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Improving Depot Efficiency Through Robotic Augmentation Towards the Replacement of Rolling Stock Brake Pads

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Abstract

This paper provides an investigation into the potential benefits that could be realised through the adoption of robotic and automated means for the completion of brake pad replacements to support the enhancement of asset, availability, reliability, worker's health and wellbeing, safety, and depot capability and performance.

Keywords: Railway Operations, Fleet Maintenance, Rolling Stock Maintenance, Robotics Systems, Maintenance Automation.

1 Introduction

The United Kingdom railway industry was previously an innovator and early adopter of modern technologies as reported in projects such as the implications of automation on human intervention of train operation at the London Underground [1] and the development of prototype for Advanced Passenger Train reported in 1982 [2]. However, the industry position at that time did not continue into privatisation of the railway industry. A recent survey conducted in 2019 and 2020 by the railway industry association on unlocking innovation [3], shows over 60% of respondents believe the UK railway sector to be quite innovative with 1% viewing it as a clear innovation leader, which is echoed in the publication by the Williams-Shapps plan for rail in May 2021 [4].

However, the UK railway industry has witnessed a gradual deployment of sensors towards the introduction of modern digital techniques for rolling stock maintenance and the increased use of remote condition monitoring and data analytics. The concept of artificial intelligence, digital twins, and installation of automatic inspection systems [5] are now used to increase capacity, improve reliability and enhance safety [6]. Rolling stock maintenance is progressively moving away from fixed-time and calendar based preventative maintenance schedules towards achieving a dynamic and agile prescriptive based maintenance regime [7]. This transformation has been achieved through remote conditioning monitoring and smart data analytics, and then comparing data against a model of known assets failure modes [8]. Data collection through methods such as the use of internal system reporting, placement of monitoring equipment on-board the rolling stock and equipment placed on the infrastructure can provide a very good insight into equipment failure patterns. Modern equipment is now being introduced which is more autonomous such as the use of drones for remote inspections, and mobile autonomous robots for the conduction of visual inspections in depots [9]. The smart use of data collection techniques, in conjunction with maintenance optimisation has improved the availability and reliability of the rolling stock, allowing more time in service operations, less time lost due to maintenance, and less service impacting failures whilst in revenue service [10]. However, these autonomous systems are primarily focused on monitoring and identification of components to support agile maintenance with very little seen in physical manipulation of components.

This paper presents an investigation into the potential benefits that could be realised through the adoption of robotic tool and automated technology for brake pad replacement.

2 Methods

An overview of the current research progress into the adoption of advanced robotics to automate rolling stock brake pad replacements to support improved rolling stock availability, improved staff utilisation, reduced staff risks from maintenance, and improved depot availability is also presented.

A desktop investigation of past projects and current working arrangement of rolling stock maintenance facilities and wider automation projects is conducted, supported by physical inspections of rolling stock units at depots to capture photographic and video images of the underframe, braking arrangements and task observation. Computer software is used to investigate the potential for the adoption of robotics. This included PTC Creo for the development of the 3D model of the rolling stock underframe and braking arrangement, and the use of RoboDK for selection of potential robotic arms and analysis of their suitability.

3 Results

The braking arrangements of modern rolling stock are a collaboration between the use of non-friction and friction elements, electronically controlled and blended to maximise the braking performance whilst saving the friction elements and returning energy back into the network. The variation seen across rolling stock fleets depends on factors such as operating speed, and operating model. Very High-Speed units require large braking forces requiring multiple callipers and discs to be fitted to multiple axles, compared to metro units which require high acceleration and braking rates at greater frequency but at lower speeds as such have more motorised axles which allows for greater regenerative braking. However, the final physical makeup of friction braking systems are very similar in design, with the braking installation consisting of callipers, discs, and pads. An example arrangement is shown in Figure 1.

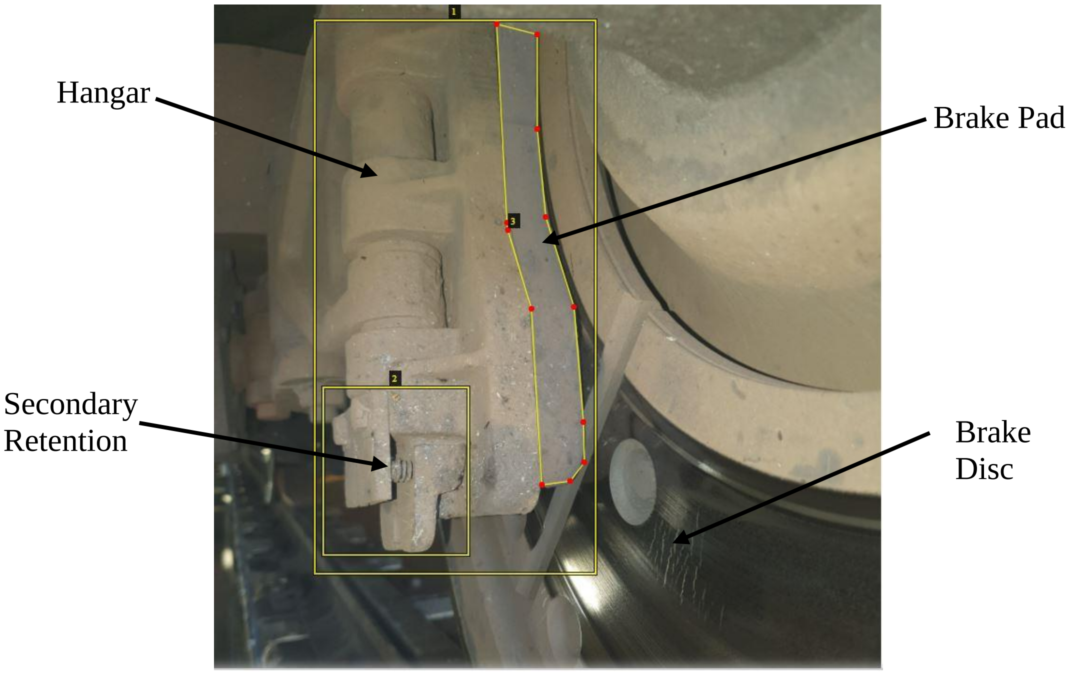

Figure 1: Typical Friction Brake Arrangement

An initial study into the breakdown of the step tasks is shown in Table 1. The tasks indicated as “Robotic System” are repetitive and simplistic, which supports the reasoning for their augmentation with robotic methods.

STEP	TASK DESCRIPTION	SYSTEM
1	Secure Unit	Train System / Driver
2	Release Brake Pressure	Train System / Driver
3	Locate Bogie and Wheelset	Robotic System
4	Identify and grasp brake pad	Robotic System
5	Release Secondary Retention	Robotic System
6	Remove worn Brake Pads	Robotic System
7	Discarded worn pads	Robotic System
8	Collect new pads	Robotic System
9	Locate new Pad on guide runner	Robotic System
10	Insert New Pad	Robotic System
11	Reinstate Secondary Retention	Robotic System
12	Confirm pad fitment	Robotic System
13	Reinstate Brakes	Train System / Driver

Table 1: Review of Steps for Brake Pad Replacement

The robotic system would require a working range that facilitates access to the inside wheel and external wheel face for replacement of both brake pads of a wheel mounted system and working payload suitable for the mounting of a developed end effector tool, camera system and weight of a new brake pad. The end effector tool is required to provide two simulation actions, grasping and manipulation of the pads whilst operating the secondary retention device.

The system would require mounting on a mobile platform to reach the various axles, supported by data supplied by the operator’s maintenance management system. Computer vision from the unit mounted camera will then be used to identify and locate the calliper and pads to be replaced, conduct the replacement, confirm final fitment and security, and collect photographic evidence for maintenance records.

The historical data collected and evidence from physical inspections is used to create the initial model of the brake system focussing on the end effector elements and the surrounding underframe. PTC Creo software is used to develop the 3D model in Figure 2 and RoboDK software is used for modelling the movement of different robotic arms, shown in Figure 3. Manipulation of RoboDK is conducted using its extensive robotic database, and from this it is possible to develop a programme that could potentially allow for the automation of the brake pad replacements.

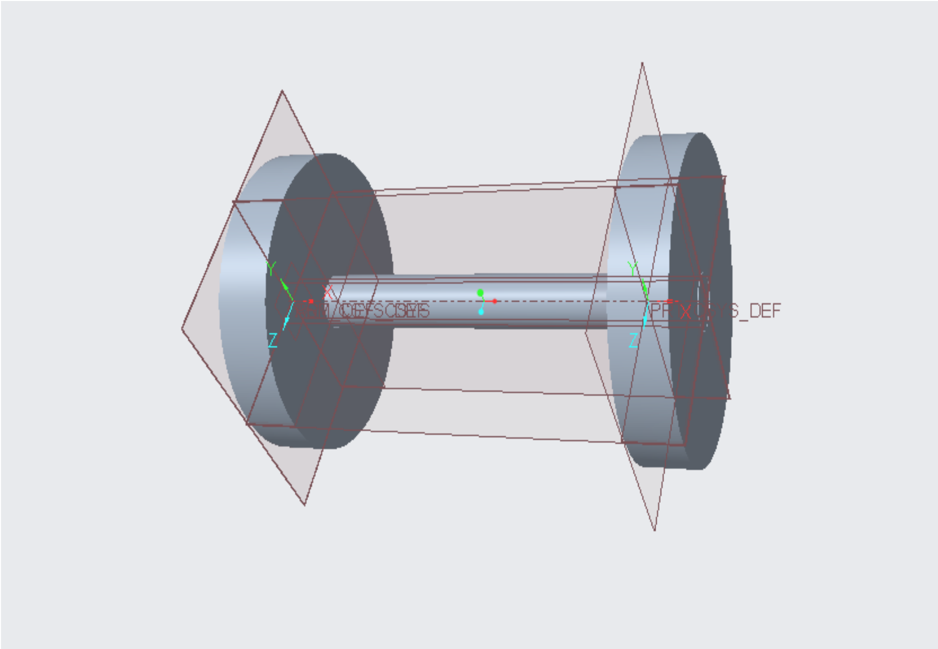

Figure 2: Initial PTC Creo Modelling

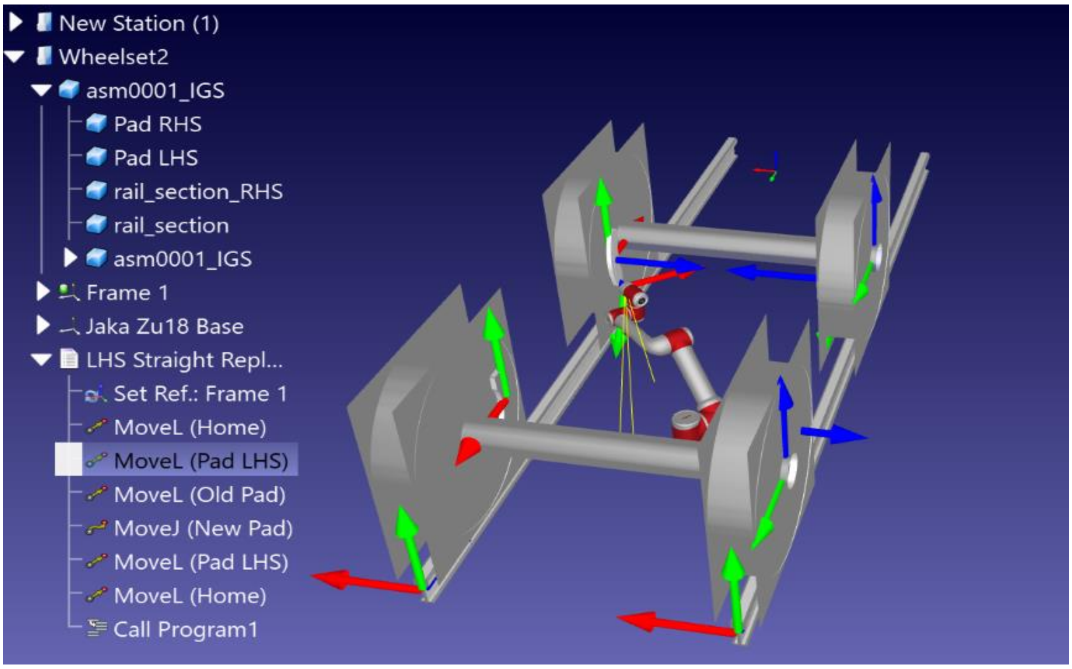

Figure 3 - Initial RoboDK Modelling (camera and final effector tool not shown)

4 Conclusions and Contributions

The potential to augment the replacement of rolling stock brake pads is presented. The movement and reach of the robotic arm is shown in Figure 3, computer software simulation package is used to achieve the movements required for the replacement of brake pads for a single axle. The robotic arm can also be manipulated to the inside and external disc brakes of the single axle and the facing tread for potential brake block replacements. However, an end effector tool and visual processing system must be developed to facilitate the maintenance activity in order to support operation in the smallest footprint possible to reduce infrastructure changes.

The analysis and observation of the brake replacement identified the repetitive and simplistic actions required by a robotic system, but some steps are required to be controlled by external systems including the stopping and securing of the rolling stock and releasing of brake pressure. A better understanding is also required to give an insight on how the brake replacement automation can be combined with other potential automated activities, such as replenishment activities, to reduce costs and complete the activity external to the maintenance sheds, remote stabling locations or at terminal stations.

The length of rolling stock varies across fleets, both their fixed formation length and in coupling formations, however, networks tend to operate a limited selection of rolling stock. To support the flexibility in length the system would have to be mobile to facilitate movement between axles and account for stopping accuracy of the rolling stock. Multiple independent systems may also be required at replacement locations depending on the maximum length of the units being serviced and the servicing time available. Mounting the system on a mobile base would allow it to exit from the underframe location to a position of safety for pad replenishment and maintenance.

To continue the development of the application of robotic systems for brake pad replacements further ongoing work is required into the following areas:

- Computer vision;
- End tool effector;
- Horizontal mover;
- Maintenance and replenishment of robotic system;
- Safety Case.

The main contribution of this paper is to demonstrate the potential to augment rolling stock brake pad replacement with robotic and automated systems to improve rolling stock availability, reduce staff risks from maintenance, and improve depot availability.

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