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SMART SWITCH: THE APPLICATION OF FIBER OPTIC CONTINUOUS STRAIN SENSING TO THE RAILROAD TURNOUTS

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ABSTRACT

This paper discusses the application of Fiber Optic-based Continuous Strain Sensing (FOCSS) to Switches (a.k.a. railroad turnouts) and presents the resulting benefits. The FOCSS technology allows effective rail break detection to all parts of the switch and reliable point position detection in a secure environment.

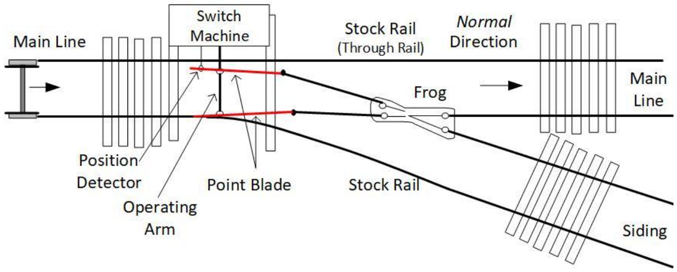
Keywords: Smart Switch, Rail Break Detection, Point Position Detection, Fiber Optic Strain Sensing

1. INTRODUCTION

Switches (alternatively known as turnouts or rail switches) are a fundamental part of the railroad infrastructure. They permit the existence of multitrack railroads by allowing a train to access an alternative path. However, track switches, as the weak link in railway line, could be damaged due to the train and other loads and its performance will also be degraded. For this reason, its maintenance is always important and difficult and requires lots of manpower, material and financial resources [1].

The common switch structure, shown in FIGURE 1, has been essentially unchanged since the very beginning. There have been many advancements in configuration and operating machinery, but the use of movable switch points remains a constant element. The two-point blades, lying between the diverging outer rails, work in tandem and are connected by a throw bar. The blade assembly slides across special tie plates. A switch machine, manual or power operated, moves the blade assembly from the "*norma*l" position to the "*reverse*" position. In the *norma*l position the train continues through the switch along the main line. In the *reverse* position the train is diverted to the siding track. The configuration shown in FIGURE 1 is a "Right Hand" switch because the divergent track is to the right of the switch entry point.

The purpose of the point blade is to redirect the front wheels of the locomotive from going straight through the switch to divert it to the divergent path. This is accomplished by converting part of the forward motion of the train into a lateral motion using a force between the wheel flange and the point blade. The faster the train, the more force the blade must exert on the wheel flange to effect the change in direction. The switch actuator (machine) moves the blade assembly from normal to reverse. It also applies a considerable force to hold the blade against the stock rail (through rail). This holding force is usually up to 2000 lbs. This force is necessary to ensure that the point will remain in contact with the stock rail. The point blade is only attached at the frog end. The point end is only held against the stock rail by the force applied by the switch actuator. A loose point will likely lead to a derailment. The point blade, when in reverse, is subject to the full force of redirecting the train.



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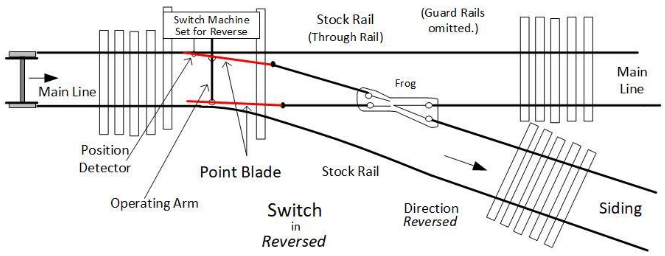

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FIGURE 1: THE COMMON SWITCH STRUCTURE (A) NORMAL POSITION (B) REVERSE POSITION

By one estimate, there are 47,000 switches in use in the freight system in North America [2][1].

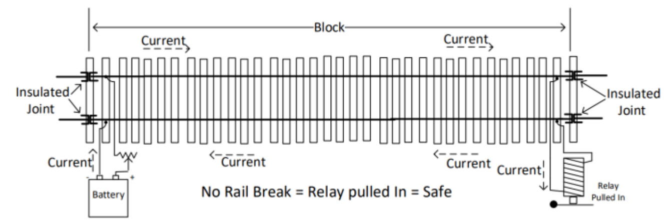
Given the vast number and variety of switches that can exist across a rail network, there is an immediate need for robust automated methods of detecting rail breaks at switch zones without expensive add-on equipment.

In the following sections of this paper, we first provide an overview of current technology for rail break detection. Then the limitations of these technologies for detecting rail breaks on switch zones are elaborated. Eventually the application of fiber optic strain sensing technology for monitoring switch zones is proposed and discussed.

2. BACKGROUND: EXISTING TECHNOLOGY

Rail break detection technology has been an integral part of railroad engineering since the invention of Track Circuits in 1872. These legacy Track Circuits served a dual function: they detected a broken rail within a block of track, and they also detected the presence of a train on the rails. The indication may also be the result of a circuit failure. When Track Circuit do fail, they will always fail in such a way as to protect the train by raising the Stop signal. However, the cause of the "stop" signal is not evident. Track Circuit technology, with minor improvements, continues to be used by the industry.

The essence of a Track Circuit operation is that a current is introduced into one end of a section of track called a block. At the other end of the isolated block the current pulls in a relay. If the current flows in both rails, the relay remains pulled in (See FIGURE 2A). If a rail breaks, the current is interrupted (See FIGURE 2B). If there is a train in the block, the current is short circuited. In either event the current stops flowing through the relay, and it falls into the open position. The open condition of the relay initiates a Stop signal to the train thus avoiding a collision or a derailment. Also, any failure of the track circuit wiring will result in the same Stop condition [3].



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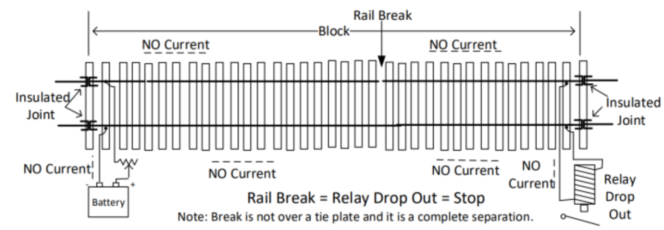

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FIGURE 2: RELAY PERFORMANCE AT (A) SAFE (NO RAIL BREAKS) (B) STOP (RAIL BREAK) CONDITIONS

The original Track Circuits were based on a DC current source. Eventually AC circuits and recently Audio Frequency circuits have come into general use. While these technologies provide continuous protection, they all suffer from an essential flaw. The broken rail is detected only *after* the rail breaks. This is little comfort to the train that is passing over the broken rail. These legacy technologies only detect breaks that are complete separation of the rail ends and only if the ends are not over a tie plate.

2.1 Track Circuits and Switches

Switches are not equipped with Track Circuits and have no other rail break detection technologies. This is not a design option but an electrical impossibility. The Track Circuit technology requires an orderly physical configuration of the rails to comprise a static circuit. There needs to be a clear start and

[1] This number appears to represent only those switches supervised by the PTC systems. That would mean 47,000 switches in some 68,000 miles of freight main line. That is an average of one switch every 1.5 miles. There are 116,000 miles of Class 1 freight tracks in North America. That would raise the estimate to about 78,000 freight switches. This does not include non-Class 1 roads, freight yards, transit systems and passenger stations

stop point for the current and no mechanical short circuits. Outside the switch environment, the orderly stop and start points are created by the use of insulated joints in the rails. Inside the switch structure, insulated joints are antithetical to the rigid structure that is required for safe switch operation. Outside the switch environment, the success of track circuits depends on the rail break not occurring over a tie plate (or other electrically conducting component) and that it be a clean break. The structural design of the switch employs copious amounts of tie plates some of which extend from one rail to another. Specifically, the switch point blade assembly rests on and slides over several Gauge plate that span the rails.

Arguably the most important rail element of the switch, the reverse point blade, is bound at only the root end. It has a starting point for the track circuit, but no fixed end point. The one element most prone to cracking or breaking is the one most resistant to the use of track circuit technology. The rails on either side of a switch may be protected by track circuit technology. But this is not the case for the switch.

2.2 Alternative Technologies

There are other technologies that can detect broken rails [4], rail defects [5], and rail damage. The most basic is direct human inspection. It is truly the legacy way to ensure the switch is intact. It is also labor intensive and does not provide the continuous monitoring provided by track circuits. Even with frequent inspection, the effectiveness of the human observer is limited by the human tendency to see what we expect to see and not what is really there.

Another useful technology is ultrasonic rail inspection [6]. In this technology a beam of ultrasonic energy is directed into the rail head [7]. The reflected ultrasonic energy is detected and assembled to an image of the rail head. Cracks and defects in the rail head can be detected in the recorded images. The technology is frequently used as part of the track geometry inspection process. The need to keep the ultrasonic sensor wheel in contact with the rail places limitations on the rapidity of the inspection process. Here too the inspection in done on a periodic basis and the switch does not have the continuous monitoring that track circuits provide.

Rail geometry inspection cars also offer machine vision inspection. This allows for considerably faster speed over the rails but it is still done as a periodic process. The stream of video from the sensors is analyzed by AI systems to identify any not-normal rail conditions such as missing attachment hardware. The technology is limited to what it can see. Dirt and refuse on the tracks can limit the effectiveness of the technology.

These technologies and several others have two limitations in common:

(1) None of these alternative technologies provide continuous observation of the condition of the rails. They all observe rail in an unloaded condition. Rail damage can start as a small flaw and over time grow into dangerous conditions. From a small crack, a broken rail can grow. Observing rail conditions is best done when the rail is under load. It is under load that the crack opens up and the bolt can be seen as loose. All of these alternative rail inspection technologies are used on self-propelled observation cars that typically weigh a fraction of a 4,000 HP locomotive.

(2) All of these technologies, and in particular the track circuit technology, are making proxy observations. Track circuits observe the ability of a rail to conduct electricity as a proxy for its structural ability to support the weight of a train.

Switch Protection Requirements

Switches, as vital elements to railroad operations, need rail break protection. They are subjected to unique mechanical forces and unique operating vulnerabilities. However, neither track circuits nor any of the alternative technologies can provide effective rail break protection for switches. In the search for a successful protective technology, it is useful to enumerate specific required capabilities.

A practical and effective technology to protect switches should have the following qualities:

- The changes observed must directly relate to structural changes in the rails. The ability to supporting the train includes the structural integrity of the rail and the integrity of the mounting hardware, tie plates, ties, and ballast. Any degradation in any supporting element must be detectable.
- The technology selected to protect switches must provide continuous monitoring of the rails. It is vital to detect abrupt changes in rail structural integrity and promptly report the change to the central train control system.
- The technology selected to provide protection must make the strain observations under actual load conditions. It must look for structural degradation under conditions of significant, real world rail loading.
- The technology selected for monitoring the structural integrity of the switch must be applicable to all rail components. It must be useable on the stock rails, the point blades and the frog.
- The technology selected must provide actionable information on a real time basis. Prompt notification of rail degradation facilitates planed maintenance.
- The technology must be self-testing and self-diagnosing. The technology must provide clear information that distinguishes between equipment failure and rail fault information. The self-diagnosis must include all sensors elements.
- The technology employed to protect switches from physical degradation must also provide a reliable means to determine and confirm the position of the rail points.

Knowing the position of the point blades is vital to the safe operation of the switch and the railroad and The technology selected to must provide significant resistance to mal-operation and vandalism.

In the following section, continuous fiber optic strain sensing is introduced as a technology which will meet all the above requirements.

3. CONTINUOUS FIBER OPTIC STRAIN SENSING FOR SWITCHES

3.1 Fiber Optic Strain Sensing Technology

Fiber Optic Strain Sensing (FOSS) technology is currently in use in the oil and gas transmission industry. These cables are designed for use with oil and gas transmission pipes that are directly buried. The sensing cable is bonded to the oil transmission pipes that connect the undersea well head to the drilling platform. The sensor cable is used to detect changes in the pipe strain and temperature that may indicate a leak. In these applications, the pipes and the cables are beyond the reach of direct inspection. The fiber optic sensor cable is what provides the alarm that the strain on the pipe wall is changing in a manner that may indicate an impending rupture. The sensor cable also provides the vital information about where the pipeline anomaly is located.

A fiber optic communications cables may include up to 288 individual fibers. A fiber optic remote sensing cable may contain as little as one fiber as depicted in FIGURE 3.

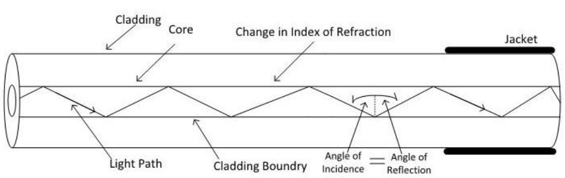

FIGURE 3: SINGLE OPTICAL FIBER

All fiber optic applications, both communications and remote sensing, use the same basic core/cladding structure composed of silica glass. The core/cladding fiber is protected by a jacket or buffer layer that provides mechanical protection for the strand or strands. The core and the cladding are both glass, but each has a slightly different density. Because of the change of density there is a difference in the speed of light in the core and in the cladding[2]. This in turn results in a reflective boundary between the core and the cladding. A light ray entering the fiber is constantly reflected off the cladding boundary as it passes down the core of the fiber. The conduction of light in the core is extremely efficient if the angle of incidence of the light energy does not exceed the angle of reflection. As the light energy ricochets off the cladding boundary, every reflection causes a slight dispersal of light, some of which is reflected to the source and is called backscatter. When the fiber is straight the backscatter is minimal though constantly present.

When the fiber is bent, as depicted in FIGURE 4, the light beam strikes the cladding barrier more frequently causing more reflected light to return as backscatter.

The more the fiber is bent the greater intensity of the backscatter from the location of the bend. The degree of backscatter is directly related to the degree of fiber bending. This phenonium is called micro-bending. It is minimal in the communications industry, but OTDR instruments are designed to detect it [3][8].

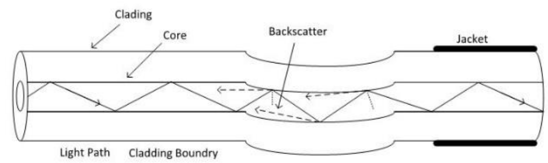

FIGURE 4: BENT FIBER AND BACKSCATTER

In communications cables, the design goal is to create a jacket that protects the fiber from external effects such as cable bending. A common descriptor for communications cables is: "jell filled and loose tube". For fibers used for strain sensing the approach to cable construction is exactly the reverse. The cable must be suitable for attachment to the rail weld. The cable must translate rail bending into fiber bending. Moreover, the fiber core to cladding interface can be optimized for maximum backscatter production.

Providing a full account of FO remote sensing technology is out of the scope of this paper. The brief explanation of the technology presented here is thought to be sufficient to describe how physical changes in the rail can be reliably detected and interpreted by a suitable wayside device. For more details interested readers might refer to [9].

3.2 Smart Switch Concept

The Smart Switch technology is the result of applying readily available Fiber Optic based remote sensing technology to the need of railroad switches for broken rails and general structural degradation. The sensor system monitors all rail elements of the switch including the frog. The sensor continuously monitors the switch for changes in observed rail strain, including and most consequentially, when the rails are under structural load by a locomotive of rail car. Moreover, it is robustly resistant to maloperation and vandalism.

As shown in FIGURE 5, The Smart Switch concept includes a wayside mounted electronics package and several fiber optic

[2] The speed of light in a vacuum is 186,282 Miles per Second (MPS). (Or 299,792,458 Meters per Second.) A typical single mode fiber core is made of very pure silicon glass with an Index of Refraction of 1.4475. The Index of Refraction relates to light traveling at 128,692 MPS in the core. A typical cladding will have an Index of Refraction of 1.4444 and a speed of 128,968 MPS. Light travels faster in the cladding than in the core. The core/cladding boundary reflected light back into the core when it encounters the cladding barrier. For more detail see AFL marketing@AFLglobal.com Blog entry: "The Basic Structure of Optical Fiber".

[3] The Single Mode Core diameter is usually 8.3 Microns (μm). The Cladding is usually 125 Microns. The laser source is normally operating at 1,550 Nanometers.

sensor cables. The fiber optic sensor cable is permanently bonded to the web of each rail segment over its entire length. It can be installed and configured to conform to the exact dimensions of the switch.

The wayside electronics package includes the electro-optic components that illuminate the cables and that detect the reflected optical signals. The wayside package also includes an analytical network that controls the detector functions and processes the strain data and analyses the data to identify out-of-normal strain conditions. The main components of the wayside package are: (1) An electro-optical system that illuminated the fiber cables with a short laser pulse. It also detects the reflected laser pulse that result from micro-bending (distortion) of fiber. It calculates the time-of-flight of the laser pulse and its reflection (backscatter) to calculate the location of the observed cable micro-bending. This function is commonly known as an Optical Time Domain Reflectometry instrument (OTDR). (2) An analytical system that records the digitized results of the OTDR after each detection cycle. The digitized data represents the most recent representation of the way the rails respond to the changes in structural loading. The analytical section adjusts the most recent data file to compensate for known variables such as rail temperature. (3) The analytical system aggregates the most recent data set with a data base of all previous observations. This creates a “normal” response reference file. (4) The analytical system compares the most recent data set with the “normal” response data set and looks for significant deviations. The presence of significant deviations may be evidence changes in rail strain patterns and strain concentrations. These changes may arise from slow but progressive changes that may be indicative of deterioration of the rail structure. Or they may be abrupt changes that may indicate rail cracking or breaking. (5) The analytical system includes a communications function that allows the wayside package to notify trin dispatch of significant changes.

OTDR instrumentation is ubiquitous in the fiber optic industry as the method of inspecting new and installed cables. It allows the identification of an exact location for all fiber anomalies from connectors, fusion splices, breaks, to bends and kinks in the fiber.

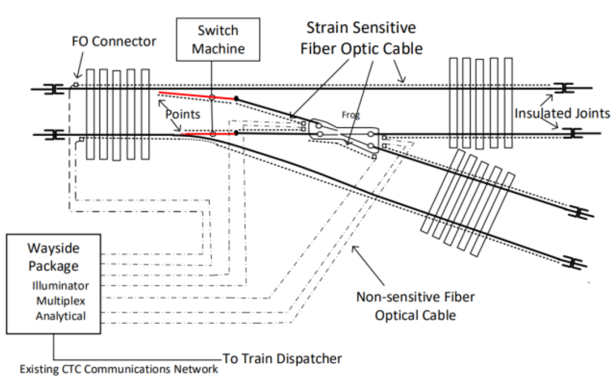

FIGURE 5: SMART SWITCH GENERAL CONFIGURATION

3.3 Applying FIBER OPTIC SENSING TO THE RAILS

FIGURE 6 depicts the Fiber Optic Strain Sensor cable bonded to the side of the rail web and a wheel pressing down on the rail [10]. The sketch depicts the rails being slightly deformed by the load. The deformation is the manifestation of strain in the rail. The sensor cable, bonded to the web, is also, proportionately, deformed. This deformation is micro-bending of the fiber and the source of a localized increase of backscatter [11].

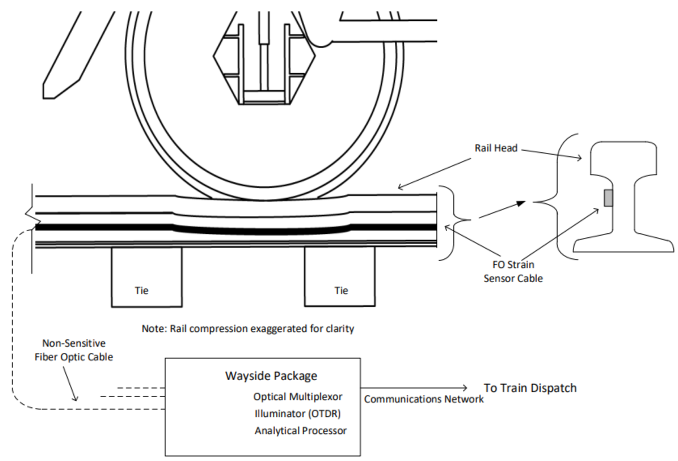

FIGURE 6: FIBER OPTIC STRAIN SENSOR CABLE BONDED TO THE SIDE OF THE RAIL WEB

Rails are composed of a uniform material in a uniform shape. They are structurally homogenous throughout their length. When loaded by a typical locomotive wheel, the rail will deflect in a predictable manner. Locomotive after locomotive will cause the rail to repeatedly deform in a consistent manner (after due adjustment for rail temperature and averaging locomotive weight) A local defect in the rail, such as a crack or missing securing hardware, will cause a local change in rail rigidity and will be evident as a local change in the degree of local bending. FOCSS technology can be used to detect this local change in rail rigidity over time. Thus, rail deterioration can be observed long before a rail breaks. The process involves making repeated FOCSS observations of a typical locomotive passing over a section of rail. The repeated observations are aggregated into a “normal” rail deflection/ micro-bending pattern.

FIGURE 7 shows the relationship between the physical consists in the strain sensing fiber and the traditional OTDR waterfall display. The fiber cable consists of a strain sensitive section and a non-strain sensitive cable that connects it to the OTDR. In the figure, two strain concentrations are depicted, one is a normal response in the fiber to the effect of a rail car and the other an acute response indicating a concentration of strain around a physical location. In the waterfall the acute response is shown as exceeding the “Normal” range of responses as defined by the process of aggregating many similar events.

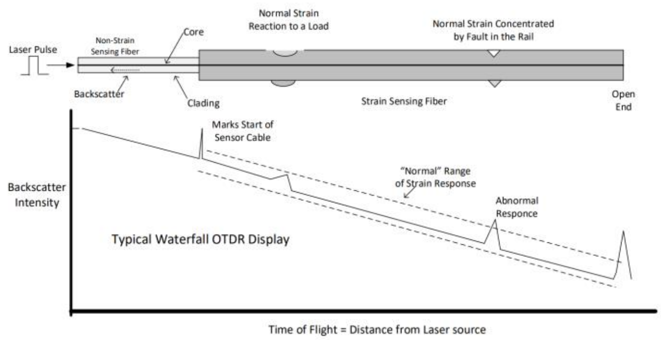

FIGURE 7: RELATIONSHIP BETWEEN THE PHYSICAL CONSISTS IN THE STRAIN SENSING FIBER AND THE TRADITIONAL OTDR WATERFALL DISPLAY

It is worth mentioning that the Fiber Optic Remote Sensing technology has advanced to the point of being able to make high resolution measurements of strain at long distances. However, switches, owing to the limited rail lengths and heavy loading, do not require advanced sensing technology to make meaningful observations of changes in rail strain. The detection of structural changes in the rails does not require absolute measurements but only the observation of changed in the rails response to loading. Smart Switch is not about making calibrated measurements at a specific time, but rather observing changes in strain response over time and detecting trends or sudden shifts.

3.4 FOSS CABLE ON THE RAIL

Thus far the focus has been on the interaction of the rail and a single fiber. The implication has been that fibers can be attached directly to rails. There have been instances where single fibers were bonded directly to the (prepared) rail web. There was partly successful work done at Transportation Technology Center, Inc. (TTCI) to detect broken rails using a single fiber bonded to the rail using an epoxy agent [12]. It was only partly successful because the fiber to rail bond did not survive the railroad environment. The fiber became detached in some portions of the track. However, the arrangement did detect broken rails prior to becoming detached.

The steel rail under repeated pounding by locomotive and freight car wheels is a tough environment. In addition, the rail and fiber is exposed to the full spectrum of environmental conditions from extreme cold to extreme heat. A fiber on the rail web is susceptible to abuse by railroad right of way maintenance equipment such as ballast tampers. Further. there is a consideration of the ease of attaching the fiber to the rail. For these and other reasons, the FOCSS fiber needs the support and protection of a custom designed jacket. Together the fiber and jacket is a FOCSS cable.

The jacket must faithfully transfer rail strain to the fiber. Strain in the rail web must cause micro-bending in the fiber.

The jacket must provide the fiber with protection against damage caused by environmental and industrial causes. It must resist the effects of extreme temperatures and the incidental injury during track maintenance. The jacket must facilitate the installation of the cable onto the rail, either in the field or in the factory. The jacket must provide a means to bond the cable to the prepared rail web. The bonding method must be fast and remain firmly attached for the life of the rail. Nominally 30 years. The design of the jacket must facilitate its removal from the rail and termination of the fiber.

FIGURE 8 represents a possible FOCSS cable design. The jacket could be fabricated from stainless steel stock using laser welding of the seam after mandrel bending. The fiber is centered in the tube using a semi-rigid polymer fill. The formation of the jacket can include a tab that can facilitate spot welding to the rail.

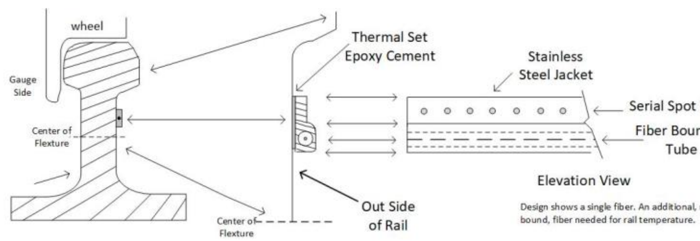

FIGURE 8: FOCSS CABLE DESIGN

4. FOCSS Technology: Other Merits and Capabilities

4.1 POINT POSITION DETECTION

FOCSS technology can provide switches with rail break detection, loose hardware detection and advanced warning of incipient rail degradation. It can also provide accurate and confirmable point position information. Accurate point position information is vital to Positive Train Control (PTC) and safe train movement. If a switch is incorrectly reported as being in the normal position, the train may approach the switch at normal speed. If the points are, in fact, in the reverse position, the switch may fail to redirect the locomotive and a derailment will occur.

The legacy technology uses an electrical contacts located either inside to switch operating machine or in an independent enclosure located adjacent to the switch. The electrical contacts are actuated by a sensor rod that is attached to the points. When the points move, the electrical contacts change (See Figure 9). The sensor rod includes an adjustable section that allows it to report the location of the points relative to the operating machine. This arrangement monitors the point position, but it does not monitor the force (up to 2000 lbs) required to hold the point against the through rail. If the switch operating machine and sensors are correctly adjusted, the sensor contacts will close when sufficient force is exerted against the rail. There is no direct confirmation that the point is against the stock rail or that it is being held there.

FOCSS technology provides the confirmation that the point rail is in contact with the stock rail and that the required holding force is being applied. This continuous monitoring is applied to both the "normal" point rail and the "reverse" point rail. When the point to rail gap is open, there is only normal (not disturbed) strain in point. At the same time, there is no concentration of strain in the stock rail. When the point is properly forced against the stock rail, there will be corresponding increases of strain in both the point and in the stock rail at the location where they touch. This corresponding change in strain is directly observable and provides direct confirmation that the point is in place and that it is being held in place.

The analytical portion of the wayside package will include specific algorithms to monitor switch point position and holding force. On a constantly repeating cycle, an algorithm will compare the strain in the points and the strain in the stock rails. The observations will be compared to the aggregated past observations to assure that the hold force is consistent with expected adjustments. It will also confirm that the location of increased strain in the stock rail matches the expected location of the point blade. It will confirm that the switch is in one of three conditions: Fully in the “normal” position; Fully in the “reverse” position; In transition. If the transition condition persists beyond expected operating time, a fault will be announced.

4.2 ROLL-OUT DETECTION

Along with Rail Break Detection and Point Position, Smart Switch also provides Roll-Out Detection. Switches monitored using Smart Switch technology can detect the presence of a rail car that has rolled onto the switch and is fouling the main line track. This may happen if a freight car is not properly secured on a siding and rolls onto the switch in a position to obstruct a passing train. The siding usually is not monitored for Block Occupancy and the switch is not able to be part of a Track Circuit needed for detecting Block Occupancy.

The use of FOCSS technology allows all parts of the switch assembly to be protected by Block Occupancy. If a locomotive or car is applying compressive loading to any part of the switch structure, Smart Switch will detect the presence of the load. In fact, the load will be detected twice. Once on each rail. The appearance of a similar loading in a similar location on each rail provides double confirmation that a vehicle is in the block defined by the switch. Smart Switch can report the exact position of the mislocated car and provide information related to the possibility that the main line is fouled.

4.3 SECURE SWITCH INFORMATION

In the current social environment, rail sabotage is a real and reoccurring threat. Recently, there have been a continuing series of attacks on BNSF rail operations. These attacks have included over 40 “Shunt Attacks” that have constituted non-hazardous harassment. On December 22, 2020 a BNSF oil tank train partly derailed and caught fire as a result of the mal-operation of a decoupler pin and two air angle cock valves [13].

These recent events illustrate that mal-operation of railroad equipment by vandals has resulted in operational delays, derailments, fires and possibly fatalities. The physical infrastructure of the railroads has not been designed to address this type of threat. Recent additions to the infrastructure, such as PTC, have robust protection from external manipulation. Much of the communications between the wayside shelters and the Central Train Control (CTC) system are also well protected from tampering. But the 19th century track circuits are still in operation and switch position is monitored still relies on a simple electrical switch.

Track Circuits are vulnerable to acts of vandalism using only a short section of wire. Switch position sensors can be disabled using a wrench and a gear puller. The vandal need not have any true understanding of the workings of the CTC system to cause the system to provide faulty and potentially deadly misinformation to the Train Dispatcher.

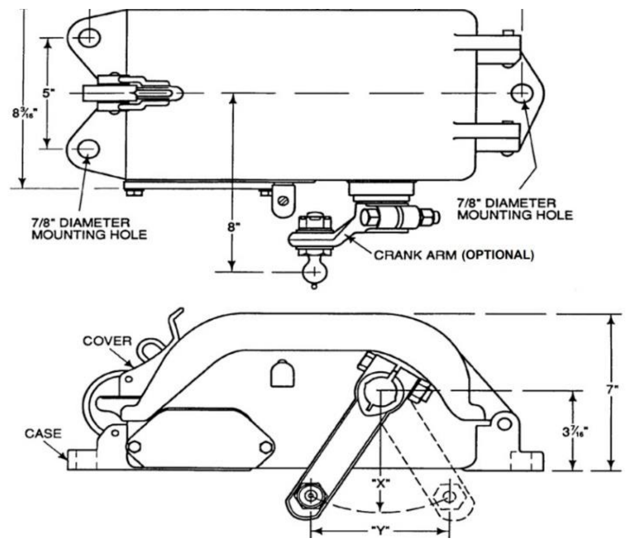

FIGURE 9: ALSTOM 7J SWITCH CIRCUIT TYPICAL APPLICATION TO DETECT SWITCH POSITION (SWITCH POINTS ARE LINKED TO THE BALL JOINT AT THE END OF THE CRANK ARM.)

The use of FOCSS technology provides robust protection for rail integrity information and switch point position information. Smart Switch is an active system. It is constantly comparing present observations to past observations and searching for changes. When the present strain profile does not match the historical profile, an alarm is generated. This searching process also applies to the start and end distance of each sensor cable. Any damage done to the sensor cable will generate an alarm. No act of vandalism can be done outside the wayside enclosure that will not be detected as equipment failure. Attempts to cause the analytical package to generate incorrect switch integrity information will require special knowledge and access.

5. OUTLINE AND CONCLUDING REMARKS

This paper provides an overview of current technology for rail break detection and elaborates on the limitations of these technologies for detecting rail breaks on switch zones. The study also proposes the application of fiber optic strain sensing technology (FOSS) for monitoring switch zones and then discusses the feasibility and merits of this technology compared to other existing technologies as follows:

- Unlike existing technologies which mainly focuses on monitoring a proxy variable (i.e., electricity), FOSS can monitor a structural variable, strain.
- FOCSS Technology used on Switches can accomplish rail break detection and rail integrity degradation detection based on changing strain.
- It is capable of switch point position detection and verification based on direct observation of strain.
- It can detect fouled switches due to a rail car on the switch approach "Roll-Out Problem"
- It protects the switch from tampering, mal-operation, and sabotage.
- FOCSS technology is derived from conventional and common OTDR technology.
- The technology needed to produce Smart Switch is available and needs only to be adapted to the railroad environment.

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