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OPTIMAL PISTON'S DIAMETER RATIO IN FOUR PISTON CALIPER

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Abstract

Researches of brakes have two ways: one direction is to increase the performance of brake and other direction is to increase life time of friction elements (brake disc, brake pad). In this study four pistons (side two) caliper were examined where optimal pistons diameter was defined. Pistons in caliper is different first piston (P1) according to a rotation direction diameters is smaller than second piston (P2) according to a rotation direction. Pressure distribution of brake pad's friction surface was examined to find optimal diameters of piston. Pistons diameter was changed where first piston's (P1) diameter is between 32-44 mm and second piston's (P2) diameter is between 32-64 mm. All case optimal diameter rations was defined which result that brake pad wear is consistent (not inclined). Optimal diameter is P1=44 mm and P2=56 mm where friction coefficient is 0,1 between brake pad and caliper. This construction gives consistent pressure distribution on brake pad friction surface.

Keywords

disc brake, brake pad, optimization, wear, FEM

1. Introduction

Nowadays researchers of vehicle examine how to increase different part's performance and how to make optimal working. Lot of agricultural vehicles have disc brake because working parameter is better than drum brake. [1] Most used brake is disc brake where it is the aim to increase the friction material's performance and to increase or to optimize life time of these parts. The aim of brake pad is to make consistent pressure distribution on friction surface. Consistent pressure distribution means that the total surface works and increases the braking performance and gives long life time to brake pad. Long life time depends on the friction material which gives high friction coefficient and wear is little. Coefficient of friction material was examined area where we checked the changing of friction coefficient and wear [2] when temperature is high [3] In this study we examined different material effect into brake pad and brake disc, how the coefficient of friction can change. [4] The other area of brake is brake's frequency, where researchers avoid the damaging frequency. [5] The other important aspect is the lifetime of brake pad and the life time of brake disc, because if the construction is not good, the brake pad and disc wear are very easy and life time is decreasing. If the wear is not right, that means the exploitage of brake pad is decreasing, it has to be changed early. It can happen that by a racecar the brake pad can't be used till the end of the race. Optimal wear depends on caliper construction where piston pushes the brake pad to brake disc. Several parameters effect on the wear. Söderberg et al examined commercial caliper (2 pistons per side) pressure distribution to define the pressure center of brake pad. [6]. This research does not examine high performance caliper pressure distribution in friction surface.

The aim of this study is to define optimal piston diameter in four pistons caliper. Pistons in caliper are different, according to a rotation direction first (P1) or second (P2) piston were defined where P2 piston's diameter is bigger than P1 piston's diameter. An optimal diameter ration results that brake pad's performance and lifetime can be increased.

2. Material and method

The brake system of vehicles is complex, where the different parts have different functions to provide safe working. Materials of parts depend on target what have to be accomplished. In case of disc brakes it is important that it has high performance and low weight (unsprung mass). This requirement effects the material which has low density and big capacity. Usually brake disc was made of gray cast iron and weight does not decrease significantly. In high performance car caliper and pistons were made of aluminium alloy (for example 7075t6), which has low density and different components increase the capacity. Other important parts are brake pads which friction on disc. Brake pads consist of two elements: one is steel plate which gives consistent pressure distribution. The other part of brake pad is friction material which makes braking torque with brake disc. Properties of materials are shown in Table 1.

Table 1. Properties of material

	Young modulus	Poisson's ration
Friction material	1 GPa	0.25
Steel plate	200 GPa	0.3
Caliper	82.4GPa	0.33
Brake disc	110 GPa	0.28

A simplified model was used to define the optimal diameter ratio of piston. This model is not a complex model, we only examined the brake pad and its context (caliper, brake disc, brake pad (steel plate and friction material) (Figure 1.).

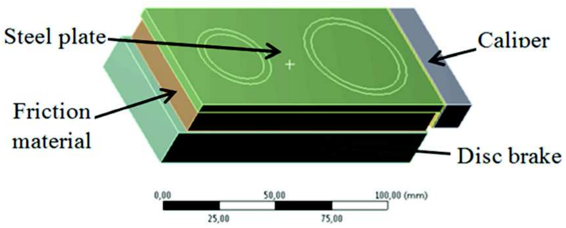

Figure 1. Examined model and parts

In this simplified model size of the brake pad's friction material 63×130 mm and friction material's thickness is 13 mm. The size of the brake pad's steel plate is 65×132 mm where thickness is 5 mm. Two pistons were pushing the brake pad to brake disc where piston's diameter was changed and pressure distribution on friction surface was examined. Piston model is only the contact surface on steel plate where 15 MPa pressure was defined. Piston's wall thickness is 3.5 mm in all cases of diameter. Diameter ration was changed to define the optimal construction where pressure distribution is consistent and brake pad's lifetime is longer. The piston's diameter is different because by braking the one side of brake pad is grazing on caliper and the other side is not. Disc brake pushes brake pad to caliper which makes friction on one side, but the other side of brake pad do not contact to other parts of caliper so there is no friction on other side. This is the reason why the piston is bigger in second place (P2) according to a direction of rotation and why is it smaller in first place (P1) according to a direction of rotation. (Figure 2.)

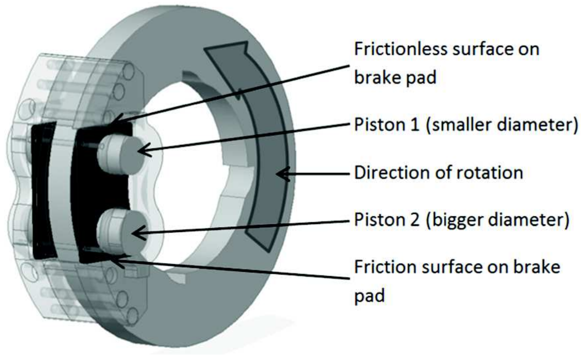

Figure 2. Examined parts of brake system name where piston's diameter is different

In this examination different diameter ration was used where first piston's diameter (P1) is fix and second piston's diameter (P2) was changed. The first piston's diameter is between 32 and 44 mm and second piston's diameter was changed between 32 and 64 mm. (Table 2.)

Table 2. P1 piston and P2 piston diameter where examined by optimal diameter ratio

P1 Diameter [mm]	Second piston (P2) according to the direction of rotation [mm]																
32	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
34		34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
36			36	38	40	42	44	46	48	50	52	54	56	58	60	62	64
38				38	40	42	44	46	48	50	52	54	56	58	60	62	64
40					40	42	44	46	48	50	52	54	56	58	60	62	64
42						42	44	46	48	50	52	54	56	58	60	62	64
44							44	46	48	50	52	54	56	58	60	62	64

We used hexagonal mesh where element size was 2 mm with the aim we could get more suitable result. Our model has 10898 elements which means 35535 nodes in the model. We defined the connection between elements where two parts of brake pad (steel plate, friction material) have bounded connection which was used in real. Friction connection is between caliper and brake pad and brake pad and brake disc. 0.1 friction coefficient is between brake pad and caliper and 0.4 is between brake pad and disc. This friction coefficient (0.4) was used by Yaoqing and by other researchers. [7]

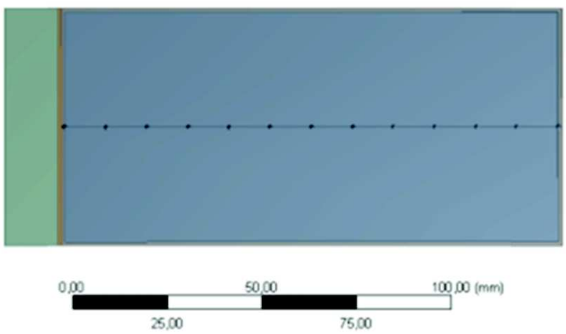

Figure 3. Examined points in center line of brake pad

3D model was made and examined pressure distribution on friction surface center line where pressure was defined in 13 points on centerline (Figure 3.)

Results show that in case of small diameter piston the pressure is low on the edge of brake pad so brake pad edge doesn't work and doesn't make suitable braking torque. By using of a big diameter piston, pistons center doesn't make suitable pressure on friction surface and the efficiency of brake pad is low. Diameters of pistons effect the friction surface distribution. When diameters of pistons are not suitable, wear of friction material isn't consistent which decreases the piston's lifetime. In this study optimal diameter ration was searched in four pistons caliper where brake pad wear was consistent because two pistons push both sides of the brake pad with the same force. Pressure distribution was defined in brake pad's center line to define optimal ration of diameter of pistons. Fig 5/a shows center line pressure where first piston's diameter (P1) was 42 mm and second piston's diameter (P2) was changed between 42 mm and 64 mm. When optimal diameters were defined, first and last point did not take into account because edge effect affects the results. Inside points (11 points) were used to define the optimal diameter ration (Figure 5/b).

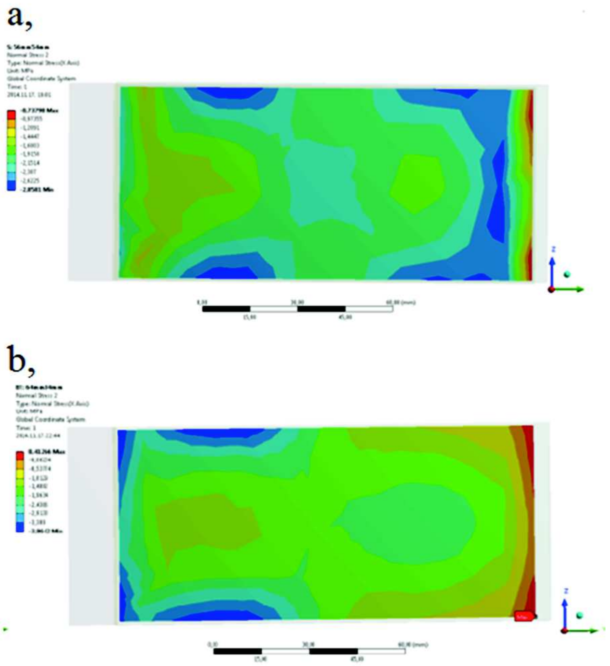

Figure 4. Pressure distribution when piston diameter is P1=54 mm and P2= 56 mm and b, when piston diameter is P1=34 mm and P2= 64 mm

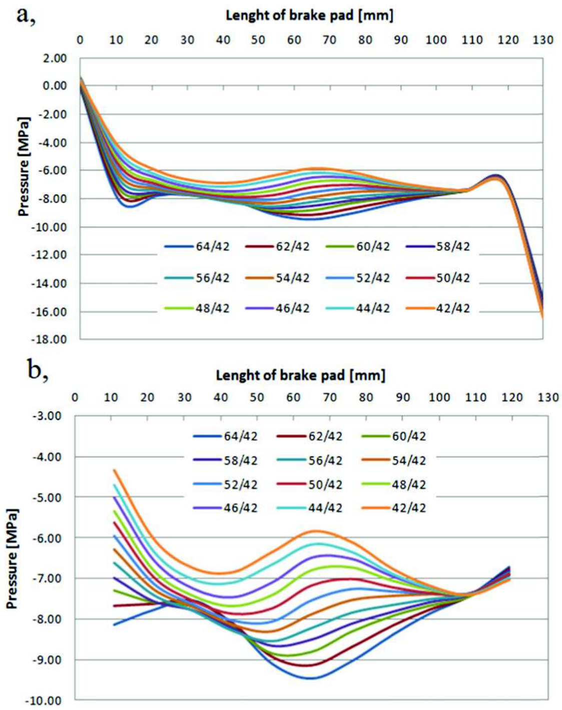

Figure 5. a, center line pressure along the entire length (13 points); b, center line pressure without outsides point (11 points)

Results show that pressure distribution depends on the piston's diameters which push the brake pad to brake disc. Furthermore pressure is lower in piston's center if there was a piston with big diameter used.

Figure of merit was made to compare the different construction to find the best diameter ration where pressure distribution is consistent. The figure of merit shows the difference between pressure and average of pressure (Figure 6.).

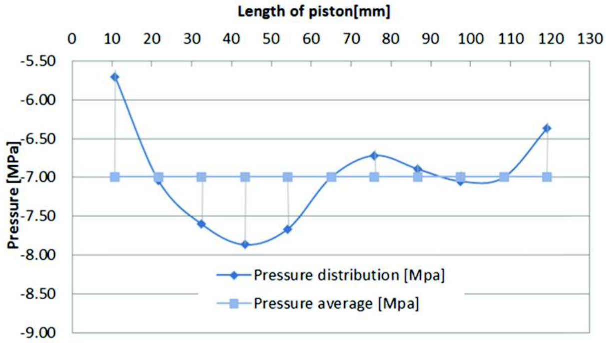

Figure 6. Definition of the figure of merit where P1=40 mm; P2=50 mm

Formula 1 helps to find the best construction which shows what diameters of ration give consistent pressure on center line of brake pad's friction surface. Smaller figure of merit shows which construction gives optimal wear of brake pad.

$$Q = \frac{s}{\bar{x}} \quad (1)$$

where Q is figure of merit, s is scatter of pressure and x¯ is the average of pressure.

Figure of merit was defined by all different diameters of pistons and result is in figure 6. where first piston's diameter was 42 mm and second piston's effect was checked. This figure shows the change of figure of merit which depends on the diameter's ration (P1/P2) (Figure 7).

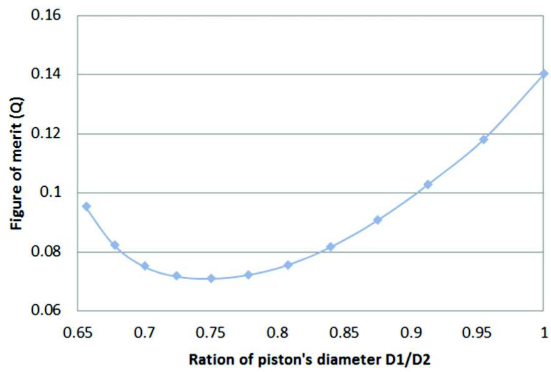

Figure 7. Figure of merit when ration of diameter was changed when first piston's diameter was 42 mm

Figure 8 shows different construction's (different piston's diameters) figure of merit. Results show that all constructions have an optimum point where brake pad's wear was consistent.

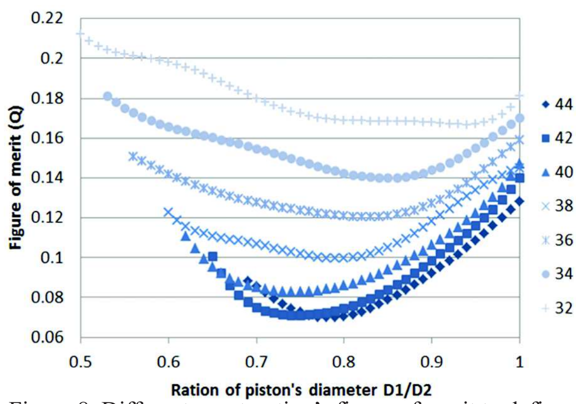

Figure 8. Different construction's figure of merit to define optimal ration of diameter

Results give which case gives optimal wear (smallest figure of merit) to increase the brake pad's lifetime because pressure distribution is consistent on center line of brake pad's friction surface. The best construction in this case is when first piston's diameter (P1) is 44 mm and second piston's diameter is 56 mm where figure of merit is 0.0698.

4. Conclusion

In this study optimal construction of piston's diameter was defined to make consistent wear of brake pad's friction surface. Pressure distribution of center line of piston was examined to find the best ration of diameter to increase brake pad's lifetime. In this study there was used a simplified model to check the piston's diameter effect to friction surface pressure distribution. Pistons of caliper are different. The diameter of the first piston (P1) according to a rotation direction is smaller than the diameter of the second piston (P2) according to a rotation. Diameter of the first piston was between 32 mm and 44 mm, diameter of the second piston was changed between 32 mm and 64 mm. Lots of cases were examined where an optimal diameter was defined, and we find the best diameter ration in all cases where pressure distribution was consistent. Figure of merit helped to compare the pressure distribution and we defined the best construction which gives long time of life. In this case we found the best construction when the diameter of the first piston (P1) was 44 mm and the diameter of the second piston (P2) was 56 mm, where figure of merit is 0.0698.

References

[1.] Horváth Á., Kalácska G., Oldal I.: 2015. Traktorokban alkalmazott fékdugattyú konstrukciója vizsgálata, Mezőgazdasági Technika, pp.2-4 ISSN 0026 1890

[2.] P.D. Neis P. D., Ferreira N. F., da Silva F. P.: 2014. Comparison between methods for measuring wear in brake friction materials Wear 319; pp. 191–199. http://dx.doi.org/doi:10.1016/j.wear.2014.08.004

[3.] Neis P. D., Ferreira N. F., Lorini F. J.: 2011. Contribution to perform high temperature tests (fading) on a laboratory-scale tribometer, Wear 271, pp. 2660-2664. http://dx.doi.org/doi:10.1016/j.wear.2010.12.023

[4.] El-Tayeb N. S. M., Liew K. W.: 2008. Effect of water spray on friction and wear behavior of noncommercial and commercial brake pad materials, Journal of materials processing technology 208, pp. 135-144. http://dx.doi.org/doi:10.1016/j.jmatprotec.2007.12.111

[5.] Lorang X., Foy-Margiocchib F., Nguyena Q. S., Gautier P. E.: 2006. TGV disc brakes queal, Journal of Sound and Vibration, 293 pp. 735–746. http://dx.doi.org/doi:10.1016/j.jsv.2005.12.006

[6.] Söderberg A., Sören Andersson S.: 2009. Simulation of wear and contact pressure distribution at the pad-to-rotor interface in a disc brake using general purpose finite element analysis software; Wear 267; pp. 2243–2251. http://dx.doi.org/doi:10.1016/j.wear.2009.09.004

[7.] Wu Y., Jin H., Li, Y., Ji Z., Hou S.: 2014. Simulation of temperature distributionin disk brake considering a real brake pad; Wear, Tribology Letters, 205–213. http://dx.doi.org/doi:10.1007/s11249-014-0400-6