work, so the heat load may modify the results in a little measure, but my models are good to check how results change, if the temperature is getting higher.

In my work tight environment of brake system was examined (calliper, piston ,brake pad), but in this model deformation of disc and other movable parts (suspension, wheel, stabilizer bar, etc) deformation was not in my model. In the future this effect will have to be checked to make exact model that gives more real results.

The optimal diameter ratio was defined but if more points and real brake pad geometry would be examined the result would give more accurate value about the pressure distribution of brake pad. In my investigation new brake pad was examined but the wear of friction material to check how the wear changes the pressure distribution and how it changes the optimal diameter ratio of pistons.

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