Disk brake contact analysis utilizing Ansys

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Abstract. The following work looks into contact analysis of braking system using Ansys software. The work starts from brief introduction and literature review on squeal propensity problem. Coefficient of friction variations between pads and disc of braking system were analyzed to gather information on pressure distribution. Results of the analysis illustrated that by increasing coefficient of friction tendency of pressure distribution will shift toward leading edge.

1. Introduction
Braking system of a vehicle is a simplest and yet compulsory part of bringing vehicle (with a such device) to a halt. In the past and modern days brake system is responsible for vehicle safety. It serves to slow or to bring to rest the rotation of a wheel, eventually decelerating or stopping the vehicle. In the present days, there are variety designs of braking systems in the market [1].

Such as: mechanical brake drive, hydraulic drive, pneumatic and electric air drive of braking mechanisms. Braking system mainly consist of disc, pads, pistons and caliper [2]. There are other parts that serves to decelerate the vehicle in the braking system, but for the work they are not covered. In the marked disc and drum brakes are used. In a disc brakes friction forces appear on the side surface of rotating disk and in a drum they appear on the internal surface of a rotating drum [3].

As the action of deceleration of a vehicle is in process, the pistons are moved toward to the pads by the hydraulic system. Hydraulic pressure forces the pistons move toward the pads in both sides against the disc, which creates a braking torque. Pistons and pads are held in caliper.

There are two types of caliper used in braking system. First one is fixed calliper, that has two or more pistons acting equaally to both sides of disc. Whereas floating calliper has only on piston acting from one side. Figure 1 represents brake system wirh the fixed calliper.

In a process of braking kinetic energy of the vehicle transition into heat, noise (squeal) and vibration. It is well known that nowadays speed and weight of vehicles are increasing, therefore making it harder for the braking system to be more efficient. With the increase of weight and speed, there will be increase of kinetic energy, which leads to increase heat energy on the brake system. Consequently, causing brake fade and thermally excited vibrations [1].
Another thing that might occur during braking is squeal. Squeal noise has no influence on performance of braking system, but it brings undesirable noise for the customer. There are a lot of research done on eliminating squeal during braking and yet the problem exists. Noise during braking can manifest itself as follows: low frequency noise, low frequency squeal and high frequency squeal. Low frequency noise or friction material exaltation can be described as grunt, groan, grind and moan, which occur between 100 and 1000 Hz. Low frequency squeal is prone to occur at frequency higher than 1000 Hz and high frequency squeal is about to appear after passing the value of 5000 Hz [4].

2. Literature review

Denimal E. al. [5] investigated multiple contact conditions in brake system using finite element method. He outlined in his research that squeal propensity is directly dependent on contact conditions. Also mentioned the necessity of taking into account all contact that might be in the braking system. For instance, not just contact between pad’s lining and disc surface, but contact between pistons and backplates of the pads if these models are involved in the analysis.

Tirovic and Day [6] did investigation with various parameters to see the influence on the pressure distribution. They used variations of friction material compressibility, coefficient of friction and disc stiffness on the interface pressure distribution. The end data showed that coefficient of friction has vast influence on pressure distribution. Squeal occur when leading edge gains contact pressure. It was found that by increasing coefficient of friction trailing edge would lose its contact, while leading edge will gain. Therefore braking system will prone to squeal.

Abu Bakar [7] also used Finite element method as Terovic and Day. The final results that were gathered by him were validated using experimental results. He used real topology of surfaces of pads and disc during performing contact analysis. Results illustrated unclear results making the problem more complex. Squeal was predicted to occur and disappear during wear progression.

To understand pressure distribution on surface of pads non-linear analysis was done by Ibrahim A. He varied hydraulic pressure from 20 to 80 Bar and used 0.42 constant value of coefficient of friction. Results of the research showed that pressure was distributed on longitudinal centreline of surface of the pad for both leading and trailing edge. It was also noted that with the smaller value of hydraulic pressure applied to the pads there will be less contact between lining of the pad and surface of rotor. With applied 20 Bar of pressure contact between lining and disc was 30% and 90% when applied pressure was 80 Bar. For trailing edge contact was 6 % lesser than for leading edge.

Nouby M. used Abaqus to look into squeal propensity. During his research, he varied values of Young’s modules, coefficient of friction and used different cuts on pads surface. He found out that coefficient of friction increase would lead to growth of friction force. Higher friction force will effect on excitation of unstable modes, which effects on standard deviation. It is known that greater standard deviation leads to squeal occurrence [8].
3. Results
Analysis was carried out using Ansys. 3D models of disc, pad and pistons were built in Solidworks, and then analyzed through Ansys. Following results are gathered by changing coefficient of friction with a constant hydraulic pressure. Three different values 0.1, 0.4 and 0.6 of friction coefficient were used to understand its influence on tendency of contact pressure distribution on pad’s lining. To do dynamic pressure distribution a small rotation was added to the disc. Figures 2 and 3 represents results of pressure distribution with coefficient friction of 0.1 and 0.6 respectively. It is notable that pressure distribution with value of 0.1 tent to act at the center of the pads figure 2. As the friction coefficient is increased tendency is toward leading edge (figure 3). Figure 3 represents all three different analysis using different coefficient of friction for dynamic pressure distribution.

**Figure 2.** Pressure distribution with 0.1 value of coefficient of friction.

**Figure 3.** Pressure distribution with 0.6 value of coefficient of friction.

**Figure 4.** Pressure distribution of variations of coefficient of friction.

Analysis of varying coefficient of friction was carried out to depict dynamic pressure distribution on pad’s surface. It is clear that coefficient values have influence on dynamic pressure distribution. By
looking at figures 2, 3 and 4 one can see that contact shifts from left to right or from trailing edge to leading edge by increase of coefficient of friction. Using value of 0.1 for coefficient of friction the pressure distribution tends to act at the centre of the surface of the pad. However, by increasing it to 0.4 and farther dynamic pressure distribution shifts toward leading edge. By increasing coefficient of friction from 0.1 to 0.4 leading edge will get 50% more contact, while trailing edge will lose 53 % of its contact. Farther increase from 0.4 to 0.6 leading edge will gain another 43% of contact while trailing edge will loose it. Tirovic and Day in their research outlined that increase of coefficient of friction would lead to shift pressure distribution from trailing edge to leading edge. Similarly, Nouby demonstrated that increase of coefficient friction will increase friction force and thus squeal will occur.

4. Conclusion
To conclude analysis performed by Ansys on pressure distribution during normal braking showed good results. For example tendency of pressure distribution was found to depend on magnitude of coefficient of friction, which was also proved by other researchers. In addition, it also was found, as in this research, by other researchers, that increase of friction coefficient will shift of pressure distribution on surface of pad from trailing edge toward leading edge.

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