

Vibration Analysis of Hexagon Shaped Friction Block for High Speed Train Braking System

¹Achmad Widodo, ^{2*}Toni Prahasto, ³Ojo Kurdi, ⁴Ian Yulianti, ⁵Dhenada Dhyo Suganda

^{1,2,3,5}Mechanical Engineering Department, Diponegoro University, Semarang, Indonesia

⁴Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia

*Corresponding Author E-mail: toniprahasto@lecturer.undip.ac.id

Abstract - The purpose of this study is to analyze the vibration characteristics of fire speed spikes of vibrating trains using the element method (FEMS). Vibration of friction blocks is an important factor affecting the safety comfort and service life of brake trains. It is very important to understand the vibration of the model and the dynamic response of the friction mass. Methods used to design effective braking systems that prevent structural damage and improve the passenger experience. FEM is used to build model shapes of hexagonal friction blocks and simulate the dynamic response to load braking. The hexagonal shape was included in the simulation to analyze bullet train variables such as fire pressure brake properties material friction properties with blocks and their effect on vibrations. The resulting simulations provide insight into the main natural frequencies of mode oscillation and the relative displacements of the different component friction masses. The main findings of the study address a deeper understanding of the characteristic vibrations of hemispherical friction masses and the factors that influence them. The present invention is a brake system with a potential control design that attenuates excessive vibration increases occupant comfort and reduces the risk of brake failure.

Keywords: Finite element method, Friction brake, Vibration.

I. INTRODUCTION

The moving fast train has great safety and no brake noise. The main material from which the brake discs are made has a significant effect on the noise level of the braking system [18]. The wear characteristics of brake materials are related not only to the material properties but also to the environment and contact materials with suitable properties [1]. It is certainly impossible for the train traffic process to be free from the possibility of problems both in the field and on the train track. Of course, this is an emergency for train traffic. Basically trains cannot brake suddenly because trains need a relatively long distance to be able to brake effectively so that trains being late in braking during emergency conditions can have

the potential for accidents, in general braking for fast trains will cause pollution sound or what is called FIVN (friction induced vibration and noise) [9].

Braking of high-speed trains is achieved mainly through friction between the pad and the disc which consumes a large amount of kinetic energy [3]. To ensure safe movement of the train it is necessary to ensure that the train can stop within a certain distance [2]s. In the friction braking mode of high-speed trains high-frequency and high-intensity FIVNs usually appear in the braking interface [4]

Over the years friction-induced vibration (FIVN) has led many researchers to further study vibration particularly car brake-squeal clutch-squeal and even train brakes. However due to the complex and complicated nature of FIVN this study attempts to propose a new mechanism for braking system called High Speed Train (HST) or High Speed Train. Because the effect of FIVN on high-speed train braking systems is as follows: it rapidly reduces the accuracy of the trains braking system deteriorates the surface degrades the quality of the braking system and creates noise pollution [11].

Over the years friction-induced vibration (FIVN) has attracted many researchers to further research on vibration particularly car brake squeal and braking training. However due to complex and complicated nature of FIVN this research tries to propose a new mechanism for braking system in HST (high speed train) as the effect of FIVN in high speed train system is to reduce accuracy. A high-speed train destroys the broken system and surface and reduces the quality of the broken system and creates noise pollution [5].

Vibration is a back and forth (reciprocating) vibration, bouncing up and down or back and forth. This movement occurs regularly from objects or media in alternating directions from their position. This can affect all or part of the body [6].

To be able to observe the vibration phenomenon that occurs in train brake blocks, it is necessary to first understand the forces that cause vibrations in the brake block. Shows a

diagram of the friction force that occurs between the train wheels and the brake block. The reaction force given by the wheels to the brake block will produce vibrations in the brake block. The magnitude of this friction force is influenced by the contact surface between the wheel and the brake block as well as the friction coefficient of the brake blocks [12].

Braking of high-speed trains is mainly carried out by friction between the brake pad and friction block, which requires large amounts of kinetic energy. Trains must be able to stop within a specified distance to ensure safe train operation [8]. In the friction brake pattern of high-speed trains, high-frequency and high-intensity FIVN usually occurs on the brake surface. This phenomenon has become very prominent along with the rapid development of operating speeds and the increase in the operating period and distance of high-speed trains [15].

II. METHOD

2.1 Research

The method used in this study involves the design of a brake system consisting of a friction block brake disc shaft and support to find the maximum value of the deformation caused by compression of 012 MPa (equal to the braking force $F = 190 \text{ N}$). The parameters calculated in the simulation are the changing deformation during braking the strain caused by the brake and the vibrations carried [16]. The material used for the brake disc is structural steel and the friction block is carbon steel and has the following characteristics:

Table 1: Material Characteristics

Structural Steel	
Density	$7,85 \times 10^{-6} \text{ kg/mm}^3$
Young's Modulus	$2 \times 10^5 \text{ MPa}$
Poisson's Ratio	0,3
Bulk Modulus	$1,6 \times 10^5 \text{ MPa}$
Shear Modulus	76923 MPa
Compressive Yield Strength	250 MPa
Tensile Ultimate Strength	460 MPa
Tensile Yield Strength	150 MPa
Carbon Steel AISI 1015	
Density	$7,85 \times 10^{-6} \text{ kg/mm}^3$
Tensile Ultimate Strength	422,60 MPa
Tensile Yield Strength	326,30 MPa

The finite element method (FEM) is a numerical method for solving problems that can be described by partial differential equations or formulated as function minimization [2]. The region of interest is represented as a set of finite elements. The approximation of a function in a finite element

is determined based on the node values of the physical field being sought. Continuous physics problems are transformed into discretized finite element problems with unknown node values. Linear problems require solving a system of linear algebraic equations. The values in the finite elements can be recovered using the nodal values.

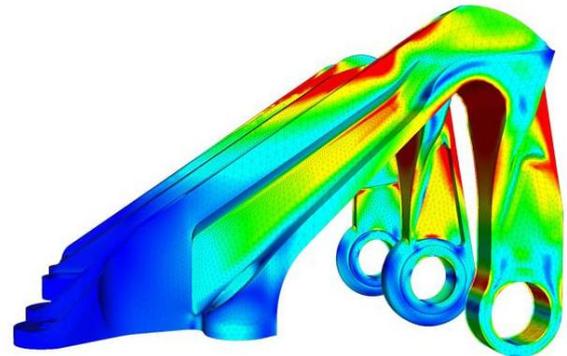


Figure 1: 9 Finite Element Analysis

An alternative method is to divide the case into small, simple parts, where in these small parts we can build a simpler mathematical model. Then the interactions between these small parts are determined based on the physical phenomena resolved. This method is known as the finite element method, because we divide the problem into a certain number of elements (finite) to represent problems that actually have an infinite number of elements (continuum). Finite element analysis (FEA) is a method or numerical technique for solving differential and integral equations. Differential equation solving methods are based on simplifying complex and numerous differential equations into ordinary differential equations and solving them by numerical integration using Euler's or Runge-Kutta methods.

In FEA, objects in the form of areas (2D) or volumes (3D) are divided into smaller elements and then into existing equations (such as differential equations). These calculations are performed iteratively (iteratively) to ensure (within tolerance) accurate results. Performing this calculation manually is difficult and time-consuming, but using a computer makes it easier and faster [17]. With the rapid development of computers, a variety of FEA software has emerged to assist in the design of components and systems. Mechanical components in the form of simple rods or blocks can be analyzed using basic mechanics techniques. However, in practice, mechanical components are rarely simple and require more complex numerical methods. For this reason, the finite element method was developed. Finite element method is a numerical method for solving technical and mathematical problems from physical phenomena.

FFT analysis is one of the most widely used techniques for signal analysis in various application areas [10]. FFT transforms a signal from the time domain to the frequency domain. FFT is an abbreviation for Fast Fourier Transform. FFT analysis allows you to examine a variety of signal characteristics more comprehensively than examining time-domain data. In the frequency domain, signal characteristics are described by independent frequency components, whereas in the time domain, they are described by a single waveform that contains the sum of all characteristics.

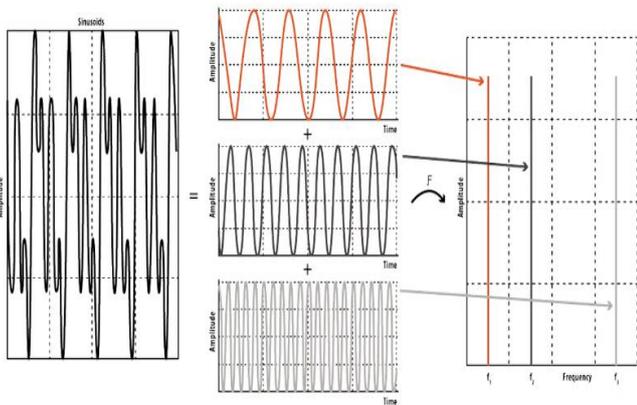


Figure 2: FFT Analysis

2.2 Modeling

Meshing is the process of dividing a domain into several cells. In general, mesh is divided into 2, namely mesh with a structured grid and mesh with an unstructured grid. In this research, meshing with a value of 3.7 mm was used for each element. Meshing is the process of dividing the components to be analyzed into small or discrete elements [14].

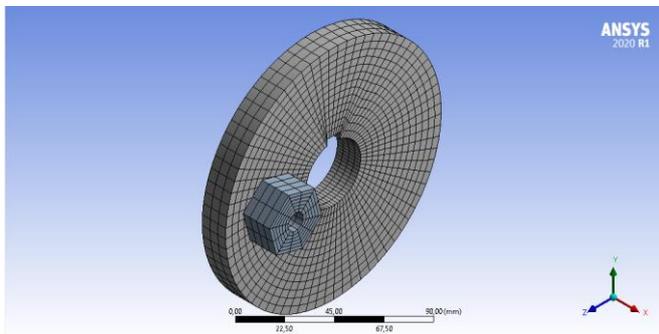


Figure 3: Meshing

Meshing is the division of a domain into multiple cells [13]. Generally, meshes are divided into two regions: meshes with structured grids and meshes with unstructured grids. In this study, a mesh with a value of 3.7 mm was used for each element. Meshing is the process of dividing the component to

be analyzed into smaller or individual elements. As the quality of the network increases, so does the level of convergence. In general, cell shapes for network processes can be divided into two types: two-dimensional and three-dimensional. Here are the specifications when using the network.

Table 2: Meshing Specifications

Bounding Box Diagonal	197,77 mm
Average Surface Area	2486,8 mm ²
Minimum Edge Length	3,7633 mm
Transition Ratio	0,272
Maximum Layers	5
Growth Rate	1,2
Nodes	20980
Elements	4632

The contact between the brake disc and the friction pad is represented by a friction coefficient of 0.2, which corresponds to the friction coefficient of a train braking system.

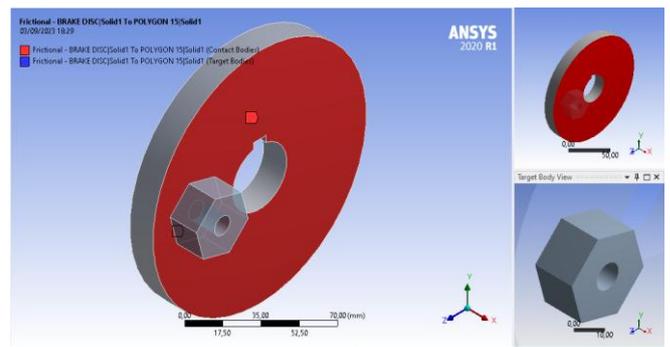


Figure 4: Contact Body

A joint is a component consisting of two hinge joints that are interconnected and allow angular movement between shafts that are not parallel[7]. The joint in this study is located right in the middle of the brake disc and connects the brake disc with the rotation of the train wheels. In this case, the brake disc rotates with an angular speed of 200 rad/min.

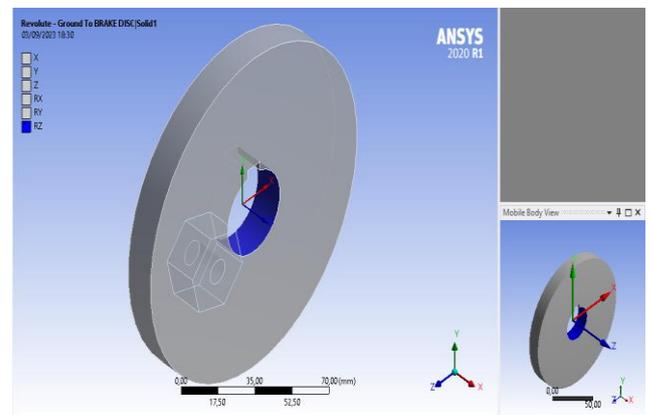


Figure 5: Joint

III. RESULTS AND DISCUSSIONS

In order to simplify the simulation process the model is simplified into two parts: brake disc and friction block. The rest of the model is represented by input parameters and modified contact areas. The braking system is defined as a brake disc rotating at an angular velocity of 200 rpm followed by the application of a friction mass of 012 MPa designed to stop the rotation of the brake disc. The difference in friction block installation is shown in the figure below.

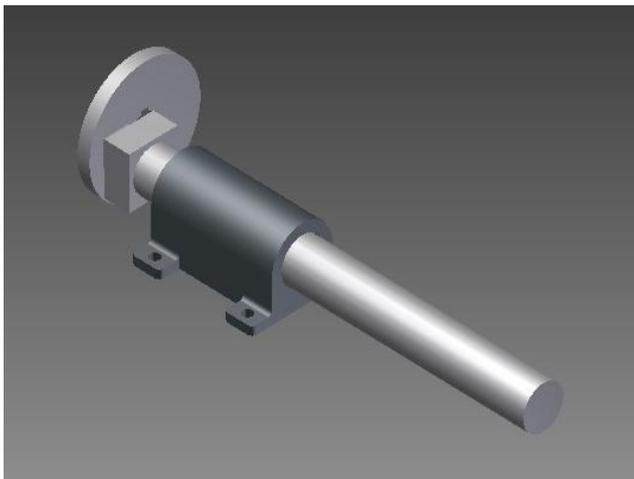


Figure 6: Brake system on high speed train

The results of modal analysis research for a brake system with a hexagon-shaped friction block that has been carried out are presented as follows. Figure 3 shows the distribution of deformation that occurs due to vibrations produced by the braking process. In other words, the distribution of deformation occurs due to pure vibration and not due to the pressure applied because at this stage, no input parameter in the form of pressure on the friction block has been given. The maximum value of the resulting frequency is 5359.8.

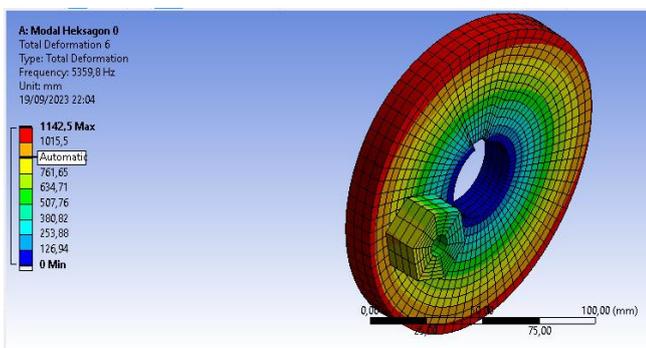


Figure 7: Deformation due to vibration in the hexagon friction block

Harmonic response analysis is a type of dynamic analysis used to evaluate the behavior of a structure or system subjected to cyclic or cyclic loading. This type of analysis is

widely used in computer-aided engineering (CAE) to design and optimize products exposed to vibration such as the brake system model in this study.

At this stage the model input parameters such as friction and stress are provided in blocks of 012 MPa. The purpose of the results presented is to determine the value of the maximum vibration amplitude at a given frequency that the model can withstand. The results of the study of the harmonic response of the fast train braking system are presented and analyzed below.

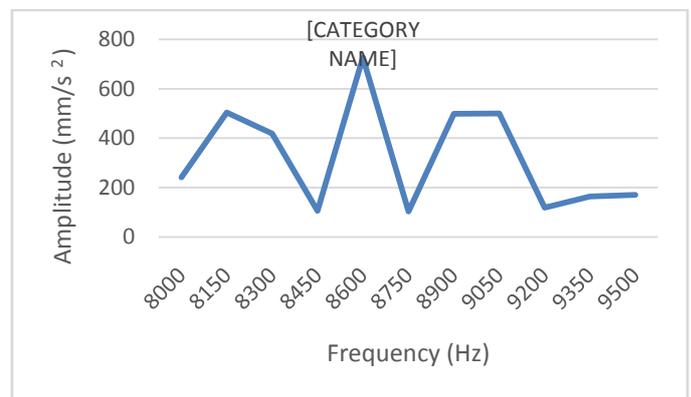


Figure 8: FFT Analysis on Hexagon Friction block

Based on an analysis of the harmonic response that has been carried out on a friction block model with a mounting angle of 0°. The maximum amplitude value is 726 mm/s² at a frequency of 8600 Hz. Then the minimum amplitude value is 103 mm/s² at a frequency of 8750 Hz.

IV. CONCLUSION

In order to ensure that the brake interface provides good contact characteristics and friction behavior the influence of the friction block installation direction and FIVN characteristics on the friction behavior must be comprehensively considered when designing the brake pad and the subsequent brake interface is ensured. Familiar FIVN features.

To find out real results, it is recommended that research be carried out experimentally with exactly the same parameters with the aim of validating the results of the research that has been carried out. Friction block model to enrich research data regarding brake systems on high-speed trains. Further research is needed regarding brake systems with different models in order to find the most effective form of brake system.

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