Innovative Technologies for Railway Track Switches


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Abstract: In this extended abstract paper, a few of the developed switches and crossings (S&C) mechatronic technologies within the Switch and Crossing Optimal Design Evaluation (S-CODE) project will be presented, where they were titled as demonstrators. Current conventional S&C are working for a long time with reasonable performances. They kept their mechanism with little changes. However, there are still many drawbacks that should be dealt with, especially its reliability and safety. Thus, the S-CODE project looked at developing radical future S&C technologies that can be integrated into existing rail network platforms, but also can achieve significant improved performances. These technologies will either accommodate potential faults in S&C through integrating condition monitoring (CM) and/or a fault tolerant control (FTC) strategies, in addition to define the optimal locations for sensors to be placed; or completely propose new actuating mechanisms (i.e., high redundancy actuator (HRA) and Maglev actuator); and/or consider a novel locking concept that base on the magneto-rheological fluid (MR) damper to improve railway track switching performances, especially with the strong tendency to introduce high-speed trains.

Keywords: Railways, switches and crossings (S&C), mechatronics, condition monitoring, reliability.

1. INTRODUCTION

The railway switches and crossings (S&C) system is a safety critical asset in the rail network that is required to be highly reliable (Hamadache et al. (2019)). Any failure in this system can cause delays in the rail network and/or even fatal accidents, such as the deadly train accident on February 4th, 2018 in Cayce, SC, United States that killed two people and injured 90 others (WIS News (2019)). Thus, within the Shift2Rail Joint Undertaking under the European Union’s Horizon 2020 research and innovation program, the Switch and Crossing Optimal Design Evaluation (S-CODE) project aims to achieve cost-effective infrastructures and improving capacity, reliability and safety, while reducing investment costs and life-cycle costs (University of Birmingham (2019)). It focuses on developing radical future S&C technologies that can be integrated to form innovative S&C with potential for significant improved performance (COMSA (2017)).

Conventional S&C are based on designs, which have been used for the last two centuries without major changes. They allow trains to change routes as shown in Fig. 1. This is accomplished by sliding the switch rails laterally over slide chairs that is nowadays achieved through electro-mechanical, hydraulic and/or pneumatic actuators. A comprehensive review of the existing CM techniques for railway S&C systems with the aim to overview the-state-of-the-art of the railway S&C technologies and its problems is detailed in (Hamadache et al. (2019)). Thus, to provide a platform for researchers, railway operators, and experts to research, develop and adopt the best methods for their applications. The sliding movement involves wear and friction. Thus, even though these current conventional S&C are working for a long time with acceptable performances, there are still many issues to be considered, especially its reliability and safety. Some of the developed technologies within the S-CODE project are introduced in this extended abstract paper, which focus on dealing with three requirements, including monitoring and fault tolerant that detect any abnormalities and accommodate potential faults in the railway S&C, in addition to define the optimal locations for sensors to be placed; actuation that proposes new actuating mechanisms by either proposing a high redundancy actuator (HRA) or exploiting the use of the Maglev technology, and locking that consider a novel locking concept that base on the magneto-rheological fluid (MR) damper.

Fig. 1. Layout of the conventional S&C system.

This paper is organized as follows: Section 2 introduces in brief the sensor placement, the condition monitoring (CM), and the fault tolerant control (FTC) demonstrators. The novel actuation technologies including the HRA demonstrator and the Maglev-based one are given in Section 3. The novel
locking concept that base on the MR damper is presented in Section 4. Finally, a conclusion is given in Section 5.

2. CONDITION MONITORING AND FAULT TOLERANCE

Diagnosing faults and incorporating this information within the analysis is also a part of the mechatronic system, which has been developed as a part of the S-CODE project. To detect and diagnose faults, sensors have to place at optimal locations. Condition monitoring on process faults and fault tolerant control on the sensor faults are developed as two independent methods to demonstrate the effectiveness of the technologies in the railway S&C domain. The following subsections explain these concepts.

2.1 Sensor placements demonstrator

Data profiles for detecting common S&C faults have been investigated based on both Finite Element (FE) and Multi-body system (MBS) simulation and two measurements trial were carried out within the S-CODE project to justify the proposed sensor location and data acquisitions. The results have shown high potential for condition monitoring S&C degradation. Furthermore, faulty train can be identify, which is important for data selection for diagnose algorithm. In the end, a holistic condition monitoring system with multiple sensors at the optimal locations and data acquisitions were developed.

2.2 Condition monitoring (CM) demonstrator

The switch performance can be changed over a long period of time due to many reasons. The model-based CM approach is developed in this work to detect any change in performance of the switch actuation. An actuator of a working switch system, high-performance switch system (HPSS) is considered in this research and a validated multibody simulation model developed using Simpack (Dutta et al. (2019)) is used to show the functionality of the CM approach. In this switch system, the system performances are monitored using data from the two sensors motor current and the displacement of the switch toe. The continuous time parameter estimation process is shown to predict the changes in the system parameters, such as motor torque, stiffness, friction in the system and overall inertia of the system.

2.3 Fault tolerant control (FTC) demonstrator

Within the actuation concept of switch by a track switch actuator, an open loop control is followed conventionally. It is necessary to feedback the displacement of switch for safety reasons. With this aim a closed feedback control loop is developed incorporating fault tolerance. This method is applied to all sensor faults through detection and accommodation. Apart from the position sensor, velocity and current sensors are also analysed as they are conventionally part of a general electric motor control loop similar to (Dixon, R. (2004)). Figure 2 shows the schematic of the method, where the three blocks in the bottom are part of fault tolerant control.

3. NOVEL ACTUATION TECHNOLOGIES

3.1 High-redundancy actuator (HRA) demonstrator

A high-redundancy actuator (HRA) is designed and built to demonstrate the provision of fault tolerance using several (small) actuators, which are assembled in parallel and series configuration to form a single (big) actuator as shown in Fig. 3. Thus, if one of these several actuators fails, the remaining actuators can take over and ensure the functionality of the total system (i.e., the S&C system). Further, it was shown in (Antong, et al., (2016a); Antong, et al., (2016b); Steffen, et al., (2009); Du, et al., (2010)) that the parallel configuration not only increases the force generated, but also improves the loose fault tolerance, and the series configuration increases the travel as well as improving the Look-Up fault tolerance. This demonstrator comprises a HRA driving against a varying load as shown below.

3.2 Maglev actuator demonstrator

A small scale demonstrator for a Maglev technology actuation has been developed in the S-CODE project. A remarkable feature of this technology is that the switch track levitates without any mechanical contact between the electromagnet actuators and the movable track rail. Figure 4 shows the rail switching concept based on Maglev actuator. Four electromagnetic actuators are used in this contactless
track switch actuator. Open-loop control algorithm of four electromagnets actuators is developed to obtain the necessary trajectory of the proposed switch rail system. The proof of a novel concept of railway track switching has been achieved by controlling the Maglev actuators in open loop control mode using LabVIEW software and NI myRIO 1900 hardware.

5. CONCLUSION

Six technologies developed within the S-CODE project for improving the railway S&C reliability and safety have been summarized in this extended abstract paper. Some of which did accommodate current problems in the conventional S&C by either integrating CM and/or FTC strategies, in addition to define the optimal locations for sensors to be placed (i.e., sensor placement technique). The others focused on proposing radical new future S&C technologies that can be integrated into existing rail network platforms such the HRA and the Maglev-based actuators. In addition to a novel locking concept that base on the MR damper. All these new technologies were fulfilled and built as demonstrators to prove their feasibility. The presentation will cover these areas in more details, including video clips and photos of the proposed new concepts.

REFERENCES


