Review on Braking system in Railways

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Abstract - *Railways play a major role in the transportation of huge masses of people and goods from one place to another. The safety of the people and goods were assured by the vital part of the dynamic vehicles called "The braking system". This paper deals with the history and evolution of the braking system in Railways. The types of brakes and their working principles were clearly explained in this paper. The application of the different braking systems in different railways based on their purpose is explained here. The advantages of each braking system over the other and their drawbacks are discussed. The importance of choosing the best material for the braking system in order to reduce their noise and increase their performance is explained. This paper gives a clear understanding of the evolution of the braking system in railways and important factors to be considered in order to increase the life and performance of the braking system*

Key Words: **Braking System, Railways, Performance, Materials, Heat, Types of brakes.**

1.INTRODUCTION

Transportation is one of the most critical fields for eradicating shortages and achieving long-term development. However, brake malfunction is the cause of many railway transportation problems. The brakes on railway train coaches are used to enable deceleration, monitor acceleration (downhill), and keep them standing when parked. While the basic concept is similar to that of road vehicles, the use and operating features are more complex due to the need to manage multiple connected carriages and to be successful on vehicles that are not equipped with a prime mover. This complexity stems from the occurrence of several events in various mechanical, electrical, thermal, pneumatic, and other systems. When you're braking Pressure, surface area in touch, amount of heat generation, and braking material used are all important factors in the control of any braking device in any vehicle.

As a result, improving the design of a brake system is a major practical problem. However, the higher thermal loads caused by high heavy loads limit this system's braking efficiency. Many different braking systems have been built over time for a variety of reasons, including vehicle construction, design, and operation, vehicle speed, axle load and form, vehicle structure and technical features, traffic situations, and so on. Manufacturers and researchers monitor higher performance brake pads on complete vehicle roads during the production process. Under different loadings, sliding speeds, temperatures, and pressures, laboratory scales were used.

Due to a combination of parameters such as weight, braking time, wear, and resistance to high temperatures, brake system components are made from a variety of materials in existing brake systems. In this regard, disc braking systems used in the adhesion efficient braking category on very high-speed trains should be treated differently. This research presents extensive information on railway vehicle brake systems, braking mechanics in brake system design, brake disc-pad materials, and studies on the selection of these materials.

2. Reviews on Retardation system used in Railways

Yonghua Zhu et al.,(2014) discussed the comparison of the brake force results created by an aerodynamic stopping of high-speed train without wing, one with curved wing, and one with straight wing It has been found that at high speeds, the braking force of the two wing versions is larger than the one without a braking wing[1].

Vaibhav Kamble et al., provided an experimental study of the factors that determine if a brake shoe made of COMPO 04 which is superior to the current material COMPO 03 in all aspects of a successful braking system. The paper also addresses the braking mechanism used in Indian railways, working and comparison of vacuum braking and air braking system [2].

Gligorche Vrtanoski et al., (2019) demonstrated an innovative railway braking mechanism for cargo trains is being put through its paces in a dynamic test. The primary role of brake systems is to decelerate and stop railway rolling stock. Since brake systems are subjected to significant static and dynamic loads in harsh environments, extensive testing is needed. Hence a dynamic testing of the upgraded braking system IBB 10 for goods trains was demonstrated[3].

B.Subramanian et al., converted the existing manual braking system to automatic braking system. Current hand brakes only have an indicating mechanism and are operated manually. An indicator light is used to ensure that the brake is applied or not. However, if there is some electrical fluctuation, the result shown by the indicator light will not be the same as the required result [4].

Anbalagan . R et al.,(2013) designed , fabricated and analyzed the braking system using vacuum. Based on the findings, it is preferable to replace the manually controlled directional control valve with a solenoid-operated directional control valve, which will minimize driver effort and also act as a brake pedal switch [5].

Paolo Presciani et al., created the mathematical model by using parameters such as braked weight percentage, goods/passenger brake location, and train length. The implementation of a braking model capable of describing the braking performances of passenger and freight trains with adequate precision and proper safety margins was necessary for the development of the new speed control system SCMT for the Italian railways [6].

Rohit Sharma et al., (2012) provides the RF frequencies kit for the trains moving in either direction. When two trains approach each other on the same track, the automatic braking system mounted will stop both trains. The drum brake is equipped with a brake shoe that is used to bring the vehicle to a halt. This essentially determines the project's key source, which is Automatic Braking [7].

Dongsoo Har (2015), has developed a system using IOT sensor data transmission and receiving. The author's main motto is passenger safety on high-speed trains, as high-speed trains have various forms of braking systems such as friction, ECB, and regenerative brakes, all of which have different types of spoilers. As a result, different types of braking depend on spoiler design. As a result, data from IoT sensors must provide essential information. As a result, the IoT sensor network should be adaptable to a variety of circumstances. Adapting to a variety of conditions necessitates the efficient operation of an IoT sensor network, regardless of the situation[8].

Don Bum Choi et al., (2020) explained how to predict and validate the the performance of a goods train's pneumatic preventive braking system that is commonly used in Korea. The author proposes that longitudinal train dynamic simulations could be used to replace costly and time-consuming train running experiments[9].

Ravi Gupta et al., (2017) explained the principle and use of the Vacuum Braking System in Railways . Experimental results of design parameters of spring used in the device were discussed. The vacuum braking mechanism is still used in the specification and updated system in this paper, which means that if there is a loss of vacuum, the brake will be applied due to spring force.[10].

Mustafa Günay et al., (2020) analysed the different forms of railway braking systems. Adhesion based and adhesion independent braking systems are the two major categories of braking systems. The paper discussed tread, disc, and combined disc brakes under adhesion dependent, as well as dynamic (electro, aero, and hydro) brakes. And also described the magnetic track and eddy current under adhesion independent braking. Ultimately, the paper gave overall idea about the different types of brakes and how to use them in different situations.[11]

Marc Ehret (2018) ,analysed about the virtual train brakes for modelling. It discussed about the system requirement ,system specification ,testing hardwares, which all includes data like brake distance ,refill and release of air in brakes. By using all these components for analysis has been developed[12].

Pei Jen Wang (1998), explains about eddy current brakes used in trains travelling at the speed 300 Km/hr. The process of DC Magnetising for stopping the train has been discussed. Analysis with Finite difference method and Fourier series method has been done. And finally compared the results from both methods[13].

Mandeep Singh Walia, described the use of Friction (Tread) brakes. The friction brakes were subjected to thermal and thermomechanical analysis by considering the Heat flux, Amount of load, temperature, wheel rail contact rolling parameter. And FEA simulation has been done[14].

Mr.Kaushik Banerjeeet et al., (2012) ideated to create a safety alarm and emergency braking system for Indian Railways. Two mechanisms of train stopping have been proposed. One of the proposed ways is to apply external magnetic force to pull the valve of the vacuum brake. This can be achieved by placing an electromagnetic bar along with the track just before the signal. Another way is to equip signals with a wave emitter that emits a specific frequency wave that is accepted by the engine with which it corresponds[15].

Jayesh Bodare, S. B (2017), discusses non-uniform braking in various types of trains at various speeds. An overview of the experimental work that was carried out to evaluate the impact of braking energy on the development of fatigue cracks. It is made up of two field trials carried out by Indian railways. i) data on locomotive wheel rim temperatures on a continuous basis ii) a single calculation of all wheels' rim temperatures. The data gathered during the trials is used to identify the causes of irregular braking and to describe the phenomenon. The discs were subjected to experimental loading, and the findings of the thermal cracking tests were addressed[16].

Rakesh Chandmal et al.,(2015) explained about the different types of braking systems used in railways. The drawbacks of vacuum braking, electromagnetic brakes, and mechanical braking have all been addressed. And finally calculation on stopping distance for trains was formulated[17].

Erhan Selçuk et al.,concluded that many metrics, such as durable, maximum strength, heat resistance, minimal cost, and flexibility of maintenance should be in the positive direction, in addition to the good performance of the brake systems. 3D design, analytical and experimental studies, which are one of the engineering design phases, will help refine these processes. The application of the finite element approach to brake disc-pad geometry and material selection, in particular, would aid in cost reduction[18].

Shoban Babu.M et al., (2016) explained about the vacuum brakes used in railways. The brakes were mainly used UK and the countries related to UK.The working principle , working of different parts in vacuum braking system has been discussed. Initially, a vacuum is formed in the piston-containing cylinder, and atmospheric pressure is applied in the vacuum, allowing the piston to be released and braking to be applied to rolling wheels[19].

Marko Reibenschuhet al., (2009) have done thermal and stress analysis of disc used in railways using FEA.On a flat surface and downhill, various loading applications have been used. Centrifugal and mixed loads were used in the experiment. Finally, it was discovered that when braking on a downhill slope, the tension is greater. To boost braking, different materials must be used for different load applications and train speeds. The modification must be made to the brake's radii[20].

Klaus Ebeling(2005) explains about the origin of railways and its development in Germany. He also discussed the evolution of speed of trains from 30km/hr to 160km/hr. He also detailed the conditions of the German Railways after world war 2 and how the German railways rehabilitated from that worst condition. The magnetic levitation system in Railway was discussed by him and the alternative to steel wheels on Rails was also discussed.[21].

Cavell, B G(1976) explains about the brakes used for stationary position: (1) hand-operated mechanical brakes, (2) spring-operated brakes, (3) "park-lock brakes", (4) hydraulic brakes. A rapid system of releasing stationary brakes is described. The space for the installation of braking systems in railways is too little. He described a new range of braking units for railways. Each brake having non depending limits were introduced for brakes like disc brakes[22].

T. SUZUKI(1982) states that the Reversible DC power-supply systems with thyristor inverters are described. Design principles applicable to and technical difficulties encountered by the reversible DC power-supply system are discussed. To give an example of application, the power-supply system of Kobe Metro is described in detail, together with principal designs, solutions adopted to overcome the technical difficulties and some operational results. Some more examples of application in Japan are referred to as further experiences of the system[23].

Satoru Sone(1994) explains about the evolution of high speed railways in the world. He also speaks about the problems in high speed trains and inferred solution for it.It has been found that the series 100 trailer has a special feature of eddy current brakes, which is used to run by motor current which in turn reduces the maintenance cost[24].

Laplaiche M(1976) the various types of brakes used for various applications are clearly explained. and the brake characteristics that affect the limits of use as a function of speed, mass per axle, deceleration required, energy consumption for operation, ease and accuracy of adjustment[25].

Ehlers, H R(1976) This paper discusses the advancements in synthetic materials for the manufacture of brake linings. Evaluation methods for brake systems are developed further. And also the advantages of combination of disc brake and shoe brake . He also discusses other brake combinations and their applications[26].

H P Roberts(1966) speaks about the ratio of air brake to vacuum brake during the 1st world war. He explains why the vacuum brakes were adopted during that time. (due to low cost,manufacturing, no patent)[27].

Izumi Hasegawa et al.,(1999) explains how Japanese brakes work. Braking Mechanisms, Electric Brake Systems, Mechanical Brake Systems, and Braking Command are all examples of braking mechanisms. To ensure the safe operation of rolling stock, government regulations specify braking distances and deceleration rates. Mechanical braking systems use the following basic braking devices. Different types of braking systems, such as electrical and mechanical, have evolved over time[28].

M R K Vakkalagadda et al.,(2015) experimentally inferred that Braking performance was more consistent for cast iron brake blocks than that for composite brake blocks. Further, thermal loads on locomotive wheels were also lower for cast iron brake blocks, particularly with time lag in braking[29].

Michael Herbert Putz et al.,(2012) explains about the VE brakes and its advantages. It is a kind of disc brake which operates in both mechanical and electrical way. The actuation produced by the VE brake is low which is produced by a small motor[30].

V Sai Naga Kishore et al.,(2021) analysed the cad model of brake with ANSYS and inferred that Maximum peak temperature rise of 215 °C is observed on the disc at 290 mm in the radial direction at about 60% of braking time while stop braking from 160 kmph[31].

KP Vineesh et al.,(2016) conclude that Non-uniformity in braking is found to be particularly severe in freight trains as compared to passenger trains. Faulty distributor valves are seen to result in maximum braking effort on wheels that is as high as seven times that of average braking effort in freight trains[32].

J.-J.SinouaA et al.,(2013) inferred that This study comes within the scope of a research program AcouFren that is supported by ADEME (Agence De l'Environnement et de la Maîtrise de l'Energie) concerning the reduction of the squeal noise generated by high power railway disc brakes[33].

S.Panier et al.,(2004) states that Their findings shed new light on the conditions that lead to the appearance of hot spots.

The goal of this research was to better classify and explain the appearance of thermal gradients on the disc's surface. On a full-scale test bench, thermographic measurements with an infrared camera were taken on the rubbing surface of brake discs. A classification of hot spots observed in disc brakes is proposed based on thermography. Theoretical approaches are compared to experimental observations, and a discussion is proposed[34].

B.Tang et al.,(2019) inferred from their experiment that The friction blocks have different geometrical shapes, according to the results. The effect of block shapes on vibration and noise generation and characteristics is evaluated and analysed. The findings show that friction blocks of various geometrical shapes behave differently in dry and wet conditions[35].

Ji-HoonChoilnLee(2004) used FEA to investigate the thermo elastic contact problem on disc brakes. The effects of the disk's rotating speed on thermoelastic behaviours such as temperature distribution and friction surface contact ratio are investigated. In addition, the phenomenon of thermoelastic instability (TEI) is investigated in this study[36].

P Dufrénoy(2004) proposed a macro structural model of the disc brake's thermomechanical behaviour, taking into account the disc-pad couple's true three-dimensional geometry. The disc material is modelled using real body geometry and thermo elasto plastic modelling. The goal of such a model is to predict the thermomechanical response of the components as well as the thermal gradients that change over time. Thermograms and thermocouples are used to compare predictions of temperature distributions to experimental results[37].

Utz von Wagner et al.,(2011) inferred that The self-excited vibrations that cause the squeal occur at low rotational speeds, well below the first critical rotor speed, which has rarely been observed in rotor dynamics, and how disc brake squeal models can be modified to model block brake squeal[38].

A.Shojaei et al.,(2007) concludes that thermal conductivity of the friction material can be influenced by indirect effects including mainly the shape and size of the filler. Fillers with larger size and platelet shape are more effective in enhancing the thermal conductivity of the friction material[39].

PengZhang et al.,(2020) experimented with copper base pad and results shows that compared with commercial copper-based brake pad, self-designed copper-based brake pad exhibits higher mean friction coefficient and smaller fluctuation of friction coefficient under all test conditions[40].

D Weiche et al.,(1995)Experimental results show the distribution and the evolution of the temperatures are calculated and compared to experimental measurements. The method can be used to assess the performance of braking systems and gives valuable indications for braking design[41].

Olivier Chiello et al,.(2013) suggested The squealing noise made by railway disc brakes is a constant source of irritation for passengers, both inside and outside of trains and stations. The development of silent brake components is required, and this necessitates a better understanding and characterisation of the phenomenon[42].

MichelaFaccoli et al,.(2019)A complex damage phenomenon occurs at the railway wheel/brake block interface due to thermo-mechanical loading, according to experiments. Finite Element (FE) simulations were used to estimate the temperature reached in the wheel rim during full-stop breaking. The formation of a discontinuous "third body" layer as material transfers from the shoe to the wheel specimen is critical to the progression of wheel disc damage[43].

Marc Ehret et al,.(2021)formulated A mathematical model is developed to link these influencing variables to the instantaneous acting friction coefficient in order to account for friction forces' characteristic behaviour in the calculation of longitudinal dynamics of railway vehicles, using data collected on a full-scale dynamometer test rig. Data from a full-scale dynamometer test rig is used to identify the model, which is then verified in terms of brake distance estimation[44].

D. F. Ribeiro et al,.(2016)proposed a mathematical model that reproduces the dynamic response of the railway pneumatic brake system during all operations. The behaviour of the fluid (compressed air) and the brake valves set were studied in order to model it, making it possible[45].

Sirichai Dangeam et al,.(2014)Eddy current brakes for a rail vehicle training set are described. The brake uses a three-phase linear induction motor to produce the electromechanical brake force by inducing eddy current on the rail. The results of the prototype eddy current brake demonstrate the brake's performance[46].

Myeong Jang et al,.(2001)explains two types of permanent magnet eddy current brakes The magnetostatic field is calculated using a finite element method. We also use the Galerkin-FEM with linear interpolation function to calculate the braking and attraction force, which may oscillate between adjacent nodes[47].

Robert C. Kull et al,.(2001)describes how Electronically Controlled Pneumatic (ECP) braking technology works by transmitting braking instructions in the form of electronic signals from the main control locomotive to each vehicle[48].

Meng Ling Wu et al,.(2013)Eddy current brake force and temperature rise, two of the most concerning questions about rail eddy current brakes, were studied using theoretical analysis and simulated methods. Theoretical analysis and simulation of brake force were used to prove that it was reasonable[49].

DR.AUNG KO LATT et al,.(2019) Theoretical approach is used to compute the stopping distance, braking time, and braking efficiency for three moving conditions of locomotive behavior of brake blocks[50].

Paul Weston et al,.(2014) proposes a method for increasing total regenerative braking energy (RBE) in a blended braking mode with both electric and mechanical braking forces available by using the Bellman-Ford (BF) algorithm to search for the train braking speed trajectory. In a discretized train-state model, the BF algorithm is used.[51]

C Cruceanu et al,.(2018) focuses on the braking capacity – evaluated by stopping distance – and on the longitudinal dynamic of the train, involving vehicles fitted with either disc brakes in fast-action, or cast iron block brakes in high power action mode. The specific dependence of the correspondent friction engenders particular braking characteristics[52].

A.-L.Cristal-Bulthé et al,.(2007)explains how third-body flows caused by the disc's waviness distortion feed the contact and lead to the formation of flat plates that stabilise the friction coefficient[53].

3. Discussions and Recomendations

The brakes on a railway are used to facilitate deceleration, manage acceleration, and keep them standing while parked. Railway vehicle braking is a complicated mechanism that contributes to traffic safety. There are different kinds of braking used in Railways which depend on different factors. Factors such as heat resistance, durable, minimal cost, maximum strength, and flexibility of maintenance. Depends on these factors the braking system is divided into friction dependent and friction independent. The vacuum brake was less effective than the air brake, taking longer to apply and having large cylinders to produce the same amount of braking force and it can't be applicable to high speed trains. Since electrodynamic braking systems have complicated circuits, they sometimes fail. As a result, they are unable to be used as emergency brakes and it is very much suitable for high-speed trains. The above braking system has been analyzed with mathematical model, IOT data, Finite element method will provide better results in turn reduce the production cost. This process of research reveals a safer mode of transportation in the future.

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