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Rethinking Rail Track Switches for Fault Tolerance and Enhanced Performance

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Abstract: Railway track switches, commonly referred to as 'turnouts' or 'points', are a necessary element of any rail network. However, they often prove to be performance limiting elements of networks. A novel concept for rail track switching has been developed as part of a UK research project with substantial industrial input. The novel design meets the set of functional requirements for track switching solutions, in addition to offering several features that current designs are unable to, in particular to enable multi-channel actuation and rail locking, and provide a degree of fault tolerance. This paper describes the design and operation of this switching concept, from requirements capture and solution generation through to the construction of the laboratory demonstrator. The novel concept is contrasted with the design and operation of the 'traditional' switch design. Conclusions to the work show that the novel concept meets all functional requirements whilst exceeding the capabilities of existing designs in most non-functional requirement areas.

Keywords: Track Switch; Capacity; Reliability; Multi-channel Redundancy; Fault Tolerance.

1. INTRODUCTION

A novel concept for rail track switching has been developed as part of a UK research project with substantial industrial input. The concept is currently at the demonstrator phase, with a scale (384mm) gauge unit currently operational in a laboratory - as depicted in Figure 1, and two published patents by Bemment et al. (2015a, b) The design meets the set of functional requirements for track switching solutions, in addition to enabling multi-channel actuation and rail locking, to provide a degree of fault tolerance.

Track switches ('turnouts' or 'points') are a necessary element of any rail network. Switches enable vehicles to take many different routes through the network. Waterloo station throat, one of the most complex pieces of track work in the UK, is responsible for the safe arrival of just under 108 million passengers per year and features 80 switches within just 500 linear metres of route (Source: ORR Online Data Portal (2013)). Figure 2 shows the simplest junction element - a single turnout arrangement.

Track switches represent single points of failure, and their failures can prevent use of extensive sections of the network. It is for this reason that rail network performance is negatively affected by switch failures to a greater degree than any other asset ORR Online Data Portal (2013).

Morgan (2009) states that existing track switch systems are the result of the evolution of a single design solution dating to early mining railways in the 1700s. The operating parameters of a modern railway system are much changed from those early days. Other elements of rail systems have undergone step changes as disruptive technologies have made an impact. Notable examples are the moves from steam to diesel and electric traction, the widespread adoption of reinforced concrete for viaducts and tunnels, and the move to SSI (Solid State Interlocking). However, apart from small incremental changes, for instance to actuation methods, a modern track switch is of the same design and operation as those early days - despite the requirements having changed significantly.

This paper considers the design and operation of track switches with a view to improving their negative impact upon network performance. Performance, in this instance, is considered as maintainability, system capacity, reliability and cost, though it is accepted other measures could be utilised. Existing systems, their limitations and impact upon performance are considered in under the Existing Systems Section. A requirements capture exercise follows in the Requirements Analysis Section, which sets out the minimum functional set required of a track switching solution. A series of solutions were generated and evaluated leading to the reduction of these options to the most appropriate. The paper then presents more detail on what has been termed 'The Repoint Solution', including its general arrangement, feasibility, and the qualitative benefits and drawbacks. Conclusions to the Repoint study are then presented alongside possible future work

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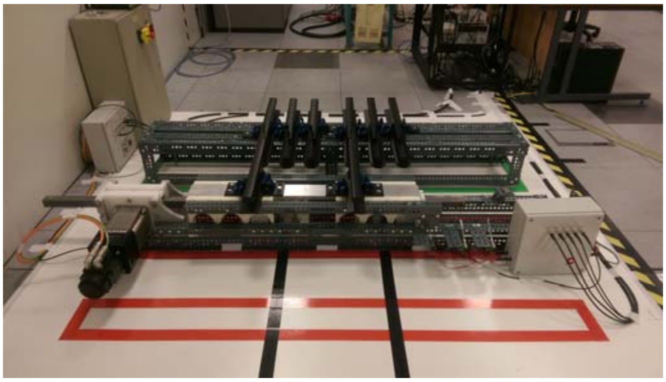

Fig. 1. The general arrangement of the novel track switching demonstrator in the laboratory at Loughborough University, at 384mm gauge.

2. EXISTING SYSTEMS

2.1 Mechanical Design

There are many methods of achieving a solution to the conflicting issues posed by track switching. However, all major railway systems throughout the world utilising the `traditional' arrangement of twin steel running rails and flanged wheels have adopted a broadly similar mechanical arrangement, extensively detailed in both industry publications, e.g. Morgan (2009) and in academic literature; Eker et al. (2011) and Silmon and Roberts (2010). This arrangement is shown in Fig. 2.

Switch arrangements consist of three distinct elements, or panels; namely 'switches', 'crossings', and 'closure panels'. The switch would generally be bracketed on all routes by sections of plain line, but in more complex junctions - especially those where footprint is restricted - switches may be adjacent or even overlap.

The switch panel comprises a pair of longitudinally extending switch rails are free to bend or pivot beyond a given point, and slide upon supporting plates or chairs, between two fixed `stock' or `running' rails. A mechanical linkage from the power source links the two switch rails, operating so as to open one rail and close the other. Actuation power and transmission is variously provided by humans and mechanical lever arrangements, pneumatics, hydraulics, or electro-mechanics.

The closure panel provides the diverging routes and bridges the gap between the switch and crossing panels. At the point where the outer rails of the two diverging routes cross, provision must be made for the wheel flanges to pass through unhindered. In common use are built-up and cast crossings, which have a gap in both running rails to allow this.

2.2 Signalling and Operational Rules

Switches remain in position and locked until commanded to move via the signalling system. The position of the blades, and the integrity of the position lock, is continually fed back to the interlocking via a subsystem known as 'detection'. When changing position, traditional switch designs move through a state which can be considered dangerous due to the inherent derailment risk, when the moveable blades are between the two set positions. Trains can be issued a movement authority to pass the switch only once the movement process is complete. This process normally takes several seconds; around 8 seconds is allowed in British signalling practice. A more detailed discussion of the British practice of switch control and operation is provided in 'Principles of power point control and detection' by Hadaway (1950).

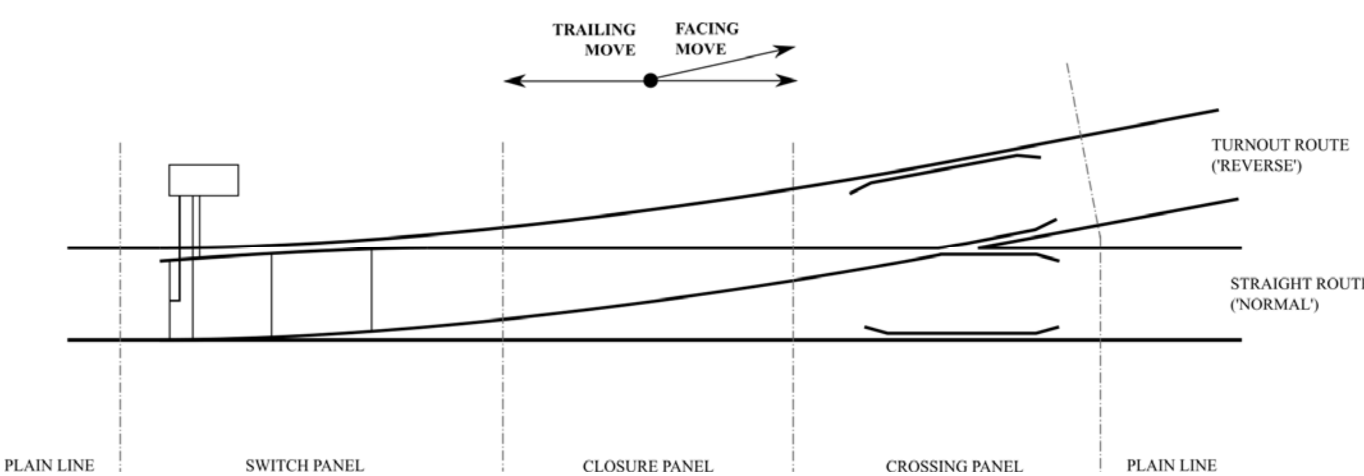

Fig. 2. Typical traditional switch layout, with sleepers/bearers omitted for clarity.