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Deformation Analysis of the High Speed Train Friction Block with Heptagon Shape Using Finite Element Method

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***Abstract* - The design of high-speed rail, which prioritizes energy economy, comfort, safety, and speed, revitalizes conventional train transit. The high-speed era of railroad transportation has begun. A crucial part that helps to slow down or stop the train is the brake. The friction that develops when the brake lining and disk come into contact is the fundamental mechanism of the brake. The purpose of this study is to use the finite element method to calculate the total deformation and equivalent stress that occur in the friction block of a fast train. There are two key instruments in this study that are used to conduct the research. The primary tool for conducting this research is the program, which comes in first. The computer hardware, which powers the software, comes in second. A heptagonal-shaped friction block was positioned at different angles: 0°, 15°, 30°, and 45°. The leading edge near the friction block has wear, according to the simulation data. For the 0o angle, the total deformation is 0.00046 mm, for the 15° angle, 0.00035 mm, for the 30° angle, 0.00040 mm and for the 45° angle, 0.00036 mm.**

Keywords: Brake, High-Speed Train, Total Deformation.

I. INTRODUCTION

Rail is a suitable option for many long-distance travelers worldwide [1]. High-speed trains can reach up to 200–220 km/h on current systems and tracks [2]. Furthermore, in order to maintain the efficacy of public transit, high-speed trains with reliable braking systems must be built in response to the growing popularity of these systems and their accelerating speeds.

In general, a brake system is defined as one that slows or stops rotation. By applying two pieces of metal to a rotating object, the braking system's basic principle transforms kinetic energy into heat and slows down rotation, which causes the vehicle to either stop or slow down [3]. Modern cars employ disc brakes as their braking system. These brakes operate by clamping a disc that is fixed to the wheel of the vehicle. A caliper powered by a piston is used to clamp the disc, and it is onto which the brake pad or brake shoe is pushed [4]. Disc brakes are one of the most crucial parts to maintain traffic safety, especially as the last line of defense in the event that other systems fail [5]. The braking system is the fundamental assurance of the safe and dependable operation of high-speed trains. Brake material wear properties are influenced by the surroundings and friction materials that have similar properties, in addition to the material's inherent characteristics [6].

A brake pad is often made up of many friction blocks. Thus, the distribution, form, and structure of friction blocks will influence the dynamic properties and tribological behavior amongst brakes [7]. For instance, the majority of the friction blocks used in China Railway High-speed (CRH) brake pads are polygonal, including triangles, pentagons, hexagons, and so forth [6]. The resulting somewhat complex contact behavior between the brake pads and disc leads to significant variations in the brake system squeaks of high-speed trains. As such, studies conducted on vehicle braking systems might not be relevant to high-speed rail brake systems [7].

Incompatible brake interfaces can result in complex interfacial tribological behavior and exceptionally high frequencies and high intensities of friction-induced vibration and noise (FIVN), which adds a great deal of uncertainty to the comfort and safety of high-speed train brakes. Specifically, the friction block's installation direction is typically determined by the designer's experience. Nevertheless, varying installation directions can result in tribological issues and underappreciated brake interface dynamics, which will negatively impact the brake pads' uneven wear, squealing, and safety. To enhance the brake system of high-speed trains, it is crucial to look into how the mounting direction of friction blocks affects the tribology and dynamics of the brake contact [8].

When a material is subjected to force, deformation takes place. The material absorbs energy when it deforms because of the force that is applied throughout the process. Elastic

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deformation and plastic deformation are the two types of deformation. Elastic deformation is defined as deformation brought on by a load such that the material returns to its initial size upon removal of the load. On the other hand, if the stress is removed, plastic deformation is permanent [9]. It is not possible to add loads to materials that have reached their maximum strength since in this state, the material has completely deformed. The object will break at the fracture strength if the load is maintained because strain hardening, a phenomenon where the material appears to strengthen, causes the strain to grow [10].

The distribution of deformations that happen in the braking system of a fast train with a heptagon-shaped friction block and a variation in the friction block's installation angle are simulated in this study.

II. MATERIAL AND RESEARCH METHODS

The method carried out in this study is to simulate the design of the brake system consisting of brake disc, friction block, shaft and holder to find the maximum value of deformation caused by a pressure of 0.12 MPa. The independent variable is the installation angle of the heptagonal shape friction block. The material used for brake disc is structural steel and friction block is cast iron with the following properties: Table 1.Material Properties.

Table 1: Material Properties

Structural Steel	
Density	7,85 x 10^{-6} kg/mm^3
Young's Modulus	2 x 10^5 MPa
Poisson's Ratio	0,3
Bulk Modulus	1,6 x 10^5 MPa
Shear Modulus	76923 MPa
Compressive Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Tensile Yield Strength	150 MPa
Cast Iron	
Density	7,13 x 10^{-6} kg/mm^3
Young's Modulus	1,71 x 10^5 MPa
Poisson's Ratio	0,275
Bulk Modulus	1,2667 x 10^5 MPa
Shear Modulus	67059 MPa
Tensile Ultimate Strength	548 MPa
Tensile Yield Strength	344 MPa

In this study, the braking system is simplified to brake disc and friction block to simplify the simulation. Other parts are raplace with appropriate constraints. Deformation distribution simulation was carried out using ANSYS 2020 R1 software. The following presents the brake disc system model used.

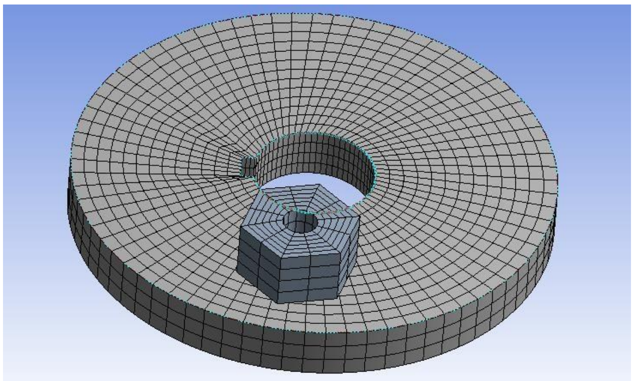

Figure 1: Modeling with ANSYS 2020 R1

Before analyzing the structure in ANSYS, material data is entered in the engineering data column. Then continued by entering research parameter data in the form of brake disc angular velocity ω = 200 r/min, brake disc pressure P = 0.12 MPa, friction radius R = 45 mm.

III. RESULTS AND DISCUSSIONS

The results obtained after analyzing the deformation of the braking system show the distribution of deformation that occurs due to pressure on the friction block. The red color shows the highest deformation value.

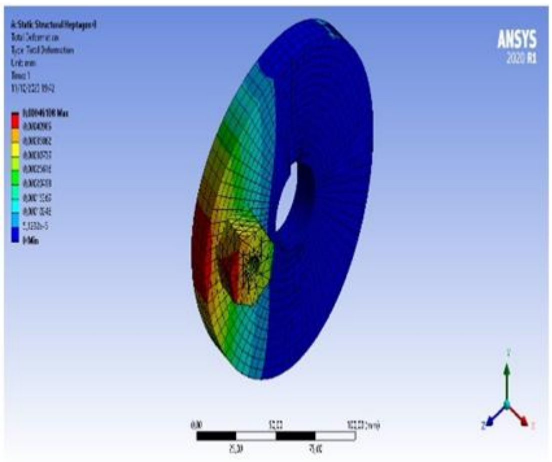

Figure 2: Heptagon Deformation 0^o

In the analysis of the deformation of the friction block heptagon shape using a variation of the installation angle of 0^o, 15^o, 30^o and 45^o. The maximum deformation value produced by the 0^o angle is 0.00046 mm, the 15^o angle is 0.00035 mm, the 30^o angle is 0.00040 mm and the 45^o angle is 0.00036 mm and the minimum value is 0 mm with the highest deformation point at the left end of the brake disc and friction block viewed from the front direction. Deformation values at other points are shown by the legend on the left side of the model.

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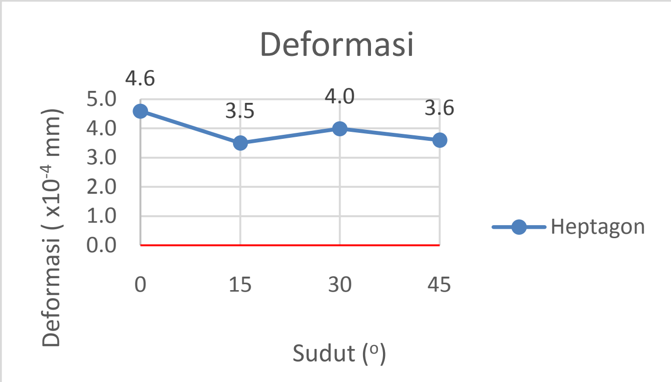

Figure 3: Heptagon Deformation 0°

Based on the results obtained, it can be seen that the installation angle variation of 0° has the largest deformation value compared to other installation angle variations. While the smallest deformation value is produced by the 15° mounting angle variation. While the 30° and 45° mounting variations have values between the two variations. This shows that there is a significant effect caused by the installation angle of the friction block.

IV. CONCLUSION

The deformation analysis results show that the largest deformation distribution occurs at the end of the brake disc caused by the friction block pressure. From the results of the analysis that has been carried out, different shapes and angles of friction block installation can affect the results of the value of deformation. The largest deformation value is shown by the friction block with a heptagon shape of 0° installation angle and the smallest deformation value is shown by the friction block heptagon shape of 15° installation angle.

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